

THE DYNAMICS OF THE INTRAABOMASAL AND INTRARUMINAL PH OF COWS AND GOATS

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Abstract

The dynamics of the intraruminal and intraabomasal pH in adult goats and cows was compared 15 min before and seven hours after unlimited hay and concentrated mixed feed based on barley, wheat and sunflower meal (goats – 0.5 kg and bulls - 2 kg) feeding. Five bulls (n=5) in the age of 1.5 and one year old goats (n=5) were included in this study. To investigate the changes of reaction of abomasum and rumen in animals before and after feeding, the uninterrupted long-lasting intragastric pH measurement method was applied together with a chronic fistula method. For the purposes of intraruminal and intraabomasal pH measurements a special pH-meter for two measurements. In conclusion it was established that in case of adult bulls pH did not significantly changed in rumen and abomasum after the feeding of the concentrated mixes feed and hay, but in case of goats pH level in the rumen and abomasum after the similar feeding decreased significantly during the two hours' period. Thereby these functional processes in rumen and abomasum are different in these ruminants. The established pH indicators in various parts of abomasum of adult bulls and kids after feeding of hay can differ considerably, therefore upon establishing the pH value it is important to indicate its location as precisely as possible. For goats this difference is not significant.

Key words: intraruminal, intraabomasal, pH, cow, goat

1. INTRODUCTION

During the recent years the number of researches on functional condition of digestive system of cows and goats in connection to the feeding regime and selected forage as well as ability to influence endocrine and metabolic processes in order to reduce methane emission into environment has increased. Fact that the influence of mixed feed on processes occurring in multi-chambered stomach of animals is not sufficiently researched and problems related to the digestive conditions are still topical is witnessed by the extensive studies carried out by scientists from various countries (Koho et al., 2011; Gressley et al., 2011; Serment et al., 2011; Carberry et al., 2012; Lee H.J, et al., 2012; Metzler-Zebeli et al., 2013; Khiaosa-ard, Zebeli, 2013; Kirat et al., 2013; Romero et al., 2013;). It is also understandable if taking into consideration very important physical, microbial and fermentation processes in the stomach of ruminants on which not only health conditions and productivity of animals but also environment depend (Constable et al., 2005; Constable et al. 2009; Lascano et al., 2009; Koho et al., 20011; Lee H.J, et al. 2012; Trevisi et al., 2014; Antanaitis et al., 2016; Arne, Ilgaza, 2016.).

One of the most important indicators of functional condition of stomach is intragastric pH which is vital also in evaluating the condition of multi-chambered stomach. It has been known for a long time that any deviation of intraruminal and intraabomasal pH can encourage the occurrence of difficult metabolic diseases and even death of animals. The most recent studies show that low intraruminal pH indicators together with a bacterial lipopolysaccharide endotoxin (LPS) in ruminants can reduce the barrier functions of a rumen epithelium which allows LPS to absorb in blood and advances systemic inflammation reactions (Fernando et al., 2010; Khafipour et al., 2011; Metzler-Zebeli et al., 2013).

PH indicators both in pouch and abomasum of ruminants not only reflect the general functional condition of stomach but also to some extent allow drawing conclusions on quality and optimum doses of mixed feed to be fed. It was proved that in order for a normal metabolic process of wood-fiber to take place in pouch in case of clinically healthy adult cows the intraruminal pH must vary from 6.16 to 7.4 (Lascano et al., 2009; Gressley et al., 2011; Lee H.J. et al., 2012; Khiaosa-ard, Zebeli, 2013), but in case

of goats - pH 6.5 – 7.5 accordingly (Bava, 2001; Koho et al., 2011; Metzler-Zebeli et al., 2013). The pH of the reticulorumen contents was also found to be influenced by the circadian rhythm and season. The lowest pH was observed in the summertime - 5.99 ± 0.001 , and the highest was in autumn and springtime - 6.18 ± 0.001 (Antanaitis et al., 2016).

In its turn, intraabomasal pH in adult goats and cows, referring to literature sources, usually ranges from 2.0 to 3.0, that is considered an optimum environment which allows transforming into pepsin (Smith, Sherman, 1994; Kitamura et al., 2003).

By analyzing intraruminal and intraabomasal environment, authors usually use average pH indicators and standard deviation - thereby establishing the range of pH fluctuations during the test. Besides, the place, where the pH level is determined, is not precisely specified in all studies. There are no sufficient data on changes of pH indicators occurring simultaneously in pouch and abomasum before and after feeding an animal in a long-term period. Therefore the objective of our paper was to determine simultaneously and compare the dynamics of intraruminal and intraabomasal pH in adult cows and goats before and after feeding of animals.

2. MATERIALS AND METHODS

Dynamics of intraruminal and intraabomasal pH in adult goats and cows before and seven hours after feeding hay (unlimited) and common concentrated mix (wheat, barley) (goats – 0,5 kg, bulls - 2 kg) is compared in this study. We included 1.5-2 years old Holstein bulls ($n=5$; 217 ± 22 kg) and 1.5 - 2 years old Saanen goats ($n=5$; 217 ± 22 kg) in the research. We performed checks during the winter period. Bulls were kept tied in individual stalls, but goats were kept untied in goat-boxes.

In order to study the reactions of rumen and abomasum in animals before and after feeding the uninterrupted long-term intragastric pH-metering combined with a chronic fistula method were applied. It is believed that it is one of the most precise and efficient methods in specifically long-term studies (Bava 2001; Andrew, Neihaus, 2008; Ahmed et al., 2002 and 2005; Constable et al., 2005; Lascano et al., 2009; Mezzomo et al., 2011; Serment et al., 2011; Khafipour et al., 2011). By selecting of common areas and applying common methods a fistula was created in both rumen and abomasum of each animal. We started research in the 14th day after creating chronic fistulas.

For the purposes of intraruminal and intraabomasal pH metering special pH-meter “3310, WTW” (permissible error of measurement $\pm 0,01$ pH units) were used. It allowed us obtaining pH indicators in rumen or abomasum simultaneously in two areas. We detected animals' intraruminal pH by inserting pH probe through the chronic fistula of rumen so that the second (II) measurement could take place in the inner ring of fistula i.e. close to the dorsal wall, but the first (I) one to be, accordingly, in 12 cm more ventral position. We determined intraabomasal pH by inserting pH probe through abomasal fistula expecting the measurement II of pH probe to register pH indicators in the area of abomasum's fundic glands (close to fistula), but measurement I of pH probe took place in 12 cm towards pyloric sphincter.

In this stage of research data on animals' intraruminal and intraabomasal pH was registered after each hour in seven hours' period, lasted for three weeks. Each week five intragastric (simultaneously intraruminal and intraabomasal) pH measurements were taken both for bulls and goats ($n=90$ in total).

During the research animals basically did not feel any discomfort - they were allowed to freely drink, eat hay, ruminate and sleep. In this paper we used only those results of research of which we were completely sure that an animal was clinically healthy and felt good during the experiment.

We used Microsoft Excel and R software to process statistical data. In order to construct a curve which shows the dynamics of abomasum and rumen of the respective group of animals, we calculated the average value and standard deviation in the pH values established by each measurement after each hour. In order to compare and evaluate the changes in pH level before and after feeding of animals in both measuring places, we used T-test for comparing the average values, one-factor dispersion analysis ANOVA (Arhipova, Bălița, S., 2006).

3. RESULTS

Changes in intraruminal and intraabomasal pH in 1.5-2 years old goats before feeding and after feeding of 0.5 kg of mixed feed and unlimited hay consumption are reflected in Figure 1.

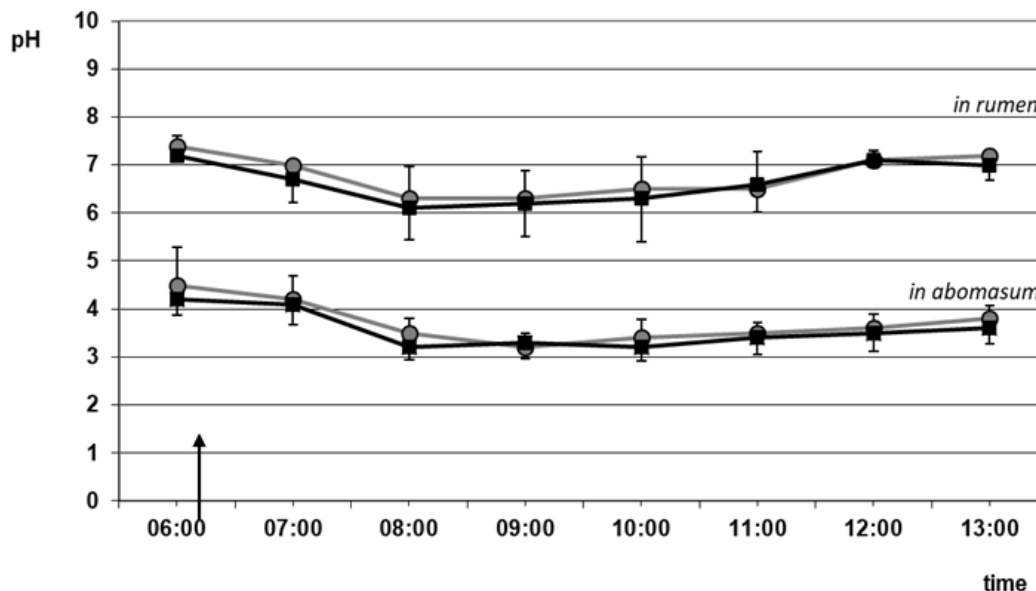


Fig. 1. Intraruminal and intraabomasal pH in adult goats before and after feeding hay and concentrated mixed feed

- - pH at the place of measurement I (average indices, $\perp$ – standard deviation);
- - pH at the place of measurement II (average indices, T – standard deviation);
- ↑ - animal feeding.

As mentioned before, pH level was determined simultaneously in two strictly defined areas in rumen and abomasum. It turned out that pH indicators at dorsal wall (measurement II) and pH indicators 12 cm ventral-wise (measurement I) of rumen of adult goats neither before feeding nor during the following seven hours after feeding differed significantly, therefore we will review them together in further analysis. We found that in the morning at 6 AM before feeding of goats the average pH indexes of animals varied from 7.4 to 7.2 (see Fig. 1). During the first two hours after eating they decreased significantly ($p < 0.05$) until 6.1 - 6.3 and remained in this range for one hour. Beginning with the fourth hour after feeding pH indicators in rumen gradually started to increase reaching 7.0-7.2 in the seventh hour.

Reaction of abomasum in these animals before feeding at 6 AM was slightly acid - ranging from 4.2 to 4.5. Starting with the second hour after feeding the pH indicators in abomasum steeply decreased reaching the lowest level - pH 3.2 - 3.5. Such relatively low pH level in abomasum remained after morning feeding of goats for approximately two hours - from 8 AM to 10 AM. Then intraabomasal pH started to increase steadily until it reached 3.6 - 3.8 in the seventh hour after feeding (see Fig. 1).

One of the main objectives of current paper was to determine pH dynamics in ruminants simultaneously in rumen and abomasum. It turned out that characteristic changes of intraruminal and intraabomasal pH in case of goats, determined within seven hours, are rather similar (see Fig. 1). After consuming forage and hay pH indicators decreased both in rumen and abomasum, staying at the lowest level on the second and third hour after feeding. Starting with the fourth hour in these both parts of multi-chambered

stomach a trend was observed that pH indicators increased, however the pre-feeding pH level was reached within seven hours only in rumen.

To make sure if there is really a correlation between pH level fluctuations in goats' rumen and abomasum, we carried out a correlation analysis between the anatomic indicators which were recorded in the measuring place I of pH probe inserted in rumen and recorded pH values in fundic glands of abomasum in the measuring place II. It turned out that there is an averagely close positive linear correlation ($r = 0,67$). It means that when pH level decreases in rumen of goats, it also decreases in fundic gland area of abomasum.

Changes in intraruminal and intraabomasal pH in case of adult bulls before and after consumption of 2 kg mixed feed and unlimited hay are shown in Figure 2.

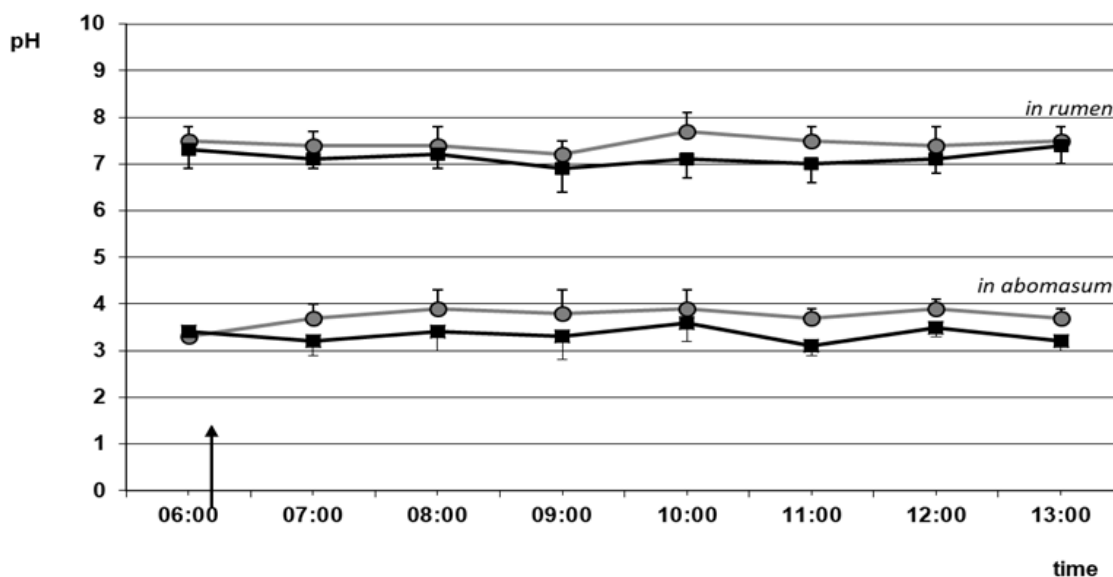


Fig. 2. Intraruminal and intraabomasal pH in bulls before and after feeding hay and concentrated mixed feed

— - pH at the place of measurement I (average indices, $\perp$ – standard deviation);

— - pH at the place of measurement II (average indices, T – standard deviation);

↑ - animal feeding.

We established that pH indicators in abomasum in areas of probe's electrode I and II at 6 AM before feeding are 7.3 ± 0.36 and 7.5 ± 0.18 accordingly. During the third hour after feeding, that is, at 9 AM, intraruminal pH decreased especially in area of measurement I, reaching 6.9 ± 0.47 which turned out to be the lowest established average pH value during the research in case of bulls. After this decrease followed an increase of pH indicators in the area of measurement I up to averagely 7.7 ± 0.56 which turned out to be the higher established average pH value during the research in case of bulls. During the next hours the average values of pH levels in area of measurement I and II varied at 7.0 - 7.5 (see Fig. 2). It must be noted that during the whole period of research intraruminal pH indicators in area of measurement II, i.e., near the created fistula at the upper part of rumen's dorsal sac, were slightly higher than in abomasum, 12 cm away from fistula (depth wise) where the measurement I of pH probe was taken. T-test for comparison of average values confirmed that difference of indicators is important ($p < 0.01$).

Regarding intraabomasal dynamic we established that in 6 AM a relatively acid reaction - $\text{pH } 3.4 \pm 0.18$ in the measurement I area and $\text{pH } 3.3 \pm 0.21$ in the measurement II area (see Fig. 2) - was characteristic to abomasum of bulls. Trend of changes in pH levels after feeding in areas of both measurements was slightly different. In the area of second measurement of probe, i.e. in area of abomasum's fundic gland a slight lowering of acid level (increase of pH level) was observed starting with the first hour, reaching $\text{pH } 3.9 \pm 0.32$ at 10 AM. Meanwhile we determined a trend in the area of measurement I - increasing of acid level, reaching the lowest pH level, 3.1 ± 0.21 , in the fifth hour after feeding.

Upon comparing the dynamics of intraabomasal pH registered by both measurement within seven hours, it must be noted that after feeding the acid level of fundic gland area (area of measurement II) in abomasum of adult bulls is considerably ($p < 0.01$) lower ($\text{pH } 3.7 - 3.9$) than we established near pyloric gland area (area of measurement I) where pH ranged from 3.1 to 3.6.

Similarly as in case of goats, we tested by means of correlation analysis if pH level fluctuations in rumen influence the intraabomasal pH also regarding the bulls. Our data witness that there is no such correlation in case of bulls.

4. DISCUSSION

Average pH values and standard error established in our research show that intraruminal pH in dorsal part of rumen of cows before morning feeding are rather similar and can vary from 6.8 to 7.6. Since we determined pH level before feeding in the dorsal sac of rumen - that is, relatively close to the opening of esophagus, reaction of intraruminal environment, established by us, is generally not so acid as mentioned in literature (Bava et al., 2001; Berends et al., 2012; Khafipour et al., 2011; Castells et al., 2013; Metzler-Zebeli et al., 2013; Trevisi et al., 2014; Antanaitis et al., 2016).

During the first two hours after feeding mixed feed and hay to bulls, the pH levels in rumen did not change considerably and showed only slight reduction trend in the area of measurement I. It corresponds with study on impact of amount of fed hay and grains to the pH level and bacterial background in rumen. It was established that intraruminal pH in bulls 2 - 3 hours after feeding of various hay can vary from 6.78 to 7.2 (Carvalho et al., 2003; Lascano et al., 2009; Lee H.J. et al., 2012;), but after feeding of grains pH level decreases considerably (Zabeli et al., 2008; Fernando et al., 2010; Mezzamo et al., 2011).

In its turn, in case of goats during the first two hours after feeding the pH level in rumen decreased considerably ($p < 0.05$), besides it remained under pH 7.0 for the following three hours. Such decreasing of pH level in goats' rumen after feeding of forage and hay was established also by other authors (Bava et al., 2001; Koho et al., 2010; Khiaosa-ard, Zebeli, 2013). A positive correlation between the amount of grains fed and decrease of intraruminal pH is marked in the literature, what means that by feeding a larger amount of grains the pH level would decrease more in a rumen (Metzler-Zebeli et al., 2013). It is possible that by including grains in special mixes this relation is not that much pronounced because in our research after feeding of 0.5 kg feed mix the pH level decreased only to 6.9 ± 0.47 which, according to the research of Metzler-Zebeli (2013) complied with the intraruminal pH level of the grain-free diet control group.

It is possible that the time of functional processes in rumen of goats and bulls are slightly different. A rapid consumption of feed mix and hay (after a conditional night rest) in case of bulls created intense rumination process in the result of which the ruminated food chunk, mixed with alkaline saliva, arrives in dorsal sac of rumen when swallowed, thus triggering neutralization of acid biologic food processing. In general we established a decrease of pH indicators by 0.4 pH divisions (from pH 7.3 to 6.9) in the upper and middle part (actually the thick sac of rumen) of dorsal sac of rumen only in the third hour after feeding and only in separate cases the middle part (area of electrode I of the probe) pH indicators decrease until 6.4. However the intraruminal pH in goats during the seven hours of testing changes from pH 7.2 - 7.4 in exit condition before feeding until even pH 6.0 in the second hour after feeding, i.e. the reaction of rumen decreased by 1.1 - 1.2 pH divisions. It is possible that fermentation processes, formation of lactic acid and volatile fatty acids in goats' rumen occur more rapidly than in cows (especially two to three hours after feeding) which have triggered a steeper decrease of intraruminal pH

level. Starting with the fourth hour in rumen of both goats and bulls the major part of food has been processed which is approved also by increased pH level. Such dynamics of functional processes in ruminants' rumen after feeding when the processing of consumed food lasts for 4 hours, reaching the maximum amount in the second hour after feeding, has been observed also by other authors (Bava et al., 2001; Lascano et al., 2009; Serment et al., 2011; Antanaitis et al., 2016).).

Changes in intraabomasal acid level before and after feeding also indicated that functional processes in abomasum of goats and bulls occur in a slightly different way. Feeding hay and mixed feed to bulls did not change the average pH levels in abomasum and they varied from 3.1 to 3.6 in area of measurement I and from 3.7 to 3.9 in area of measurement II. In case of goats pH level in areas of both measurements in abomasum after morning feeding was relatively higher, varying from 4.2 to 4.5, but after feeding it decreased steeply ($p < 0.05$) reaching pH 3.2 - 3.3. in two hours and remaining in the same level for two more hours. To some extent our data correspond to the results obtained by examining the impact of various foodstuffs on secretion of abomasum of sheep which are also so called "small ruminants". It was established that after feeding the juicy food the secretion of abomasum of sheep generally increased from the fourth to fifth hour, but after mixed feed - starting with the third hour (Anderson et al., 1988). Different functional indices of abomasum of cows and goats were established also by other authors (Koho et al., 2011; Khiaosa-ard, Zebeli, 2013; Webb et al., 2013; Oztule, Ilgaza, 2014).

Our research shows that in various areas of abomasum of adult bulls the acid level closer to pyloric gland area, that is in the area of measurement I of pH probe, is higher in the area of fundic glands - area of measurement II. We did not establish such correlation in case of goats. Obviously the alkaline or slightly acid content coming from the pouch of bulls can decrease the acid concentration in fundic gland area of abomasum but as content mixes with the abomasal juice and moves further to pyloric gland area, it reaches the highest concentration of acid (lower pH level). It has been known for a long time that the acid content of abomasum is one of factors irritating the pH-sensitive receptors of abomasum and "starting" the reflex of pyloric sphincter.

5. CONCLUSION

1. After feeding of hay and mixed feed to goats an averagely close positive linear correlation was established between intraruminal and intraabomasal pH dynamic of goats. We observed a material decrease of pH indicators twice - three hours after feeding: in rumen, varying from pH 7.4 - 7.2 to 6.1 - 6.3 and in abomasum from pH 4.2 - 4.5 to 3.2 - 3.5.
2. PH in dorsal sac of rumen after such feeding of bulls changes very slightly - from pH 7.3 - 7.5 to 6.5 - 7.2. After feeding the acid level in fundic gland area of abomasum is considerably lower (pH 3.7 - 3.9) than we established near the pyloric gland area (pH 3.1 - 3.6).
3. The established pH indicators in various parts of abomasum of adult bulls and kids after feeding of hay can differ considerably, therefore upon establishing the pH value it is important to indicate its location as precisely as possible. For goats this difference is not significant.

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