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THE INFLUENCE OF FEEDING CONDITIONS ON URINE pH AND PLASMA BICARBONATE LEVELS IN HEALTHY SHEEP

By

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In healthy sheep the reaction of the urine has generally been accepted to be on the alkaline side (*Bentinck-Smith* 1963). Thus *Healy et al.* (1928) only found 2 of 40 healthy sheep with an acid urine. *Bentinck-Smith* reported that nursing animals in contrast to adults will produce an acid urine. However, the influence of feeding on urine pH and plasma bicarbonate levels in sheep does not seem to have been systematically investigated. During recent years it has often been observed in this laboratory that healthy animals, examined as a matter of routine, may produce an acid urine. Based on these observations healthy sheep under different feeding conditions were examined in order to elucidate the influence of the diet on the pH of the urine and the plasma bicarbonate content. Since an excessive lactic acid production and increased fat metabolism may also influence the acid-base balance, the lactic acid concentration of rumen fluid was determined, and the urine was tested for ketone bodies.

MATERIALS AND METHODS

Experiment I

In a preliminary investigation determinations of urine pH were made once in healthy lambs, ewes and gimmers, and twice a day for 4 weeks in rams. This investigation comprised the following groups:

- a. 60 lambs, 3 months old, kept on pasture together with their dams.
- b. 150 ewes, 2—8 years of age, kept on pasture and supplemented with 600 g of concentrates per day.
- c. 18 gimmers, 1½—2 years of age, kept indoors and fed hay, silage and water ad lib. and 300 g of concentrates per day.
- d. 8 rams, 2 years old, kept indoors and fed hay, silage and water ad lib. and 300 g of concentrates per day.

Experiment II

Urine pH and urinary titratable acidity were determined in the following groups:

- a. 19 housed lambs, 8 months old, fed hay, silage and water ad lib. and 300 g of concentrates. The lambs were tested twice.
- b. 38 ewes, 2—6 years old, on pasture, each supplemented with 1.4 kg of silage and 300 g of concentrates per day. The urine was tested once.
- c. 4 housed ewes, 2 years old, fed hay and water ad lib. and 200 g of concentrates per day. The ewes were tested daily for 3 weeks.

Experiment III

In this experiment, in which the effect of various feeding conditions was more closely studied, urine pH, urinary titratable acidity, plasma bicarbonate and the lactic acid content in the rumen fluid were measured daily for 12 days. In addition, the urine was tested for ketone bodies. Urine samples, rumen fluid and blood samples were collected in the morning, that is before feeding of the housed animals. 8 yearlings were divided into groups of 4 each. These animals were examined under the following feeding conditions:

- a. Hay and water ad lib.
- b. " " " " and 300 g of concentrates
- c. Pasture and water ad lib.
- d. " " " " and 300 g of concentrates
- e. Silage and water ad lib.
- f. " " " " and 300 g of concentrates

At the end of each experimental period the animals were fed the successive diet for 3 days before samples were collected. Each experiment lasted for 12 days. pH measurements were made using a Metrohm pH-meter. The titratable acidity of the urine was determined by potentiometric titration with 0.01 N-NaOH to pH 7.4, expressed as geq./l of free acid converted into HCl. During

titration the samples were mixed by a magnetic stirrer. Tests for ketone bodies were carried out with "Acetest" tablets (Ames Company). The determination of plasma bicarbonate was made using the Van Slyke manometric method as described by *Wootton* (1964). Lactic acid was determined by the method of *Barker & Summerson* (1941). Formic acid was used to preserve the silage. The protein content of the commercial concentrate mixture was 19 % crude protein corresponding to 15 % digestible crude protein. In experiments I d and II a and c the animals were supplied with 15 g per day of a mineral mixture of which the chief components were Ca 10 %, P 8.4 %, NaCl 10 %, Na 7.4 % and Mg 1.7 %. The housed animals were fed silage and concentrates in the morning and hay in the afternoon.

RESULTS

Experiment I

The results will be apparent from Table 1. Urine pH was above 7 in 7 of the 60 lambs (11.7 %) and in 6 of the 150 ewes (4 %). In 20 of the 444 urine samples from the rams (4.5 %) pH was above 7 both before and after feeding.

Table 1. Urine pH in lambs, ewes and gimmers tested once, and in rams tested twice a day for 4 weeks.

Experiment I.

Animal groups	Age	Feeding conditions	Number of observations	Urine pH mean and range
a 60 lambs	3 months	on pasture with their dams	60	6.02 (4.80—8.35)
b 150 ewes	2—8 years	pasture and concentrates	150	5.90 (4.95—8.15)
c 18 gimmers	1½—2 years	hay, silage and concentrates	18	5.87 (5.55—6.25)
d 8 rams	2 years	hay, silage and concentrates	444	6.05 (5.10—8.15) before feeding 5.95 (4.95—8.70) after feeding

Experiment II

Fig. 1a shows the relation between urine pH and the titratable acidity of the urine expressed as g HCl/l. pH was lower in the

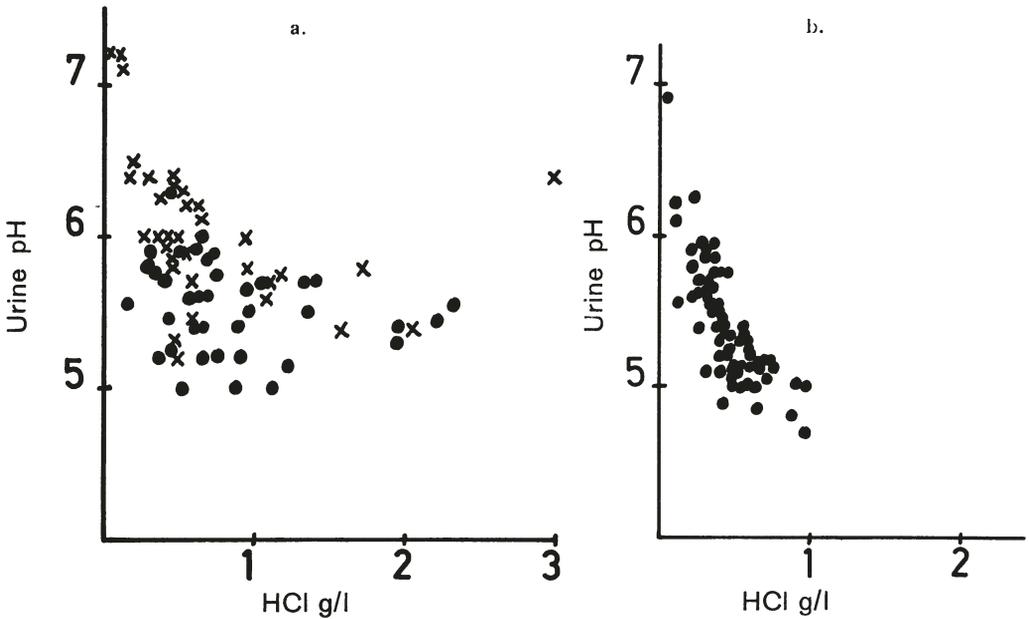


Figure 1 a. Urine pH and titratable acidity in the urine from housed lambs fed hay, silage and concentrates (●) and from ewes on pasture (x).

Figure 1 b. Urine pH and titratable acidity in the urine from 4 housed ewes fed hay and concentrates. The ewes were tested daily for 3 weeks.

urine from housed lambs than in the urine from ewes on pasture, the mean pH of the former being 5.53 and of the latter 6.15, 4 of these being above 7.40. The mean titratable acidity was 0.85 and 0.69 g HCl respectively. In the housed ewes (Fig. 1 b) the mean pH was 5.45 and the mean titratable acidity 0.44 g/l.

Experiment III

The results are summarized in Table 2, showing the mean values and range of urinary pH, urinary titratable acidity, plasma bicarbonate and lactic acid of rumen fluid under the different feeding conditions. Fig. 2 shows the relation between the urinary pH, the titratable acidity of the urine and the plasma bicarbonate level illustrating the daily variations in the pasture group and the group on pasture supplemented with concentrates.

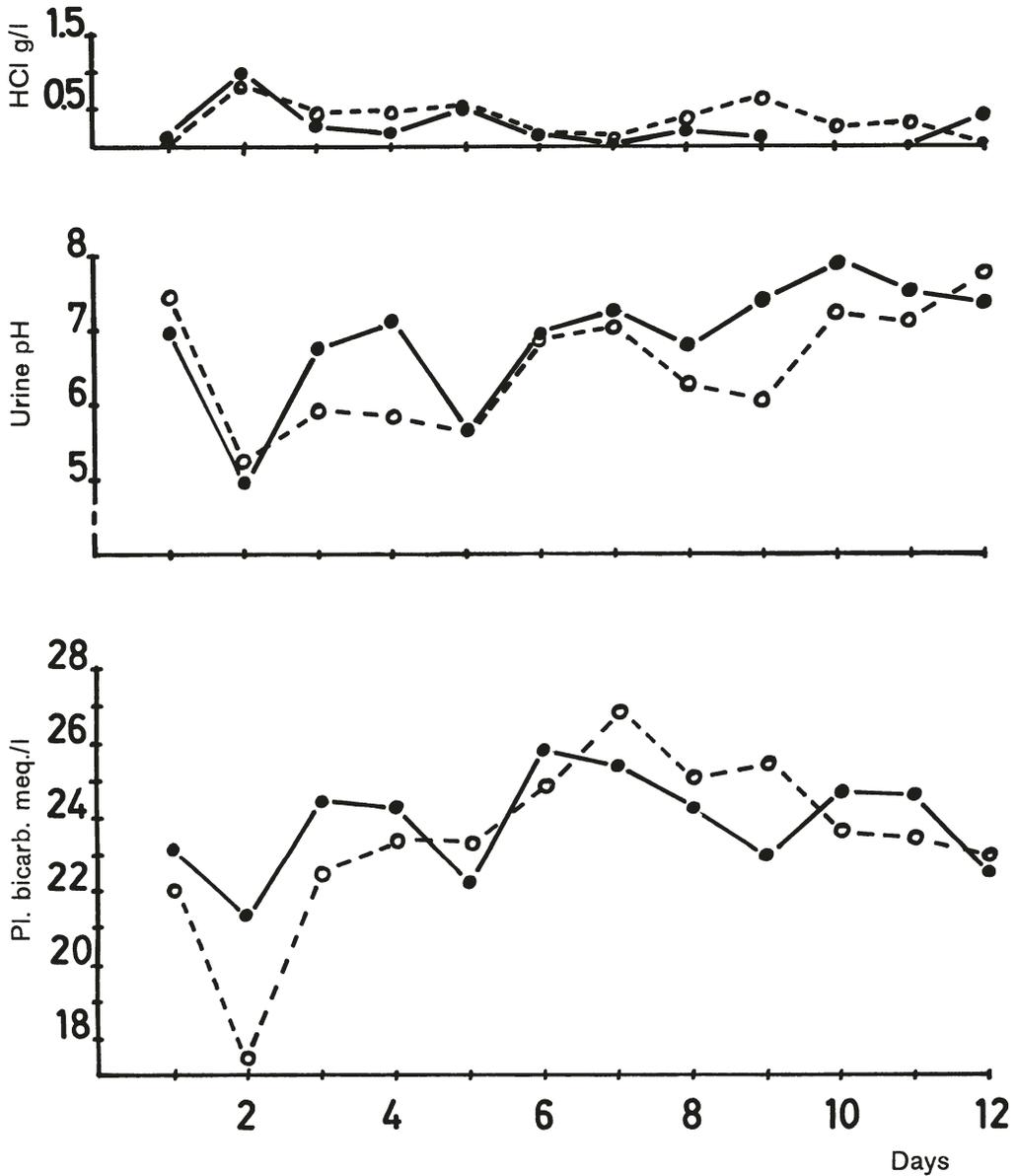


Figure 2. Plasma bicarbonate level, urine pH and titratable acidity of the urine from the pasture group (●-●) and from the group on pasture supplemented with concentrates (o----o). Each curve represents the mean values for 4 yearlings.

Table 2. Urine pH, titratable acidity in the urine, plasma bicarbonate and lactic acid levels in rumen fluid from 8 yearlings under different feeding conditions. Mean and range of 12 observations.

Experiment III.

Exp. III	Urine		Plasma	Rumen liquor	Feeding conditions
	pH	HCl g/l	plasma bicarbonate meq/l	lactic acid mg/100 ml	
a	7.59 (5.25—8.40)	0.11 (0—1.52)	25.2 (18.2—30.8)	0.19 (0—0.38)	hay
b	7.70 (5.75—8.30)	0.03 (0—0.57)	25.7 (21.3—30.4)	0.12 (0—0.45)	hay and concentrates
c	6.96 (4.98—8.20)	0.28 (0—1.60)	23.8 (18.7—27.8)	0.05 (0—0.46)	pasture
d	6.58 (4.90—8.40)	0.33 (0—1.18)	23.3 (14.7—28.6)	0.04 (0—0.65)	pasture and concentrates
e	6.49 (5.20—8.00)	0.09 (0—0.58)	23.9 (18.7—28.2)	0.19 (0—0.35)	silage
f	6.32 (5.30—7.80)	0.09 (0—0.44)	24.4 (19.1—29.1)	0.23 (0—2.55)	silage and concentrates

DISCUSSION

In contrast to what is generally accepted, the results of the present investigations, based on more than 1250 observations on altogether 244 sheep, show that even under markedly different feeding conditions, the pH of the urine of normal sheep is usually below 7. In the material as a whole, 92 % of the urine samples showed an acid reaction with a mean pH of about 6.0. In experiment II all the urine samples were on the acid side, but the titratable acidity of the urine was highest in the housed lambs. Silage, pasture and concentrates seemed to have a more acidifying effect than did hay-feeding supplemented with concentrates. Similar observations were made in experiment III, where the animals were tested for a longer period. In this experiment there was a tendency toward higher urinary pH values in the groups fed hay; the addition of concentrates inducing a slight rise of urine pH coincided with a decrease in titratable acidity of the urine. In the groups fed pasture or silage the concentrates seemed to lower urine pH, and pasture or silage alone had a more acidifying effect on the urine than hay alone. Pasture apparently caused the most acid urine judged by the titratable acidity and plasma bicarbonate (Table 2, Fig. 2). According to *Dittmer* (1961) plasma bicarbonate levels in normal sheep vary from 20 to 25 meq./l. In the present investigation a wider range, 14.7—30.8 meq./l, was observed. This range must be considered normal.

In pregnancy disease, where an excess amount of ketone bodies produces acidosis, *Sampson et al.* (1933) found a reduction in the alkali reserve. However, as urinary ketone bodies were not detected in the present investigation, there was apparently no excessive fat metabolism to produce acidosis. Nor does it seem reasonable that physical activity of the animals was of such intensity as to produce an excess of lactic acid to be excreted in the urine as seen in man following heavy exercise (*Judge & van Eys* 1962). Neither the blood nor the urine were tested as to lactic acid. However, in the rumen fluid the lactic acid concentration was less than 1 mg/100 ml except for one sample (2.55 mg/100 ml) and could not possibly influence the pH of the urine. In the rumen contents of sheep there is normally no lactic acid or only small amounts (*Hyldgaard-Jensen & Simesen* 1966) as this acid is fermented into volatile fatty acids (*Elsden* 1945). In experimentally induced rumen overloading the former authors found an increased lactic acid concentration in the rumen fluid, but the increase reflected an acid urine (pH about 6.50) only at levels of about 2500 mg/100 ml rumen fluid. *Krogh* (1961) in his studies of excessive starch feeding to hay-fed sheep found a decrease in the pH of the urine (in 1 animal tested) at low pH values in the rumen, the lowest urinary pH being 5.0 and approaching neutrality with increasing pH of the rumen fluid. The concentration of lactic acid in the rumen fluid was not mentioned. The feeding of concentrates and mineral mixture (some of the components being acidifying) may explain the acid urine reaction in the animals where these substances were given. However, pasture alone also produced an acid urine. The concept that the ordinary diets of ruminants contain an excess of base to be excreted with the urine thus seems to need modification. In the present investigation the "alkalinity" of the diets as such was not determined. However, it is felt that the reported observations may be of some value in establishing the normal range of urinary pH values in sheep under feeding conditions often met with in our country.

ACKNOWLEDGMENT

I wish to thank Professor Dr. Weiert Velle for his advice and helpful suggestions in preparing this manuscript.

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SUMMARY

The present investigation comprises pH-determinations in 1248 urine samples taken from a total number of 244 healthy lambs, gimmers, ewes and rams under different feeding conditions. 92 % of all urine samples showed an acid reaction with a mean pH of about 6. In one experiment 8 yearlings were fed hay, pasture and silage alone or with supplements of concentrates. Urine pH, amount of titratable acid in the urine, plasma bicarbonate and lactic acid content in rumen fluid were determined. In 83 % of the samples from the hay-fed group of animals the pH of the urine was above 7 (mean pH 7.59), and supplement of concentrates gave a rise in urine pH (mean pH 7.70). Mean pH in the groups of animals on pasture and those given silage were 6.96 and 6.49 respectively with 63 % and 40 % above 7. The

addition of concentrates reduced urine pH 0.38 and 0.17 pH units in average respectively. The plasma bicarbonate levels were ranging from 14.7 to 30.8 meq./l and reflected the urine reaction. The rumen lactic acid concentration was less than 1 mg/100 ml in all animals.

ZUSAMMENFASSUNG

Der Einfluss verschiedener Fütterung auf pH im Harn und Plasmabikarbonat bei Schafen.

In einem Material von insgesamt 1248 Harnproben von gesunden Lämmern, jungen weiblichen Schafen, Mutterschaften und Wittern, im ganzen 244 Tieren, unter verschiedenen Fütterungsverhältnissen, war das pH in 92 % der Proben unter 7, im Durchschnitt etwa 6. In einem Versuch mit 8 einjährigen Lämmern bestand das Futter aus Heu, Gras und Silage mit oder ohne Beigabe von Kraftfutter. pH im Harn, Menge der titrierbaren Säure im Harn, Plasmabikarbonat und Milchsäuregehalt im Pansensaft wurden gemessen. Bei den Tieren, die mit Heu gefüttert wurden, waren 83 % der Harnproben alkalisch, durchschnittliches pH 7,59. Eine Beigabe von Kraftfutter erhöhte das pH im Harn auf durchschnittlich 7,70. Bei den Tieren, die auf der Weide gingen, und bei denen, die mit Silage gefüttert wurden, war das durchschnittliche pH im Harn 6,96 und 6,49 mit 63 % bzw. 40 % auf der alkalischen Seite. Eine Beigabe von Kraftfutter reduzierte das pH im Harn durchschnittlich mit 0,38 bzw. 0,17 pH-Einheiten. Die Plasmabikarbonatwerte variierten von 14,7 bis 30,8 meq./l und widerspiegelten das pH im Harn. Der Milchsäuregehalt im Pansensaft war bei sämtlichen Tieren geringer als 1 mg/100 ml.

SAMMENDRAG

Innvirkningen av forskjellig fôring på urin pH og plasma bikarbonat hos sau.

I et materiale på ialt 1248 urinprøver fra friske lam, gimrer, søyer og værer, ialt 244 dyr, under forskjellige fôringsforhold, ble det i 92 % av prøvene målt pH lavere enn 7, i gjennomsnitt ca. 6. I et forsøk med 8 ett år gamle lam ble det fôret med høy, beite og silo med eller uten tilskudd av kraftfôr. Det ble målt urin pH, mengde titrerbar syre i urin, plasma bikarbonat og melkesyreinnhold i vomsaft. 83 % av urinprøvene fra dyr, som fikk høy, var alkalisk, gjennomsnittlig 7,59, og tilskudd av kraftfôr ga en økning i urin pH, gjennomsnittlig 7,70. Prøver fra dyr, som gikk på beite og fra dem som fikk silo, hadde gjennomsnittlig urin pH 6,96 og 6,49 med henholdsvis 63 % og 40 % på den alkaliske side. Tilskudd av kraftfôr reduserte urin pH, i gjennomsnitt henholdsvis 0,38 og 0,17 pH-enheter. Plasma bikarbonatverdier varierte fra 14,7 til 30,8 meq./l, og gjenspeilte urinens pH. Melkesyreinnholdet i vomsaft var mindre enn 1 mg/100 ml hos alle dyr.

(Received May 31, 1968).