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FERMENTATION PATTERN IN THE BOVINE RUMEN AFTER FEEDING STRAIGHT FEEDS*

By

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JENSEN, KURT: *Fermentation pattern in the bovine rumen after feeding straight feeds.* Acta vet. scand. 1977, *18*, 98—107. — The influence of straight feeds on the fermentation pattern in the bovine rumen was investigated by feeding with hay, grass pellets, dried beet pulp with molasses and rolled oats. The study comprised 3 rumen-fistulated dairy heifers, and the parameters measured were ammonia, pH and volatile fatty acids (VFA) in the rumen fluid, and non-glucogenic/glucogenic ratio (NGGR) in the VFA mixture.

Typical differences related to the structure and chemical composition of the diets were demonstrated by the parameters measured. Fermentation of the easily digestible feeds resulted in so extensive variations that representative means could be obtained only by analyzing samples collected frequently throughout the feeding cycle.

Rumen pH was found highly correlated to total VFA concentration for all the feeds examined, and the regression coefficients showed that diets, based upon beets and oats, were fermented under low buffering capacity.

straight feeds; cows; ammonia; pH; VFA; NGGR.

In the past a considerable number of experiments have been made to study the fermentation pattern in the bovine rumen after feeding grass based diets and mixed rations of roughage and concentrates. However, several investigations have been based on examinations of very few ruminal samples collected some hours after feeding (e.g. *Balch & Rowland* 1957, *Shaw* 1961, *Bath & Rook* 1965). Furthermore, the diurnal variation in experiments with discontinued feeding makes it difficult to obtain representative means of the fermentation pattern. The development of less tedious analytical methods has made it practicable to study the pattern of fermentation by analyzing samples col-

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lected frequently, and detailed investigations on the fermentation in the bovine rumen after hay feeding were recently published (*Fenner et al.* 1967, *Jensen* 1975), but the influence of straight feeds with high content of easily fermentable carbohydrates has not yet been clearly demonstrated.

The aim of the present study was to examine the composition of the fermentation pattern in the rumen of cattle fed some straight feeds commonly used in feeding practice.

MATERIALS AND METHODS

Experimental plan

The investigations were carried out in 3 non-pregnant Jersey heifers, average weight 342 kg, fitted with large rumen cannulae. The feeds were grass hay and grass pellets, representing 2 typical forms of roughage with high content of structural carbohydrates, and rolled oats and dried beet pulp with molasses, i.e. feedstuffs with high content of starch and sucrose, respectively.

The straight feeds were fed as single component rations throughout 4 periods as shown in Table 1. Each animal was fed 3.0 kg of air-dry feed every 12th hr. In addition, they were given supplementary minerals and vitamins and had free access to water.

In each period the feeding regime was unchanged for at least 2 months before sampling to ensure adaptation to the diet. Samples of rumen liquid-small particle phase were taken once an hour throughout a feeding cycle, i.e. a total of 13 samples per animal in each period.

Analytical methods

Bulk samples of the feeds were collected and analyzed by conventional methods (*Anon.* 1965) supplemented with determination of structural carbohydrates according to *Goering & Van Soest* (1970). The chemical composition of the feedstuffs is shown in Table 1.

Sampling and preparation of rumen fluid and determination of pH were performed as previously described (*Jensen* 1975). The content of ammonia in the rumen fluid was determined titremetrically after microdiffusion (*Conway* 1957). Rumen fluid total VFA concentration and the molar proportion of the individual acids were determined by gas-solid absorption chroma-

Table 1. Chemical composition of the experimental feeds.

Feed	Hay	Dried beet pulp with molasses	Grass pellets	Rolled oats
Experimental period	I	II	III	IV
Dry matter (DM), %	91.7	91.1	92.6	91.2
Composition of DM, %				
crude protein	15.9	12.6	13.6	11.2
crude fat	2.6	0.7	4.2	4.7
crude fibre	32.5	11.3	23.0	10.2
N-free extracts	42.6	67.9	51.7	70.5
crude ash	6.4	7.5	7.5	2.7
Structural carbohydrates, % of DM				
hemicellulose	30.3	7.7	25.2	30.1
cellulose	33.6	15.5	23.9	11.7
lignin	3.9	0.8	3.4	2.7
Energy, kcal/kg DM	4423	4108	4522	4309

tography (*Jensen* 1974). The ratio non-glucogenic/glucogenic acids (NGGR) in the VFA mixture was calculated using the formula given by *Ørskov* (1975).

RESULTS

The concentrations of fermentation end-products in rumen fluid are shown as daily means in Table 2. Fermentation of grass pellets, dried beet pulp with molasses and rolled oats resulted in almost identical means of pH, whereas hay showed a significantly higher pH. The diurnal variation of pH is illustrated in Fig. 1. The easily digestible feeds resulted in systematic variation of pH related to time of feeding with a pronounced decline when the increase of the fermentation commenced. The minimum pH was recorded 1—2, 2 and 3—4 hrs. after ingestion of grass pellets, dried beet pulp with molasses and rolled oats, respectively, and, expressed in the same order, the declines of pH were 0.4, 0.5 and 1.2 units. The initial pH was re-established 7 hrs. after feeding grass pellets and dried beet pulp with molasses, and 12 hrs. after feeding rolled oats. In the period with hay, the pH varied only slightly during the feeding cycle.

The daily mean of total VFA concentration was highly influenced by the diets (Table 2). The highest concentration was found after feeding dried beet pulp with molasses, whereas hay

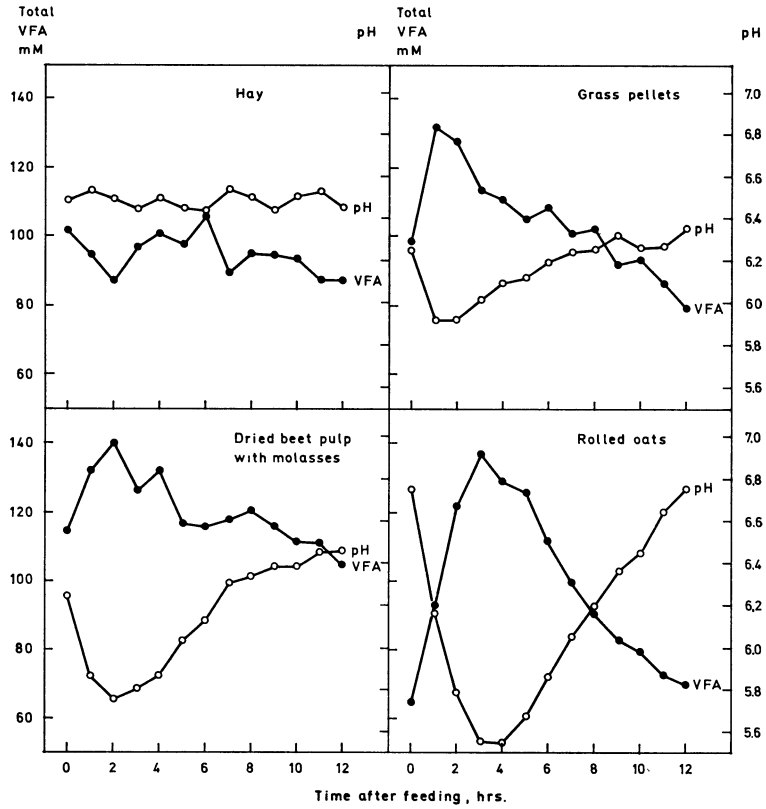

Figure 1. Diurnal variations in rumen pH and concentration of volatile fatty acids. Each point represents the mean from 3 animals.

resulted in the lowest concentration, and the means from grass pellets and rolled oats were intermediate. The diurnal variation of total VFA concentration was inversely related to the pH (Fig. 1). The initial concentration was increased by 26, 30 and 72 mmol/l rumen fluid until the peak values were found 2, 2 and 3 hrs. after feeding in the periods II, III and IV, respectively, whereas hay showed only small fluctuations.

The molar percentage of acetic acid was greater after feeding hay than after feeding easily fermentable feeds. The propionic acid showed a higher proportion after feeding rolled oats and grass pellets than after the other diets. The proportion of butyric acid was significantly different between all the diets, and dried beet pulp with molasses was highly butyrogenic. The daily fluctuations in the molar proportions of the main acids were

Table 2. Influence of straight feeds on the average pH and on the average concentrations of ammonia and volatile fatty acids in rumen fluid. Daily mean ± s.e.m. from 3 heifers (n = 39).

Feed	Hay	Dried beet pulp with molasses	Grass pellets	Rolled oats
Experimental period	I	II	III	IV
Ammonia, mmol/l	4.51[a]	2.42[ab]	1.24[b]	5.50[a]
	0.696	0.328	0.351	0.662
pH	6.51[a]	6.16[b]	6.16[b]	6.10[b]
	0.025	0.050	0.052	0.082
Total VFA, mmol/l	94.3[a]	120.5[b]	104.9[c]	100.6[ac]
	1.43	2.52	2.95	4.93
Composition of total VFA, mol %				
acetic acid	75.1[a]	61.4[b]	61.2[b]	63.2[c]
	0.11	0.91	0.91	0.70
propionic acid	17.4[a]	17.1[a]	20.6[b]	20.8[b]
	0.06	0.24	0.85	0.53
butyric acid	5.5[a]	20.2[b]	15.6[c]	12.0[d]
	0.04	0.86	0.63	0.33
valeric acid	0.59[a]	1.29[b]	1.79[c]	2.51[d]
	0.055	0.065	0.159	0.293
isobutyric acid	0.54[a]	0.04[b]	0.48[a]	0.81[a]
	0.029	0.008	0.034	0.101
isovaleric acid	0.82[a]	0.04[b]	0.38[c]	0.48[c]
	0.031	0.010	0.040	0.073
NGGR	4.81[a]	5.61[b]	4.21[c]	3.83[d]
	0.019	0.079	0.040	0.052

[a-d] Means with unlike superscripts are significantly different ($P<0.01$).

small, except in the period with the sucrose-containing diet where the proportion of butyric acid increased from 13 to 26 % 2 hrs. after feeding. The molar proportion of valeric acid showed a systematic pattern of variation with the peak values 2—3 hrs. after feeding. The proportions of the branched-chain isomers of butyric and valeric acids were quite low and only slightly affected by the diets in the periods I, III and IV, but in period II an extremely low amount was found.

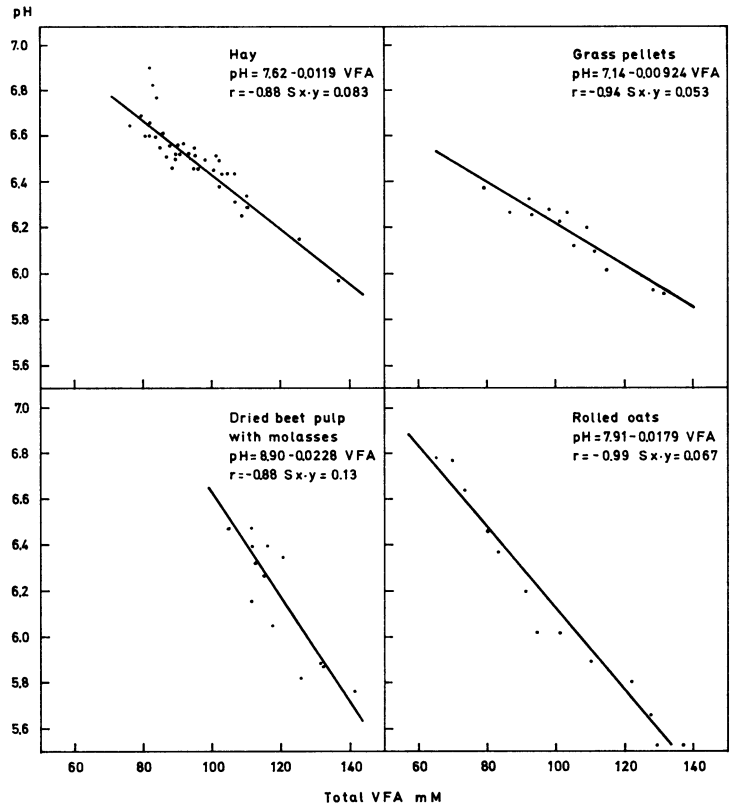

Figure 2. Rumen pH as related to concentration of volatile fatty acids. Each point represents the mean from 3 animals.

According to the observed differences in the molar composition of the VFA mixture, the NGGR showed significant differences between all the diets, and particularly the beet based diet was extremely non-glucogenic.

The daily mean concentration of ammonia is also shown in Table 2. All the diets resulted in low means, particularly the grass pellets. The diurnal variation was found closely related to time of feeding, and the shape of the concentration curve was similar in all periods, only the concentration level differed. The peak values were found in the sample taken 1 hr. after feeding, followed by a rapid decline to a minimum level. The concentration remained low 3—7 hrs. after feeding, after which time it increased slowly toward the initial level.

The relationship of rumen pH and total VFA concentration is demonstrated in Fig. 2. To ensure a broad range of variation for the figures representing fermentation of hay, the results plotted include those previously obtained by hay feeding (*Jensen* 1975). The pH was found highly correlated to the concentration of total VFA for all the straight feeds examined ($P < 0.001$). Indirectly, the slope of the regression line shows the buffering capacity of the digesta. Calculated from the regression equations in Fig. 2, the buffering capacity, expressed as meq. acid or base necessary to change pH 1 unit in 100 ml rumen fluid, was 10.8, 8.4, 5.6 and 4.4 meq. in the periods III, I, IV and II, respectively. The grass based diets possessed twice as much protection against change of pH than the diets with low content of structural carbohydrates, although the differences were not statistically significant.

DISCUSSION

Fermentation of hay occurred without significant changes of ruminal pH and total VFA concentration throughout the feeding cycle. However, increased feeding level of hay has previously been shown to result in some variation of the fermentation rate related to time of feeding (*Fenner et al.* 1967, *Jensen* 1975). The diurnal variation was considerable in the other experimental periods, mainly due to the readily established microbial attack of carbohydrates in the mechanically disintegrated feeds. According to the observations made by *Bath & Rook* (1963) in experiments with concentrates, these results emphasize the necessity of sampling digesta at frequent intervals throughout the feeding cycle in order to achieve representative mean values of the parameters measured.

The composition of the VFA mixture was highly affected by the treatment due to different structure and chemical composition of the diets. The fermentation of grass pellets increased the proportions of propionic and butyric acids, which confirms that grass pellets are both propionogenic and butyrogenic when compared with hay. Dried beet pulp with molasses was found highly butyrogenic, particularly in the period of peak fermentation. This result agrees with the observations made from feeding beet pulp (*Bath & Rook* 1965), and from experiments with purified diets in which the butyrogenic effect of sucrose was demonstrated

(*Ørskov & Oltjen* 1967). The propionogenic effect of rolled oats was not as pronounced as previously found (*Wolstrup et al.* 1974), but according to experiments made by *Sutton & Johnson* (1969) and *Whitelaw et al.* (1972), it is difficult to predict the proportion of propionic acid from cereal diets because of high variability influenced by the level of feeding and by the composition of the rumen microorganisms.

The molar composition of the VFA mixture is suitably expressed by a single figure giving the proportion between C_2 and C_3 units originating from fermentation of carbohydrates, as emphasized by *Ørskov* (1975). Without regard to the preferential level of this ratio for the efficiency of VFA utilization in the energy metabolism of the host animal, dried beet pulp with molasses yielded the least glucogenic VFA mixture followed by hay and grass pellets, and rolled oats was most glucogenic.

The concentration of ammonia in the rumen fluid was quite low in all the periods, but within the acceptable range (*Møller* 1973). According to the in vitro experiments made by *Satter & Slyter* (1974), who found the microbial protein production drastically reduced when the ammonia concentration was below 4 mmol/l, utilization of NPN in ruminants could be expected at concentrations below this level. Grass pellets and dried beet pulp with molasses resulted in mean concentrations of ammonia below this level, and particularly 3—7 hrs. after feeding additional NPN might be utilized in the microbial protein synthesis. According to the observations made by *Satter & Slyter*, the concentration of VFA has presumably not been depressed by lack of protein, since they found the VFA production appreciably affected only when the crude protein was below 8 % of dry matter in the ration.

The highly negative correlation of rumen pH to total VFA concentration is in agreement with the observations made by *Briggs et al.* (1957) in experiments with sheep. They found, like *Rumsey et al.* (1970) in experiments with steers, that rations with high content of concentrates were fermented under lower protection against decline of pH than was roughage. The grass based diets possessed a buffering capacity twice as high as that of the diets with low content of structural carbohydrates. This might contribute to explain the frequently occurring rumen acidosis after ingestion of beets and concentrates.

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SAMMENDRAG

Fermentationsmønstret i kvægets vom under omsætning af fodermidler i renbestand.

Sammensætningen af forgæringsmønstret i vommen hos 3 fistulerede kvier blev undersøgt efter fodring med hø, grønpiller, snitfoder og havre i renbestand. Effekten af forsøgsbehandlingen blev karakteriseret ved ammoniak, pH og flygtige fedtsyrer (VFA) i vomsækken samt non-glucogen/glucogen ratio (NGGR) i VFA-blandingen.

Gennemsnitsværdierne for de enkelte parametre viste betydelige forskelle i relation til fodermidlernes kemiske sammensætning og struktur. Endvidere medførte de let forgærbare fodermidler så betydelig daglig variation af vomvæskens sammensætning, at repræsentative gennemsnitsværdier kun kunne opnås ved analysering af prøver udtaget hyppigt mellem fodringerne.

Vomindholdets pH fandtes højt korreleret til koncentrationen af total VFA for alle fodermidlerne, og regressionskoefficienterne viste, at forgæringen af snitfoder og havre fandt sted under lav stødpudekapacitet.

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