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Rumen fermentation and retention time of the digesta in growing cattle of the breeds Black-White Dairy Cattle, Galloway, and Highland

Dedicated to Prof. Dr. habil. agr. H. Hagemeister on the occasion of his 65th birthday

Summary

The objectives of this study were to describe ruminal fermentation, mean retention time (MRT) of the particulate digesta in the whole gastrointestinal tract and the apparent digestibility of nutrients in growing cattle of the genotypes Black-White Dairy Cattle (B), Galloway (G), and Highland (H). Two experiments were carried out in bulls aged 11-12 months (mean weight 260 kg) or 9-10 months (mean weight 210 kg) at the beginning and fed diets varying in the nutrient composition and nutrition level. B bulls had a higher rumenoreticular volume, a higher MRT when fed a low nutrition level, a higher ruminal pH and a lower acetate/propionate ratio in the rumen than G bulls ($P<0.05$). In comparison with H bulls, rumen pH and MRT were higher ($P<0.05$) and the acetate/propionate proportion, NH_3 level, and the protozoa number in the rumen were smaller in B bulls. The differences between genotypes in apparent digestibility of organic matter (OM) and crude cellulose were small. In some cases digestibility was significantly ($P<0.05$) higher in B bulls as compared to G and H bulls. In B bulls, the digestibility of OM at 30 °C environmental temperature was 2 units lower than at 3°C or 18 °C ($P<0.05$). The results show that B bulls implement a more efficient ruminal digestive process than do G or H bulls.

Key Words: cattle, breed, rumen fermentation, mean retention time, digestion

Zusammenfassung

Titel der Arbeit: **Pansenfermentation und Retentionszeit der Digesta von Rindern der Rassen Schwarzbuntes Milchrind, Galloway und Highland**

Das Ziel der Arbeit bestand darin, die Pansenfermentation, mittlere Retentionszeit der partikelgebundenen Digesta (MRT) im Gastrointestinaltrakt und die scheinbare Verdaulichkeit der Nährstoffe bei wachsenden Bullen der Genotypen Schwarzbuntes Milchrind (B), Galloway (G) und Highland (H) vergleichend zu untersuchen. Dazu wurden 2 Experimente an Bullen, die zu Versuchsbeginn 11-12 Monate (mittlere LM 260 kg) bzw. 9-10 Monate (mittlere LM 210 kg) alt waren und mit Rationen unterschiedlichen Nährstoffgehaltes bei differentem Ernährungsniveau gefüttert wurden, durchgeführt. Die B-Bullen besaßen im Vergleich zu den G-Bullen ein größeres Pansenvolumen, eine höhere MRT bei einem Ernährungsniveau $\leq 1,4$, einen höheren pH-Wert sowie ein engeres Acetat-Propionat-Verhältnis im Pansen ($P<0,05$). Gegenüber den H-Bullen waren der pH-Wert im Pansen sowie die MRT erhöht und das Acetat-Propionat-Verhältnis, der NH_3-Spiegel und die Protozoenzahl im Pansen erniedrigt ($P < 0,05$). Die Differenzen in der scheinbaren Verdaulichkeit der organischen Substanz (OM) und der Rohzellulose waren zwischen den Rassen gering; in Einzelfällen war die Verdaulichkeit bei den B-Bullen signifikant höher ($P<0,05$). Bei diesen Tieren sank die Verdaulichkeit der OM um 2 Einheiten, wenn die Umgebungstemperatur von 3 bzw. 18 °C auf 30 °C erhöht wurde ($P<0,05$). Die Ergebnisse zeigen, dass die ruminalen Verdauungsprozesse bei den B-Bullen effektiver ablaufen.

Schlüsselwörter: Rind, Genotyp, Pansenfermentation, Retentionszeit, Verdauung

Introduction

Breeds of cattle like Galloway (G) or Highland (H) used for extensive meat production on the one hand and breeds of cattle like Black-White Dairy Cattle (B) used for

intensive milk or meat production on the other hand are adapted to different conditions over many generations. Thus, under poor conditions, robust breeds of cattle like Brahman crossbred are better able to maintain live weight than do cattle selected for high beef production (FRISCH and VERCOE, 1984; KENNEDY, 1982) which suggests that there were differences between breeds in feed efficiency. There is a lack of understanding of the mechanisms responsible for the observed difference in feed efficiency between breeds of cattle. Differences in the digestive process between breeds could be one of the reasons. However, in earlier studies only small or no differences were noted in the apparent digestibility of nutrients and energy between G and B animals (JENTSCH et al., 1994).

As part of a comparative study of physiology, the mean retention time of a particle marker in the gastro-intestinal tract, rumen fermentation and digestibility of diets differing in fibre content and nutrient level were studied in G, H, and B bulls. The results of digestibility have been published in detail (JENTSCH et al., 1995).

Material and Methods

Experiment I

Eight G and eight B bulls, initially 11-12 months of age and all of approximately 260 kg body weight (BW), were housed in individual pens in a metabolic house at 18-20 °C and a humidity of 70 %. They were given six diets in 10 experimental periods as shown in Table 1.

Table 1
Composition of the diets and nutrition level (Futtermittelanteile in den Rationen und Ernährungsniveau)

Diet	Composition of the diet (% Dry matter)		Nutrition level[1]			
	Experiment I	Experiment II	Experiment I		Experiment II	
1	55 % Rye grass hay 45 % Barley	40 % Rye grass hay 40 % Hot air dried grass 20 % Barley	1.1	1.9	1.1	1.8
2	80 % Rye grass hay 20 % Barley	50 % Rye grass hay 50 % Hay from national park	1.1	1.8	1.3	-
3	90 % Hot air dried grass 10 % Dried sugar beet pulp	50 % Rye grass hay 50 % Ray straw	1.0	1.5	1.1	-
4	90 % Meadow grass hay 10 % Dried sugar beet pulp	80 % Hot air dried grass 20 % Barley	1.0	1.4	1.5[2]	-
5	100 % Hay from national park		1.0			
6	100 % Wheat straw (+ 42 g Urea/(animal · d))		0.9			

[1]Nutrition level 1.0 = 450 kJ ME/(kg $BW^{0.75}$ · d); [2] Diet was fed at three temperature levels (3, 18 and, 30 °C)

Four diets were offered in two nutrition levels (low 1 times maintenance (450 kJ ME/(kg $BW^{0.75}$ · d)), high 1.4–1.9 times maintenance). The animals received equal

portion of their diet daily at 07.00 and 15.30 hours. Additionally, 50 g of a mineral-vitamin-mixture were given per animal and day. The chemical composition of the diets used is presented in Table 2. The diets were weighed out for each experimental period including a preliminary period of 18 days and a sampling period of 10 days. Representative samples of roughage and concentrate were oven dried (65 °C), air equilibrated, ground to pass a 1 mm sieve, and stored until to the analysis. Feed residues were collected daily, pooled over the sampling period, sampled and prepared for analyses as indicated for the diet samples.

Table 2
Energy content (MJ/kg DM) and chemical composition of the diets (g/kg DM) (Energiegehalt (MJ/kg TS) und chemische Zusammensetzung der Rationen (g/kg TS))

Diets	Gross energy	Organic matter	Crude protein	Crude cellulose	Starch	Cellulose/ Starch	WSC[1]
Experiment I							
1	18.06	945	103	181	292	0.6	103
2	18.09	938	103	250	135	1.8	117
3	18.30	899	174	290	16	18.1	66
4	18.01	917	102	341	19	18.0	84
5	18.45	942	64	391	20	19.6	72
6	18.95	950	34[2]	443	2	221.5	6
Experiment II							
1	18.11	919	134	222	127	1.7	128
2	18.24	933	92	325	4	81.2	128
3	18.38	934	82	364	10	36.4	95
4	17.86	893	153	216	127	1.7	78

[1] Water soluble carbohydrates; [2] With added urea 54 g crude protein/kg DM

During the sampling period daily 10% of the days mixed faeces were collected with a level of accuracy of ±10 g and stored at a temperature of 0-3 °C. After homogenisation of the faeces at the end of the collection period, samples were taken to determine N and DM content. Two further samples each of 750 g were lyophilised and then ground through a 1 mm sieve. The daily urine excretion was collected in a canister and its pH was kept below 3 by addition of 3 M H_2SO_4. Urine sampling followed the same procedure as the faeces sampling. The samples were stored at 0-3 °C and after homogenisation used for N determination.

On the first day of the sampling period, the animals received a single dose of a pelleted TiO_2-wheat flour mixture (100 g with 14 g TiO_2 per animal). Subsamples of faeces were collected 24, 36, 48, 60, 72, 96 and 120 h after dosage of TiO_2. Rumen fluid was sampled by an oesophagus tube (STEGER et al., 1968) in the last day of each period 3 hours after morning feeding, transported into the laboratory and analysed for pH, NH_3, volatile fatty acids (VFA) and protozoa number.

In diet and faecal samples, the determination of dry matter (DM), ash, crude cellulose, and N was done following the Weender standard procedures (NAUMANN and BASSLER, 1988). Starch and water soluble carbohydrate were determined by the method of ZWIERZ et al. (1981). In faecal samples TiO_2 was determined after Kjeldahl digestion by the method of BRAND and ALLAM (1987). The concentration

of VFA in samples of rumen fluid was determined by gas chromatography with i-capronic acid as internal standard (GEISSLER et al., 1976) using a SHIMADZU GC-14A with an FFAP 25m x 0,25mm I. D. column. pH was measured with a glass electrode and NH_3 levels were determined by microdiffusion (VOIGT and STEGER, 1967).

The animals were slaughtered at an age of 18–19 months and a body weight of 300–320 kg. Subsequently, the volume of empty rumen was estimated in a water bath using pressures of 5 mbar above atmospheric pressure by the method described by NAGEL and PIATKOWSKI (1972).

Experiment II

The study was carried out in each 8 young H bulls and 8 young B bulls aged 9-10 months and weighting initially 210 kg each. Housing of the animals was equal to Exp. I. The bulls were fed four diets in 7 experimental periods as shown in Table 1. The temperature in the metabolism chamber was maintained at 18 °C, for diet 4 also at 3 °C and 30 °C. The animals were kept at these temperatures over a period of 10 days. The chemical composition of the diets is shown in Table 2.

The experimental procedure, feeding, sampling and analysis were carried out as in Exp. I. Additionally, Protozoa number in rumen fluid were determined by the method of FERBER and WINOGRADOWA-FEDEROWA (1929). The identification of rumen ciliate protozoa was done as described by DOGIEL (1927) and HUNGATE (1966). In each case 100 protozoa were counted and assigned to *Holotrich* protozoa (*Isotricha, Dasytricha*) and *Ophryoscolecidae* (*Entodinium, Diplodinium, Ophryoscolex, Epidinium*).

Calculations and statistical analysis

The mean retention time of the passage marker TiO_2 (MRT) in the whole gastrointestinal tract was calculated according to BLAXTER (1956):

$$MRT = \frac{\sum_{i=1}^{n} (t_i \, x \, m_i)}{\sum_{i=1}^{n} m_i}$$

where m_i is the amount of marker excreted at the *i*th sample and t_i is the time elapsed between dosing and the mid-point of the *i*th collection interval.

The results were statistically analysed by ANOVA and multiple factorial GLM procedure of SPSS (Version 8.0; SPSS Inc.), and when appropriate, means were compared by the Scheffé multiple range test. Interactions were investigated and included in the model if they reached significance at the 5 % level. When only breeds were compared, the Student's *t* test was performed ($P < 0.05$).

Results

1. Digestibility

The digestibility of nutrients in Exp. I and II is shown in Table 3 and Table 4, respectively. For total diets in Exp. I, apparent digestibility of organic matter (OM) and crude cellulose in the whole gastrointestinal tract did not differ significantly between G and B cattle. Among bulls fed the low fibre high NL diet, B animals digested more ($P<0.05$) OM than G animals did. The digestibility of OM and crude cellulose was also higher ($P<0.05$) in B bulls than in G bulls given the straw diet 6.

Averaging all diets in Exp. II, B bulls digested more ($P<0.05$) OM and crude cellulose than H bulls. The digestibility of OM in B bulls at 30°C was lower when compared with the 3 and 18 °C treatment temperature ($P<0.05$).

Table 3

Experiment I: Intake of dry matter (DMI) and digestibility of nutrients (%) (Means ± SD) (Versuch I: Aufnahme an Trockensubstanz und Verdaulichkeit der Nährstoffe; Mittelwerte ± s)

Diet	NL	n		DMI [g/(100 kg BW · d)]		Digestibility			
						Organic matter		Crude cellulose	
		G	B	G	B	G	B	G	B
1	1.1	8	8	1028	1013	80.8 ± 1.4	81.5 ± 1.3	78.5 ± 2.4	78.7 ± 2.1
1	1.9	8	8	1705	1883	70.3 ± 2.2^{a}	73.5 ± 2.1^{b}	57.6 ± 9.3	63.2 ± 5.2
2	1.1	8	8	1112	1115	78.3 ± 1.1	78.8 ± 0.5	83.1 ± 1.4	83.8 ± 0.8
2	1.8	8	8	1856	1828	74.1 ± 2.9	73.6 ± 2.0	77.1 ± 5.1	77.5 ± 2.8
3	1.0	4	4	1144	1135	71.3 ± 0.5	70.5 ± 0.9	80.4 ± 0.8	79.2 ± 2.5
3	1.5	4	4	1781	1681	69.2 ± 0.8	68.1 ± 1.4	77.4 ± 1.9	76.1 ± 2.8
4	1.0	3	4	1371	1295	62.9 ± 0.8	63.6 ± 1.6	67.9 ± 1.0	70.3 ± 1.6
4	1.4	3	4	1885	1845	62.5 ± 0.2	61.5 ± 0.9	66.4 ± 2.0	66.7 ± 3.1
5	1.0	8	8	1510	1481	57.9 ± 0.9	58.5 ± 1.2	68.0 ± 2.0	67.2 ± 1.8
6	0.9	8	8	1159	1243	54.6 ± 1.8^{a}	56.7 ± 2.2^{b}	68.3 ± 2.2^{a}	70.9 ± 2.6^{b}
Total diets						68.2 ± 8.6	68.6 ± 8.4	72.5 ± 8.0	73.4 ± 6.6

^{a,b} Means with different superscript letters within a row are significantly different ($P < 0.05$, Student's non-paired t test)
NL Nutrition level; B Black-White Dairy Cattle; G Galloway

Table 4

Experiment II: Intake of dry matter (DMI) and digestibility of nutrients (%) (Means ± SD) (Versuch II: Aufnahme an Trockensubstanz und Verdaulichkeit der Nährstoffe; Mittelwerte ± s)

Diet	NL	n	DMI [g/(100 kg BW · d)]		Digestibility			
					Organic matter		Crude cellulose	
			H	B	H	B	H	B
1^{2}	1.1	8	1218	1174	73.9 ± 0.6	74.5 ± 0.9	72.5 ± 1.6	73.5 ± 1.2
1^{2}	1.8	8	1956	1956	71.8 ± 1.2	71.9 ± 1.5	68.0 ± 2.6	67.7 ± 2.3
2^{2}	1.3	8	1617	1549	63.8 ± 0.9^{a}	66.8 ± 1.7^{b}	67.7 ± 2.0^{a}	73.7 ± 2.5^{b}
3^{2}	1.1	8	1437	1393	61.0 ± 1.4	62.2 ± 1.3	68.5 ± 2.2	70.6 ± 1.4
4^{1}	1.5	4	1521	1533	70.6 ± 0.9^{a}	72.4 ± 0.3^{bA}	69.4 ± 1.1^{A}	70.3 ± 1.4
4^{2}	1.5	8	1551	1582	70.9 ± 1.1	72.1 ± 1.1^{A}	66.2 ± 3.6^{aAB}	71.1 ± 1.1^{b}
4^{3}	1.5	4	1195	1625	70.4 ± 0.7	70.5 ± 0.9^{B}	66.6 ± 0.6^{aB}	69.0 ± 2.1^{b}
Total diets					68.9 ± 4.6	70.1 ± 4.2*	68.4 ± 2.1	70.8 ± 2.2*

^{a,b} Means with different superscript letters within a row are significantly different ($P < 0.05$, Student's non-paired t test)
* Significant difference between breeds ($P < 0.05$, Students paired t test of the mean values, 6 df))
^{A,B} Means with different superscript letters within a column show significantly difference between temperature treatment ($P < 0.05$, Student's non-paired t test)
^{1,2,3}Environmental temperature 3 °C (1), 18 °C (2) and 30 °C (3)
NL Nutrition level; B Black-White Dairy Cattle; H Highland

Table 5
Experiments I and II: Ruminal physiological parameters (Versuche I und II: Pansenphysiologische Kennwerte)

Diet	NL	Crude fibre g/kg DM	pH		VFA mmol %		Acetate mol %		Propionate mol %		Butyrate mol %		Acetate/Propionate		NH_3 mmol/l	
Experiment I:			G	B	G	B	G	B	G	B	G	B	G	B	G	B
1	1.1	181	6.85	6.87	90.3	90.3	66.7^{a}	64.3^{b}	17.7	20.3	15.6	15.4	3.83	3.20	4.4	6.0
1	1.9	181	6.55	6.61	99.6	95.2	61.8	61.4	21.3	21.4	16.9	17.2	2.98	2.93	1.7	2.1
2	1.1	244	6.94	6.99	80.7	81.1	67.6^{a}	64.9^{b}	18.7^{a}	22.9^{b}	13.7	12.2	3.62	2.87	5.0	5.2
2	1.8	244	6.55	6.72	92.0	96.0	65.3	64.2	20.0^{a}	23.0^{b}	14.7	12.9	3.30	2.81	4.7	3.8
3	1.0	282	6.96	7.02	71.8	71.4	76.2	75.5	15.3	15.6	8.5	8.9	5.00	4.84	11.7	10.9
3	1.5	282	6.74	6.82	77.4	75.5	75.2	74.6	15.8	16.8	9.0	8.7	4.78	4.46	12.8	10.7
4	1.1	348	6.86	6.86	77.0	72.2	71.7	72.8	20.9	18.9	7.4	8.2	3.45	3.85	5.8	7.3
4	1.4	348	6.73	6.91	76.5	75.3	73.8	74.7	17.4	17.6	8.8	7.7	4.24	4.25	6.0	7.3
5	1.0	392	6.83	6.96	68.8	69.9	74.4	74.4	16.8	17.5	8.9	8.0	4.44	4.27	2.7	4.0
6	0.9	497	7.04^{a}	7.24^{b}	62.1	62.8	77.2	77.6	15.8	16.6	7.0	5.7	4.90	4.69	9.8	8.3
Total diets			6.80	6.90*	80.9	80.5	70.1	69.8	18.1	19.3*	11.8	10.9	3.98	3.74*	5.8	5.9
Pooled SE			0.19		0.76		2.4		1.8		1.8		0.40		1.6	
Interaction									Breed*Diet						Breed*Diet	
Experiment II:			H	B	H	B	H	B	H	B	H	B	H	B	H	B
1	1.1	220	6.96	6.90	57.7	61.6	61.9	61.6	17.5^{a}	21.1^{b}	16.2^{a}	12.7^{b}	3.54^{a}	2.92^{b}	6.8^{a}	5.5^{b}
1	1.8	323	6.57	6.61	76.5	72.9	58.8	57.7	20.0^{a}	24.1^{b}	17.4^{a}	14.3^{b}	2.95^{a}	2.41^{b}	8.7^{a}	6.2^{b}
2	1.3	379	6.55	6.69	71.5	71.5	64.2	63.8	21.2	21.0	11.5	12.2	3.08	3.07	4.8^{a}	2.3^{b}
3	1.1	238	6.66	6.80	67.5	60.6	65.3	65.5	20.4^{a}	22.7^{b}	10.8^{a}	8.6^{b}	3.21^{a}	2.90^{b}	5.1^{a}	3.6^{b}
4[1]	1.5	238	7.13	7.27	54.9^{aA}	60.7^{b}	70.9	70.7	14.4	13.9	10.2	10.1	4.96	5.12	7.1^{aA}	8.8^{b}
4[2]	1.5	238	7.14	7.40	65.1^{B}	69.9	71.5	71.8	14.2^{a}	13.4^{b}	9.8^{a}	10.7^{b}	5.05^{a}	5.39^{b}	7.1^{aA}	7.6^{b}
4[3]	1.5	238	7.17	7.37	52.3^{aA}	64.9^{b}	71.2	70.9	14.2	14.1	8.6	10.3	5.05	5.04	9.1^{B}	8.3
Total diets			6.88	7.00*	63.4	66.2	66.3	66.0	17.4	18.6*	12.1	11.4	3.98	3.84*	7.0	6.0*
Pooled SE			0.20		7.2		1.5		1.3		1.7		0.35		1.2	
Interaction									Breed*Diet		Breed*Diet				Breed*Diet	

[a,b] Means with different superscript letters within a row are significantly different ($P < 0.05$, Student's non-paired *t* test)
[A,B] Means with different superscript letters within a column show significant differences between temperature treatment ($P<0.05$, one-factorial ANOVA)
* Significant difference between breeds ($P < 0.05$, three-factorial GLM in Exp. I, four-factorial GLM in Exp. II))
[1, 2, 3] Environmental temperature 3 (1), 18 (2) and 30°C (3)
NL Nutrition level
G Galloway, H Highland, B Black-White Dairy Cattle

2. Rumen fermentation

The differences between G and B bulls in mean pH, mol-% propionate and the acetate/propionate ratio were significant (Table 5). In comparison to G bulls, B bulls produced more propionate per mol VFA. There was no significant difference between G and B bulls in the concentration of ruminal NH_3. In Exp. I, interactions were observed between breed and diet for mol % propionate and NH_3 level.

In Exp. II, the pH and the propionate ratio were higher and the acetate/propionate ratio and NH_3 concentration were lower ($P<0.05$) in B bulls than in H bulls. The higher propionate level was particularly pronounced in diet 1 with a higher content of sugars.

The total number of protozoa significantly differed ($P<0.05$) between H and B animals. The protozoa population was larger in H bulls than in B bulls (Fig. 1). In H bulls, the proportion of *holotricha* was larger and that of *ophryoscolecidae* smaller than in B bulls ($P<0.05$).

3. Mean retention time and rumen volume

In Exp. II, the mean retention time (MRT) of the used particulate flow marker was higher ($P<0.05$) in B animals (28.6 ± 2.4 h) than in H animals (25.3 ± 2.3 h). In H bulls, but not in B bulls, MRT increased with growing temperature (Fig. 2).

As to MRT, in Exp. I there was no significant difference between the breeds (G 27.7 ± 3.1 h, B 28.6 ± 4.0 h), however, the relationship between the nutrition level and the MRT appeared to be different (Fig. 4). The regression coefficient was lower ($P<0.10$) in G animals than in B bulls and so was the effect of NL on MRT. In comparison to G bulls, the rumen volume was larger in B animals (Fig. 3).

Discussion

The observed variation in the feed efficiency of cattle (ARCHER et al., 1999) can be based on differences in requirement for maintenance, body composition, proportion of visceral organs, level of physical activity, interactions to environmental conditions, and digestion efficiency. JENTSCH et al. (1994, 1995) found a 15 % higher energy maintenance requirement of B bulls in comparison to G bulls, but no difference between B and H bulls. The aim of this study was to look for differences in digestion parameters between the breeds of cattle. Nutrient digestion gives an estimate of how effective an animal is in making energy in feed available for absorption.

The results of Table 3 show that, on the average, no significant difference exists between G and B bulls when digesting diets with a high variation of nutrient content. However, digestion capacity in B bulls seemed to be greater than in G bulls when diets with a low and high cellulose/starch ratio were fed. The high depression of digestibility of diet 1 by the increase of the nutrition level from 1.1 to 1.9 was lower in B bulls than in G. With this diet and the straw one, digestibility of OM was higher ($P<0.05$) in B bulls when compared with G bulls. This can be explained by differences in the rumen volume and in the MRT of the particulate digesta. The rumen volume was significantly larger in B bulls ($P<0.05$; Fig. 3). When the nutrition level (NL) did not surpass 1.4, MRT was also higher in this breed (29.2 ± 1.9 vs. 30.8 ± 2.2, $n = 40$, $P<0.05$, Fig. 4). This indicates the digesta stays longer in the gastro-intestinal tract

whereby the degree of digestion rises (Table 3). The smaller digestive system in robust breeds of cattle in comparison to purebred like Holstein or Jersey was discussed by McDOWELL et al. (1996). HUNTER and SIEBERT (1985) found a lower MRT of digesta in Brahmans compared with Herefords. The lower influence of NL on MRT in G animals than in B animals (Fig. 4) can not be explained by the difference in rumen volume (Fig. 3). Perhaps there exists a compensatory effect in the postruminal tract.

The digestibility of OM and cellulose (Tab. 4) was significantly lower ($P<0.05$) in H animals than in B animals. The lower digestibility in H was associated with a significantly ($P<0.05$) lower MRT (25.3±2.4 vs. 28.6± 2.3 h, all treatments were pooled; Fig. 4). The influence of the environmental temperature on particulate MRT and digestibility was small in both breeds. MRT revealed a rising tendency in both breeds (Fig. 2) as the temperature was increased from 3 to 30 °C. In contrast to WARREN et al. (1974) we could not confirm that increased MRT in a warm environment was associated with increased digestibility of organic matter. The ability to digest nutrients at an intermediate temperature (18 °C) appeared to be similar to that at 3 °C but higher than at 30 °C (Table 4). The pattern of VFA was not influenced by the temperature treatment but VFA levels were highest at 18 °C (Table 5).

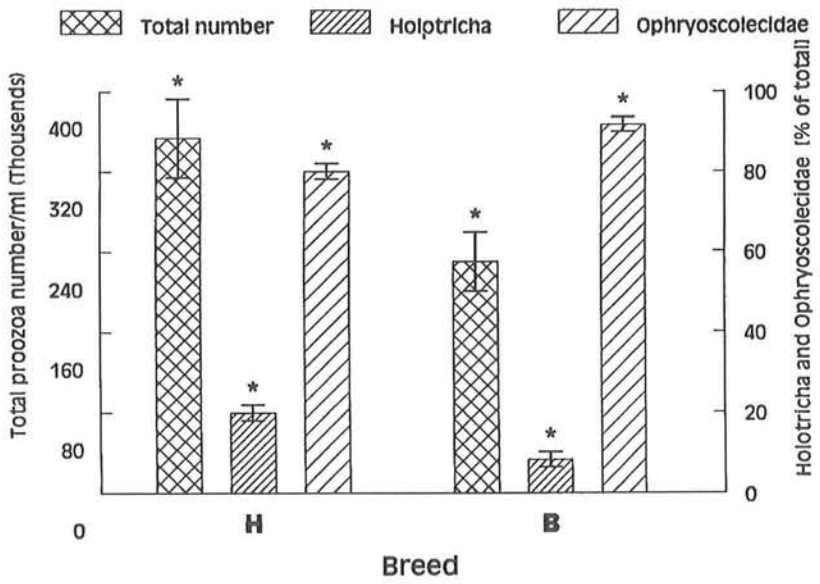

Fig. 1: Total number and composition of rumen protozoa in Exp. II (Anzahl und Zusammensetzung der Protozoen im Exp. II)

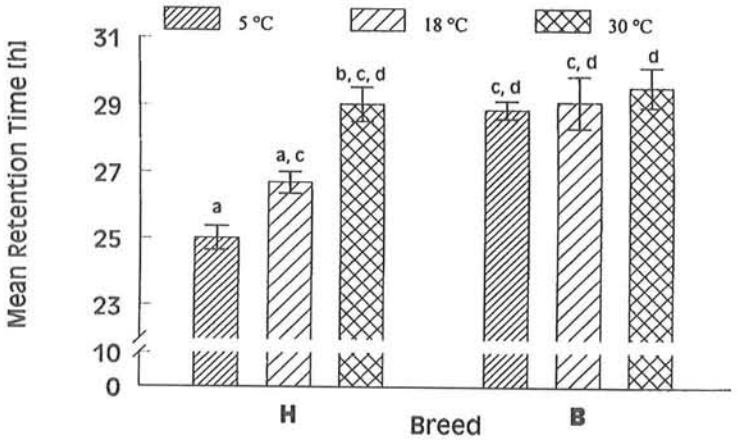

Fig. 2: Effect of environmental temperature on mean retention time (MRT) of particulate digesta (Einfluss der Umgebungstemperatur auf die mittlere Retentionszeit (MRT) der partikelgebundenen Digesta)

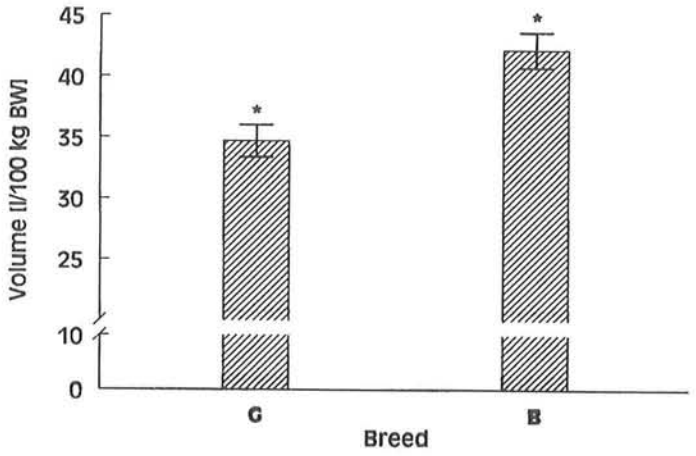

Fig. 3: Rumen volume of Galloway and Black-White Dairy cattle (Pansenvolumen von Galloway und Schwarzbunten Rindern)

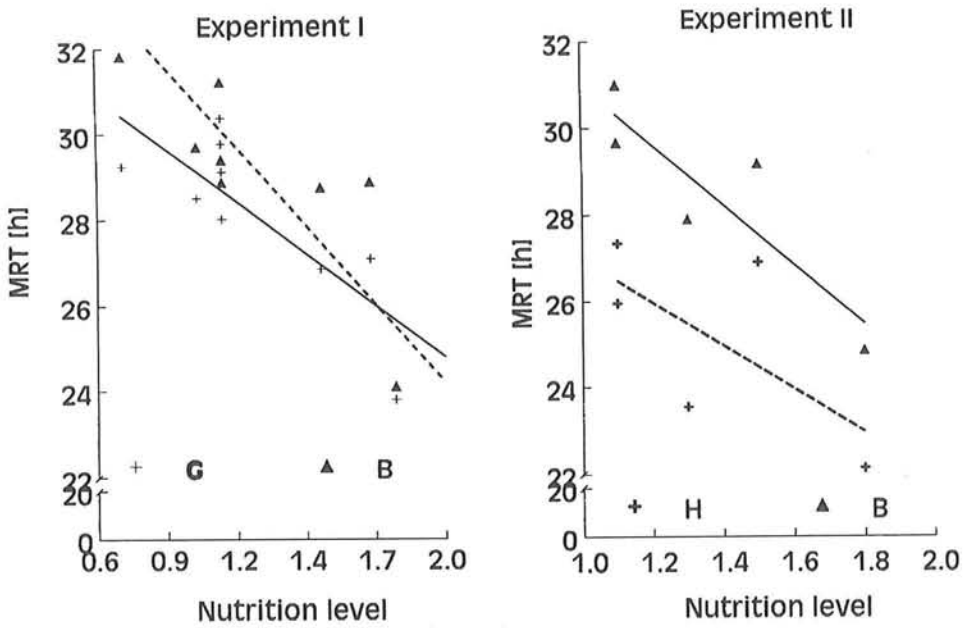

Fig. 4: Influence of Nutrition level (NL) on mean retention time (MRT) of digesta flow marker (Einfluss des Ernährungsniveaus (NL) auf die mittlere Retentionszeit (MRT) des Digestaflussmarkers)
Experiment. I:
$MRT_G = 33.4 - 4.3 \cdot NL$; RSD = 1.2 $MRT_B = 37.3 - 6.6 \cdot NL$; RSD = 1.7
Experiment. II:
$MRT_H = 32.0 - 5.0 \cdot NL$; RSD = 2.0 $MRT_B = 37.9 - 6.9 \cdot NL$; RSD = 1.3

Unfortunately, the results of the H bulls at 30 °C cannot be compared with those of the B bulls. The rise of MRT in H bulls at 30 °C can be associated with reduction in feed intake that occurred as a thermoregulatory response at this temperature. At this high temperature the H bulls refused to eat the total diet.

Rumen fermentation differed between the breeds. Rumen pH was 0.1 unit higher ($P<0.05$) in B bulls than in G or H bulls (Table 5). Surprisingly, the molar proportion of propionate of the volatile fatty acids was higher and the acetate/propionate ratio was lower ($P<0.05$) in the former. Consequently, the content of glucogenic energy of the volatile fatty acids produced in the rumen is higher in B bulls. However, the differences were small and moreover interactions existed between breed and diet. The lower rumen ammonia level in B bulls as compared to H bulls ($P<0.05$) was associated with a lower number of protozoa and a higher proportion of *Ophryoscolecidae*. Protozoa stimulate significantly the rate of bacterial protein turnover (WALLACE and McPHERSON, 1987) and reduce the yield of microbial protein in the rumen (IVAN et al., 2000).

In conclusion, the data reported herein document differences in some parameters of digestion between B bulls as an intensively used breed of cattle and G or H bulls as extensively used breeds. However, the differences are small and should be insignificant for the nutrition requirement. The results show that B animals implement a more efficient ruminal digestive process than G or H bulls. The effect of environmental temperature on the digestive process is small. Further investigations are necessary in order to distinguish between ruminal and postruminal digestion in the individual breeds of cattle.

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