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RUMEN FERMENTATION AND METHANE PRODUCTION IN THE AFRICAN BUFFALO *SYNCERUS CAFFER* (SPARRMAN, 1779) IN THE KRUGER NATIONAL PARK

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Abstract – Fermentation experiments were performed on 36 buffaloes *Syncerus caffer*. Body mass varied from 135–580 kg with an average for adults of 500 kg. Net mass of the reticulo-rumen content varied from 14–134 kg with a DM of 14,5%. Fermentation rate was found to be 167,08 ± 13,53 μmol gas_{NTPD}/gDM/hour and an adult of 500 kg produced 317,6 ℓ of methane per day from the rumen alone. An equivalent of 40,5% of the daily maintenance energy requirement is lost as methane. Caecal gas composition was found to be 60,63 ± 10,69% CO_2, 19,44 ± 8,0% CH_4, 0,33 ± 0,26% H_2 and 19,55 ± 11,43% N_2. Ruminal gas composition: 73,85 ± 1,91% CO_2, 25,89 ± 1,79% CH_4 and 0,029 ± 0,007% H_2. Total VFA concentration, 12,06 ± 1,23 mmol/100 ml.

Introduction

The management of wildlife species in South Africa has become progressively more intensified over the past years and parallel to this, the study of wildlife nutrition has become more and more important. Wildlife nutrition must not only be concerned with the feeding habits of animals, but also with the nutrient requirements of ruminants and their ability to convert plants to animal tissue.

Studies on the nutrition of the African buffalo *Syncerus caffer* in the past have mainly emphasized it's feeding habits. Van der Schijff (1959) states that buffalo in the Kruger National Park (KNP) utilize grasses mainly, with some sedges and occasional shrubs. From the same area, Anon (1960) and Pienaar (1969) report that apart from the grasses, leaves and shoots of occasional forbs, shrubs and trees are also utilized. Several rumen parameters of buffalo were measured by Giesecke & Van Gylswyk (1975).

The aim of the present study was to determine the fermentation rate of food in the reticulo-rumen of buffalo of different age classes in the KNP, Republic of South Africa, and then to determine the amount of digestible energy that is lost as methane. All the buffaloes investigated, were culled as part of the annual control of buffalo numbers.

Methods

The buffaloes used in this investigation were shot with an overdose of succinyl choline and the rumens were removed from the carcasses within 10 minutes after death. Those dealt with here were selected from a total of 250 in order to obtain a size graded representative sample. The mass of each carcass was determined before and after removal of the digestive tract, by means of a large spring balance, hoisting the animals up with a mobile crane.

Before opening up the rumen a 10 ml sample of the gas phase in the reticulo-rumen (R-R), as well as the caecum, was taken and stored in a vacutainer. A small slit was made in the rumen wall and a 150 ml sealed flask filled with CO_2 was entered. After stirring the rumen contents the stopper was removed and the flask filled to the three quarters mark and recapped. After removal from the rumen it was immediately placed in a waterbath at 39°C. CO_2 was then led through the contents for four minutes.

The rate of gas production was measured after sealing the flask and allowing the excess gas to escape. Gas production was measured as described by El-Shazly & Hungate (1965), using a glass syringe with a tight fitting plunger well lubricated with distilled water. Readings were made every minute and after 20 minutes the syringe was withdrawn, the mass of the flask plus contents was determined and fermentation was stopped by adding 0,2 ml concentrated mercury chloride. Gas production data were corrected for ambient temperature and atmospheric pressure. The R-R content was dried by placing the flasks in a convection oven at 75°C for 10 days, and the dry matter mass was determined. The actual R-R fill was determined and 1 kg amounts were dried for dry matter (DM) determinations.

The gas samples were analysed on a gas chromatograph with a thermal conductivity detector on Molecular Sieve 5A mesh 90/100 with argon as carrier gas. Samples of the rumen contents preserved in 25% H_3PO_4 were used for volatile fatty acid (VFA) analysis and treated as described by Van Hoven (1978).

Determination of the pH was performed with a portable pH-meter by inserting the electrode into the digesta within 10 minutes after each buffalo was killed. Total VFA was estimated by titration with 0,1 N NaOH after extraction of the fatty acids by steam distillation (Fenner & Elliot 1963). The molar ratios of individual VFA's were determined with a gas chromatograph, using a flame ionization detector on chromosorb

WAW 80/100 mesh coated with 10% SP 1 000/1% H_3PO_4. After centrifuging a sample for 20 minues at 2 000 r.p.m., 0,6 $\mu\ell$ of the supernatant was used for the gas chromatography.

Results

The mass of the largest buffalo selected from 250 individuals was lower (Table 1) than the 740 and 875 kg reported by Giesecke & Van Gylswyk (1975), from the same area of the Kruger National Park. The total dry matter in the R-R is therefore also lower than the findings of Giesecke & Van Gylswyk (1975). Meinertzhagen (1938) gives the average mass of six adult bulls from Malaŵi and Kenya as 750 kg; Robinette (1963) found 609 kg average for 10 bulls and 432 kg for four cows in Zambia. Shortridge (1934) states that 680 kg is the average mass for buffalo in South West Africa.

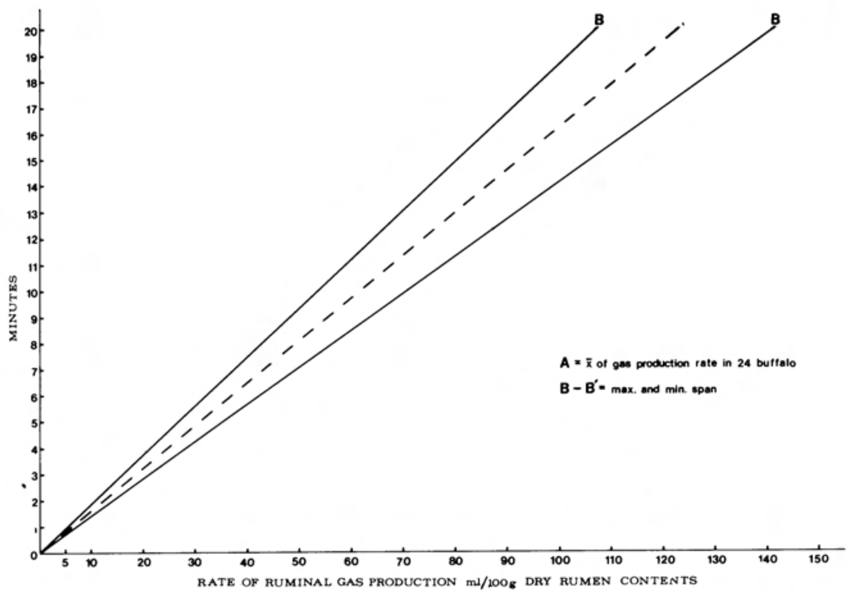

Fig. 1. The rate of gas production/100 g dry rumen contents in 24 buffaloes.

Figure 1 illustrates the rate of gas production/100 grams of dry rumen contents as determined in the fermentation flasks. The 24 buffaloes, listed in Table 1, were used. The average rate of fermentation was found to be 167,08 ± 13,53 μmol gas_{NTPD}/gDM/hour. From Fig. 1 it is clear that the substrate has not become limiting since no reduction in the gas production rate occurred during the 20 minutes that the incubation lasted. It can also be assumed that the accumulation of soluble end products had no effect on the rate of gas production during this time. It was therefore unnecessary to implement the zero-time rate method as discussed by Carroll & Hungate (1954).

Table 1

Relationship between body mass (kg) and rumen-reticulum characteristics of different age groups of buffaloes from the Kruger National Park

Buffalo	Age months	Sex	Body mass (kg) x	R-R content wet mass (kg)	% R-R content of body mass y	% Dry matter in R-R content	Dry matter in R-R (kg)	R-R dry matter as % of body mass
1	4	♀	135	14	10,37	14,36	2,01	1,49
2	6	♂	140	16	11,43	14,44	2,31	1,65
3	6	♂	145	14	9,66	14,57	2,04	1,41
4	6	♀	165	32	19,39	13,41	4,29	2,60
5	8	♂	180	28	15,56	14,36	4,02	2,23
6	8	♂	180	36	20,00	14,33	5,16	2,87
7	10	♂	235	27	11,49	14,22	3,84	1,63
8	10	♀	240	34	14,17	14,29	4,86	2,02
9	12	♀	265	39	14,72	14,62	5,70	2,15
10	12	♀	286	39	13,64	14.23	5,55	1,96
11	17	♂	295	58	19,66	14,33	8,31	2,83
12	17	♀	345	60	17,39	13,95	8,37	2,43
13	Adult	♀	365	62	17,00	14,52	9,00	2,46
14	Adult	♂	380	56	14,74	14,36	8,06	2,12
15	Adult	♀	380	56	14,74	14,25	7,98	2,10
16	Adult	♀	390	57	14,62	14,37	8,19	2,10
17	Adult	♂	400	57	14,25	14,42	8,22	2,05
18	Adult	♂	415	62	14,94	14,56	9,03	2,18
19	Adult	♀	440	92	20,91	14,38	13,23	3,00
20	Adult	♂	505	100	19,80	14,37	14,37	2,85
21	Adult	♀	530	124	23,39	14,03	17,40	3,28
22	Adult	♀	560	141	25,18	14,57	20,55	3,67
23	Adult	♂	570	133	15,96	14,44	19,20	3,37
24	Adult	♀	580	134	22,76	14,37	19,26	3,32
Mean		—	326,08	—	16,50	—	8,79	—

In Table 1 relationships between body mass and rumen-reticulum characteristics of 24 buffaloes are listed in sequence from the smallest to the largest buffalo. In Table 2 the fermentation rate and gas composition of the same buffaloes are listed. With the exception of eight buffaloes, results from an anaysis of the caecal gas composition are also listed. The average values of the gas composition in the 24 buffaloes was 73,85 ± 1,91% CO_2, 25,89 ± 1,79% CH_4 and 0,029 ± 0,007% H_2. The N_2 test was only positive in three buffalo rumens. The composition of the caecal gas differed from that produced in the rumen. A much larger variation was

Table 2

Rumen-reticular fermentation rate, gas composition and gas composition of the caecum of buffaloes from the Kruger National Park

Buffalo	Fermentation rate*	R-R gas composition				Caecum gas composition			
		CO_2	CH_4	H_2	N_2	CO_2	CH_4	H_2	N_2
1	176	73,93	26,04	0,03	0	55,91	36,11	0,18	7,80
2	182	73,97	26,01	0,02	0	77,06	17,10	0,17	5,69
3	188	74,70	25,28	0,02	0	76,62	3,58	0,28	19,51
4	167	73,90	26,08	0,03	0	66,13	19,97	0,16	13,74
5	177	67,73	31,51	0,03	0,73	—	—	—	—
6	192	72,59	27,39	0,03	0	50,96	11,50	1,11	36,42
7	180	74,12	25,85	0,03	0	64,79	29,90	0,10	5,20
8	173	74,87	25,08	0,05	0	52,59	9,24	0,53	37,64
9	171	74,62	25,95	0,04	0	—	—	—	—
10	170	74,66	21,98	0,02	3,33	70,72	15,82	0,21	13,25
11	187	72,39	27,58	0,03	0	—	—	—	—
12	160	76,22	24,80	0,03	0	59,09	22,50	0,28	18,13
13	153	73,86	26,11	0,03	0	57,70	22,08	0,13	20,08
14	172	72,81	27,16	0,03	0	—	—	—	—
15	167	74,18	25,79	0,03	0	64,11	14,16	0,44	20,49
16	160	74,92	25,05	0,03	0	45,46	17,26	0,34	36,91
17	146	69,88	27,58	0,02	2,52	61,44	26,62	0,15	11,79
18	169	75,01	25,00	0,02	0	71,48	19,88	0,11	8,56
19	150	75,46	24,51	0,04	0	57,24	20,07	0,34	22,36
20	162	74,79	25,18	0,03	0	—	—	—	—
21	150	72,39	27,58	0,03	0	—	—	—	—
22	144	74,06	25,92	0,03	0	—	—	—	—
23	153	76,40	23,58	0,02	0	—	—	—	—
24	151	75,60	24,29	0,04	0	38,82	25,31	0,67	35,20
Mean	167,08	73,85	25,89	0,03	—	60,63	19,44	0,33	19,55
±SD	±13,53	±1,91	±0,007	—	±10,69	±8,00	±0,26	±11,63	

*µmol gas_{NTDP}/gDM/hour — = No data

also found between the different animals, as can be seen from the larger standard deviations: CO_2 60,63 ± 10,69%, CH_4 19,44 ± 8,0%, H_2 0,33 ± 0,26% and N_2 19,5 ± 11,43%. The biggest difference between the caecal and ruminal gas composition lies in the fact that almost ten times more H_2 is produced in the caecum. On the average 25% less methane is produced in the caecum than in the rumen, although large individual variations occurred in the caecum. Nitrogen formed 20% of the caecal gas, but was virtually absent in the rumen.

The data in Table 3 were derived from 12 buffaloes other than those dealt with in Tables 1 and 2. The R-R pH in these 12 was 6,28 ± 0,11 and the total VFA concentration 12,06 ± 1,23 mmol/100 ml. The molar ratios of the VFA and gaseous composition of the 12 buffaloes are also listed in Table 3.

Table 3

The age (months), sex, ruminal pH, VFA composition and gas composition in 12 buffaloes from the Kruger National Park

Buffalo	Age (months)	Sex	Rumen pH	Total VFA mmol/ 100 ml	Molar % of FVA in the rumen						% Composition rumen gas		
					C_2	C_3	i-C_4	C_4	i-C_5	C_5	CH_4	CO_2	H_2
1	9	♂	6,30	13,75	71,58	15,69	0,74	10,44	0,79	0,75	26	74	0,06
2	Adult	♂	6,40	10,27	72,88	14,86	0,69	10,37	0,69	0,69	25	75	0,03
3	Adult	♀	6,40	12,40	73,04	14,64	0,79	10,31	0,74	0,49	24	76	0,03
4	Adult*	♀	6,40	12,38	74,26	14,64	0,58	9,46	0,66	0,41	26	74	0,02
5	6	♂	6,40	12,89	73,14	15,23	0,67	9,85	0,72	0,38	28	72	0,02
6	Adult	♂	6,30	13,70	73,38	15,75	0,60	9,24	0,56	0,47	29	71	0,07
7	Adult	♂	6,20	11,39	73,40	15,71	0,51	9,53	0,45	0,40	28	72	0,02
8	16	♀	6,20	10,05	71,73	16,10	0,73	10,36	0,54	0,50	29	71	0,02
9	24	♀	6,20	11,25	69,88	16,46	0,67	11,75	0,72	0,52	28	72	0,02
10	Adult	♀	6,15	12,30	71,26	16,13	0,65	10,87	0,57	0,52	28	72	0,02
11	12	♀	6,25	11,19	70,61	16,56	0,73	10,85	0,73	0,52	29	71	0,02
12	24	♂	6,10	13,11	70,12	17,29	0,59	10,90	0,59	0,50	27	73	0,02
Mean			6,28	12,06	72,11	15,77	0,66	10,33	0,65	0,48	27,25	72,75	0,03
±SD			±0,11	±12,23	±1,47	±0,82	±0,08	±0,72	±0,10	±0,11	±1,66	±1,66	±0,017

* = pregnant

It is known that there is a relationship between body mass and rumen volume in different ruminants. This, however, is untrue for body mass and actual reticulo-rumen fill (Church 1969). The factors that normally affect the actual reticulo-rumen fill are the type of food, time of day, season, water availability and digestability. The buffaloes used in the present study were all shot within 15 minutes on any particular day, from the same herd on any of four consecutive days. The above factors could therefore not have had any influence on the actual fill of the reticulo-rumens of the different animals.

In relating the reticulo-rumen content as a percentage of the body mass to the actual body mass a correlation of r ± 0,468 was found ($p<0,05$) (Fig. 2).

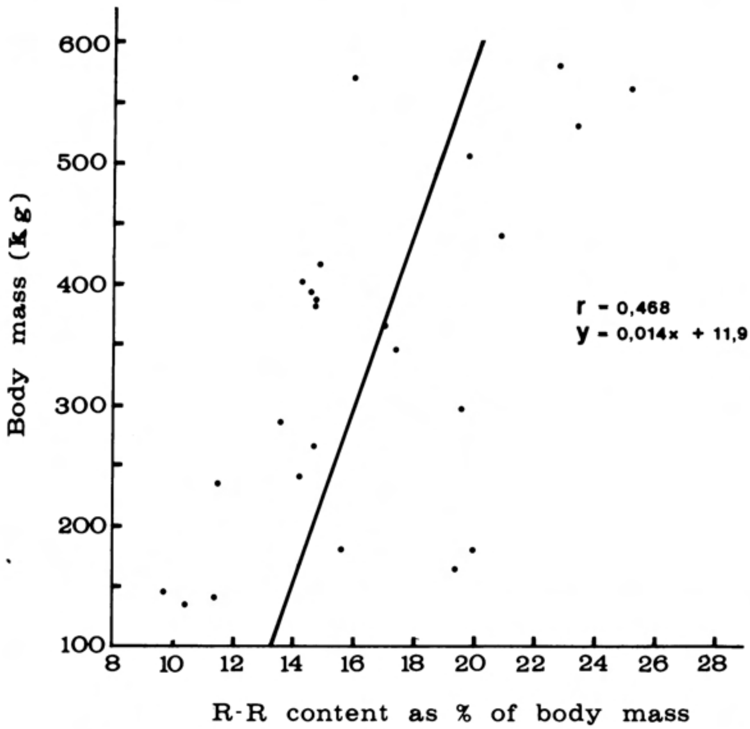

Fig. 2. The relation of the reticulo-rumen content as a percentage of the body mass to the actual body mass.

Since the percentage dry matter in the reticulo-rumen content was virtually constant in all buffalo, this relationship would also apply on the dry matter as a percentage of the body mass.

The reason for the tendency of larger buffalo to have a somewhat larger reticulo-rumen fill in relation to body size than the smaller and younger animals, may lie therein that the young animals are more selective in grazing. This could be due to having a smaller mouth and the successful selection of young and more nutritious shoots and plants. This was not confirmed in this study since no botanical analysis was performed. The rate of fermentation, however, partly confirms this since a negative correlation ($r = -0,763$)($p<0,01$) was found between the fermentation rate and the dry matter content of the reticulo-rumen. A negative correlation ($r = -0,808$)($p<0,01$) between fermentation rate and body mass was also found (Figs 3 & 4).

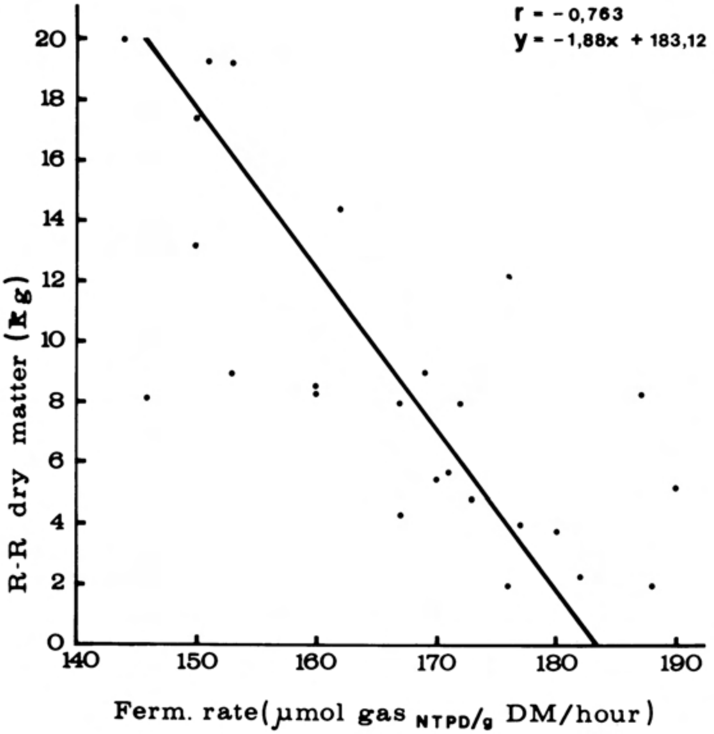

Fig. 3. The relation between fermentation rate and the dry matter content of the reticulo-rumen in 24 buffaloes.

Hungate (1966) and Hoppe, Quortrup & Woodford (1977) have shown that the higher fermentation rates in wild grazers when compared to cattle can be attributed primarily to the selection of green leaves and sheaths. Due to the high content of crude protein and soluble carbohydrates, green leaves and sheaths constitute a substrate which is easily accessible to rumen microbes and is therefore rapidly fermented.

Because the reticulo-rumen capacity in cattle becomes fully developed at the age of one and a half years (Sisson & Grossman 1953), this might also be the case in the buffaloes. The eight adult animals with a body mass in excess of 400 kg each (Table 1), have an average mass of 500 kg. According to Fig. 4 a buffalo of 500 kg has a fermentation rate of 154 μmol

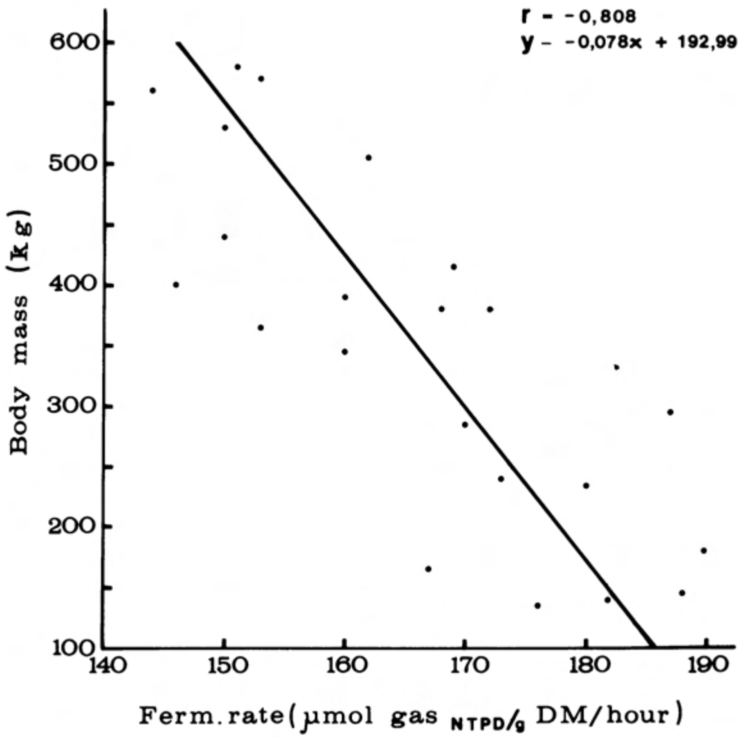

Fig. 4. The relation between fermentation rate and body mass in 24 buffaloes.

gas_{NTPD}/gDM/hour. Giesecke & Van Gylswyk (1975) found that four adult buffaloes under similar conditions as those described here, and from the same general area in the KNP, produced an average of 166,07 ± 50,00 μmol gas_{NTPD}/gDM/hour. Under the circumstances that prevailed with this investigation a buffalo with a fermentation rate of 154 μmol gas_{NTPD}/gDM/hour would, according to Fig. 3, have 15,6 kg DM in the reticulo-rumen. This in turn would produce 53,8 ℓ of gas/hour. This is in reasonable agreement with the findings of Colvin, Wheat, Rhode & Boda (1957) of 30 ℓ/hour for animals with a mass in the order of 454 kg. Dougherty & Cook (1962) measured gas production in two cows and found it to be 34 and 49 ℓ/hour for each respectively.

Methane accounts for a large proportion of the energy consumed by ruminants. According to Washburn & Brody (1937) *vide* Church (1969) methane production accounted for 12–14,6% of ingested energy in cows fed at twice maintenance level, and slightly above maintenance respectively. Blaxter & Clapperton (1965) point out that irrespective of feeding level, on diets with an apparent digestibility of 40%, 60% and 80% the energy apparently lost as methane is 15–16%, 12% and 8–11%.

From Tables 1 and 2 it is calculated that an average adult buffalo of 500 kg produces 13,23 ℓ of CH_4/hour or 317,6 ℓ CH_4/day. This tends to agree with the statement of Blaxter (1962) that cattle may produce as much as

400 ℓ CH_4/day. Bratzler & Forbes (1940) used the following formula to estimate methane prduction:

$$E = 4{,}012\times + 17{,}68$$

where E = gram CH_4 produced and × = gram × 100 of carbohydrate digested. In applying this formula to the buffalo it is estimated that the average adult of 500 kg digested 4,08 kg carbohydrate per day.

When applying the equation of 1 litre CH_4 = 39,54 kJ (Brouwer 1965) to the fact that an adult buffalo produces 317,6 ℓ of methane per day, one finds that 12 558 kJ/day from the food is lost as methane. A buffalo with a body mass of 500 kg has a metabolic body size ($kg^{0,75}$) of 105,74 and a basal metabolic rate of 30 991 k J/day when using the formula 293,09 k $J/kg^{0,75}$/24 hour (Kleiber 1961). This means that an equivalent of 40,5% of the daily maintenance energy required is lost as methane.

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