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Comparative Study on Energy and Nitrogen Metabolisms between Brahman Cattle and Swamp Buffalo Fed with Low Quality Diet

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Abstract

A metabolism trial was conducted with four Brahman cattle and four swamp buffaloes fed with Ruzi grass hay (*Brachiaria ruziziensis*, 0.77% N). There was no significant difference in energy and nitrogen balances, and nutrient digestibilities between cattle and buffaloes. However, fasting heat production was significantly lower in buffaloes. Urinary excretion of allantoin tended to be lower in buffaloes than in cattle although there was no significant difference. Free fatty acid content in the blood serum during the fasting period was lower in buffaloes than in cattle although it was not different when the animals were fed. On the other hand, urea content in the blood serum during the fasting period was higher in buffaloes than in cattle.

Discipline: Animal industry
Additional key words: energy metabolism, fiber digestion

Introduction

The nutrition of swamp buffaloes is as neglected as the species itself. There is a general belief that buffaloes possess an inherent ability to utilize dietary fiber better than cattle. However, the manner in which roughage is utilized needs a lot more elucidation[5]. The number of swamp buffalo in Thailand has been dramatically decreasing mainly due to the introduction of agricultural machinery. Considering the existing numbers, however, the role of swamp buffalo as meat producer is still very important. As Northeast Thailand is a center of animal production in the country, there is a need to sustainably increase animal production by exploiting the feed resources available in the region with native ruminants. This study aims at characterizing energy and nitrogen metabolisms of Brahman cattle and swamp buffalo fed a low quality diet in order to clarify advantages of using swamp buffalo with a locally available low quality diet.

Materials and methods

Four castrated male Brahman cattle and four castrated male swamp buffaloes (average body weight 336±13 and 255±7 kg, respectively) were used for the study. The trial was conducted two times with 2 Brahman cattle and 2 swamp buffaloes each in August. They were housed individually in metabolic crates with free access to water. All animals were treated to remove

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endo- and ecto-parasites prior to the start of the experiment. They were fed with Ruzi grass hay (*Brachiaria ruziziensis*), 1.5% of body weight on the basis of air dry matter for 3 weeks. Feeds were offered in two equal meals at 0800 and 1700 h. If the hay was refused, the refusal was collected and the dry matter (DM) measured. The amount of feces was measured over the collection period (last 5 days of feeding period). An aliquot of feces sample was dried at 60ºC and the DM measured. The total amount of urine was collected into acid and measured over the 5-day collection period. After the feeding trial, the animals were fasted for 4 days. Furthermore the total amount of urine was collected over the last 2 days of the fasting period. Blood was taken from the jugular vein at 0730 h before feeding at the end of the feeding trial and at the end of the fasting period. The serum was separated by centrifugation and kept in a freezer until the analysis.

Oxygen consumption and methane production were measured with a ventilated flow-through method, using a face mask, during the last 4 days of the feeding period and during the last 2 days of the fasting period. The system consisted of a face mask (Sanshin Kogyo Ltd., Japan), a flow cell (Thermal flow cell FHW-N-S, Japan Flow Cell Ltd., Japan), an oxygen analyzer (Model 505, Beckman Instruments, Inc., USA), and a methane analyzer (PA404, Servomex Ltd., UK). Gas analyzers were calibrated against certified gases (Saisan Ltd., Japan) with known gas concentrations at least twice a day. These measurements were conducted 6 times per day, each 6–10 min in duration, with the following schedule: 0700, 1000, 1300, 1600, 1900, 2200, and 0100 h. The details of the respiration trial are described in the report of Kawashima et al.[8].

Five feces samples collected from each animal during the collection period were ground, mixed and subjected to chemical analysis. The crude protein (CP), ether extract (EE), and ash in oven-dried (60ºC) feed and feces samples were determined by the method of AOAC[2]. The acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined by the method of Goering and Van Soest[6]. The nitrogen content in urine was determined by the method of AOAC[2]. Glucose and urea nitrogen (BUN) in the blood serum were measured using diagnostic kits (Biotech Reagent, Thailand) based on the enzyme-calorimetric method. Total protein content in the blood serum was measured using diagnostic kits (Biotech Reagent, Thailand) based on the Biuret method. Non-esterified fatty acid (NEFA) in the blood serum was measured using diagnostic kits (NEFA C-Test Wako, Wako Pure Chemical Industries, Ltd.). Heat of combustion of oven-dried feed and feces samples, and oven-dried (60ºC, 48 h) urine were determined using an adiabatic calorimeter (Shimadzu CA-4PJ, Japan). Heat production (HP, kJ) was calculated by the equation, $HP = 21.20 \times O_2 - 6.40 \times CH_4 - 5.99 \times N$, where O_2 and CH_4 represent volumes of oxygen consumed and methane produced (l), respectively, and N is the quantity of urinary nitrogen excreted (g)[13].

The significant difference between the animal species was determined using Student's T-test. Data are presented as means and standard deviations of the means except for the data on the blood serum. A general linear model[20] was used to analyze the effects of animal species, treatment (feeding or fasting), and their interaction on the parameters in the blood serum with a model as follows:

$$Y_{ijk} = \mu + S_i + A_{ij} + F_k + SF_{ik} + e_{ijk}$$

where μ is the overall mean, S_i the effect of animal species, A_{ij} the random variable caused by the animal nested in the animal species, F_k the effect of feeding treatment, SF_{ik} the interactions, and e_{ijk} the residuals.

Results

The chemical composition of Ruzi grass hay is shown in Table 1. As some of hay was refused, the actual DM consumption was 1.25% and 1.33% of body weight in Brahman cattle and swamp buffalo, respectively (Table 2). Energy and nitrogen balances on the basis of metabolic body weight in Brahman cattle and swamp buffalo during the feeding and fasting periods are also shown in Table 2. The decrease in body weight during the 3-week trial period tended to be higher in Brahman cattle than in swamp buffalo (17.5±4.5 kg and 1.0±12.7 kg in Brahman cattle and swamp buffalo, respectively). Although the values during feeding period was calculated from actual measured body weight, the calculation during the fasting period was based on the body weight estimated from the one during the feeding period by the division of 1.08 as suggested by Agricultural Research Council[3]. There was

Table 1. Chemical composition of Ruzi grass hay

CP (%DM)	EE (%DM)	Ash (%DM)	NDF (%DM)	ADF (%DM)	GE (MJ/kgDM)
4.8	1.6	6.3	72.0	43.0	18.2

Table 2. Body weight, feed intake, energy and nitrogen balances, and urinary allantoin excretion of Brahman cattle and swamp buffalo fed low quality roughage

		Brahman cattle		Swamp buffalo	
		Mean	Std	Mean	Std
During feeding					
Body weight	kg	336	13	255	7
Feed intake	g/day	4,206	374	3,380	164
Gross energy (GE) intake	kJ/BW$^{0.75}$ kg/day	974	65	963	30
Digestible energy (DE) intake	kJ/BW$^{0.75}$ kg/day	466	31	479	5
Metabolizable energy (ME) intake	kJ/BW$^{0.75}$ kg/day	398	29	412	6
Energy loss					
Feces	kJ/BW$^{0.75}$ kg/day	508	65	484	26
Urine	kJ/BW$^{0.75}$ kg/day	25.3	3.7	31.7	6.3
Methane	kJ/BW$^{0.75}$ kg/day	42.8	9.4	35.3	4.2
Heat production	kJ/BW$^{0.75}$ kg/day	353	11	349	18
Energy retention	kJ/BW$^{0.75}$ kg/day	45.1	28.3	63.1	13.1
Nitrogen intake	g/BW$^{0.75}$ kg/day	0.435	0.029	0.430	0.013
Fecal nitrogen output	g/BW$^{0.75}$ kg/day	0.273	0.048	0.284	0.014
Urinary nitrogen output	g/BW$^{0.75}$ kg/day	0.116	0.037	0.102	0.052
Nitrogen retention	g/BW$^{0.75}$ kg/day	0.045	0.049	0.044	0.061
Methane/DM intake	L/kgDM	20.4	5.3	16.9	1.8
Urinary allantoin excretion	mmol/day	28.6	16.1	13.1	6.2
During fast					
Heat production	kJ/BW$^{0.75}$ kg/day	337	15	287**	12
Urinary nitrogen output	g/BW$^{0.75}$ kg/day	0.276	0.089	0.368	0.189

Values are mean and standard deviation of 4 animals.
**: $p<0.01$.

Table 3. Nutrient digestibility of cattle and buffalo fed with low quality roughage

	Brahman cattle		Swamp buffalo	
	Mean	Std	Mean	Std
DM (%)	49.6	4.0	50.9	1.2
OM (%)	51.8	4.0	53.6	1.2
CP (%)	37.3	8.7	33.9	3.0
EE (%)	23.6	5.8	22.5	3.9
NDF (%)	51.8	5.3	55.5	1.2
ADF (%)	42.9	5.1	46.8	2.5

Values are mean and standard deviation of 4 animals.
OM: Organic matter.

no significant difference in energy and nitrogen balances between Brahman cattle and swamp buffalo during feeding. While, heat production during fasting was significantly lower in swamp buffalo. Urinary excretion of allantoin tended to be lower in swamp buffaloes than in Brahman cattle although there was no significant difference. Methane production on the basis of DM intake was not significantly different between Brahman cattle and swamp buffalo. ME content of Ruzi grass hay was 7.61 MJ/kgDM from the average of all the animals.

Apparent digestibilities of nutrients are shown in Table 3. There was no significant difference in digestibilities between Brahman cattle and swamp buffalo.

NEFA, glucose, total protein and BUN contents in blood serum of Brahman cattle and swamp buffalo during feeding and fasting periods are shown in Table 4. NEFA content in blood serum was generally higher in Brahman cattle than in swamp buffalo, and it became higher during fasting period than during feeding. In the comparison between Brahman cattle and swamp buffalo during fasting, NEFA content in Brahman cattle was even higher than in swamp buffalo. While serum glucose was lower in swamp buffalo than in Brahman cattle, total protein was higher in swamp buffalo than in Brahman cattle. BUN contents were generally higher in swamp buffalo than in Brahman cattle, and increased during fasting period in both animals. However, it was higher in swamp buffalo than in Brahman cattle during fasting period.

Discussion

According to Devendra[5], the bulk of the evidence suggests that the swamp buffalo probably does have an inherent capacity to utilize dietary fiber relatively more efficiently than cattle. This conclusion must necessarily be tentative, since it is based on a few comparisons in which the experimental details are not clear. In the present study, there was no significant difference in the digestibility of fiber. There should be some factors involved in the inconsistent results reported in the past regarding the specific difference in fiber digestion between cattle and buffaloes. The CP content of Ruzi hay utilized in the present study was 4.8%, which was similar to the value of rice straw according to Standard Tables of Feed Composition in Japan[1]. Lower quality roughage than this hay is often utilized in the practice of local feeding management. If such low quality roughage is used, a specific difference may become clear.

There was little study on basal metabolism of swamp buffalo. However, Khan et al.[10] reported that the fasting heat production of Murrah buffalo was 286 kJ/BWkg$^{0.75}$, which was lower than that of crossbred cattle (341 kJ/BWkg$^{0.75}$). The value of Murrah buffalo was quite similar to the fasting heat production of swamp buffalo in the present study. Khan et al.[10] concluded that the ME requirement for maintenance of buffaloes was 451 kJ/BWkg$^{0.75}$, which was lower than that recommended by Ranjhan[18] and Kearl[9] as 510 and 523 kJ/BWkg$^{0.75}$, respectively. The ratio of heat production during fasting to that during feeding was 0.95 and 0.83, in Brahman cattle and swamp buffalo, respectively, in the present study. As the energy retentions during feeding were 45.1 and 63.1 kJ/BWkg$^{0.75}$ in cattle and buffalo, respectively, the energy intake by both animals was slightly more than the maintenance. Thus, the ratio should be slightly lower than the efficiency of utilization of ME for maintenance (K_m). According to the Agricultural Research Council[3], K_m was expressed as 0.35q + 0.503, where q is metabolizability of GE at maintenance. Therefore, the value, especially in cattle, was considerably high. During the fasting period, erection of hair and shivering was sometimes observed in Brahman cattle, even at ambient temperature of about 30ºC. Fasting might have induced metabolic disorder in Brahman cattle. The fasting HP may not be simply applied for the basal metabolism in Brahman cattle. Extrapolation of various data on energy retention against ME intake would be a better procedure to obtain the basal metabolism in Brahman cattle.

Methane is one greenhouse-effect gas, of which many researchers have been trying to estimate total emission from ruminants. There are a number of ruminants in the tropics, where little data on the production of methane from ruminants has been accumulated. It is necessary to accumulate more data on the methane production from many kinds of ruminants with different feeding managements for the establishment of accurate figures of methane emission from ruminants allover the world. Methane production was not significantly different between Brahman cattle and swamp buffalo in the present study. However, energy loss into methane production on the basis of

Table 4. NEFA, glucose, total protein, and BUN levels in blood serum of Brahman cattle and swamp buffalo during feeding and fasting

		Brahman cattle			Swamp buffalo			Effect[a)]		
		Feeding	Fasting	SE	Feeding	Fasting	SE	A	F	A*F
NEFA	mEq/L	0.45	2.14	0.15	0.23	0.71	0.08	**	**	**
Glucose	mg/dL	91.8	82.1	3.9	63.3	72.7	7.5	*	–	–
TP	G/dL	7.65	7.82	0.07	8.14	8.25	0.13	**	–	–
BUN	mg/dL	4.40	13.48	0.52	9.29	33.89	2.57	**	**	**

a): A, an effect of animals; F, an effect of feeding; A*F, an interaction between animals and feeding.
**: P<0.01, *: P<0.05.
NEFA: Non-esterified fatty acid, TP: Total protein, BUN: Blood urea nitrogen.

GE intake tended to be lower in buffalo (3.7%) than in cattle (4.4%). These values were relatively lower than the value suggested by Crutzen et al.[4] estimated from the study of Krishna et al.[11]. Kurihara et al.[12] measured methane production by Brahman cattle given either Angleton grass (CP 2.4%) or Rhodes grass (CP 8.9%) and energy loss as methane was 10.4 and 11.4%. Mohini and Singh[14] reported that energy loss as methane had amounted to 3.0–3.2% of GE in buffalo calves given green jowar *ad libitum*. While, Mohini and Singh[15] also reported wide variation of energy loss as methane that amounted to 4.8–9.7% of GE in buffalo calves given concentrate feed and maize fodder. During our respiration trial, the change of oxygen consumption showed constant rhythm consistent with breath in both animals, which was considered to confirm that the animals adapted well to the mask and behaved ordinarily. On the other hand, in swamp buffalo, methane sometimes did not come out until 6 min after the mask was placed on their mouth, while there were peaks of methane production observed every 1–2 min in cattle. Therefore, the duration of each respiration trial was extended up to 10 min in buffalo. There might have been a suppressive effect of the mask on eructation in swamp buffalo. It is necessary, therefore, to accumulate more data on methane production from swamp buffalo by improved measurement methods of methane production for obtaining a conclusion.

There was a clear difference in NEFA and BUN contents in the blood serum between Brahman cattle and swamp buffalo. Although there was no report on the difference in NEFA content between these species, Norton et al.[17] reported that plasma urea concentration was higher in water buffalo than cattle, and suggested higher renal resorption of urea in water buffalo. Homma[7] reported that ammonia nitrogen in rumen fluid was higher in swamp buffalo than in Holstein cattle when both animals were given Thimothy hay *ad libitum*. He suggested that this was related to a higher nitrogen content in saliva of swamp buffalo and to their ability to concentrate rumen fluid by a higher ability to absorb water from rumen. In the present study, an increase in BUN content in blood serum during fasting in comparison with during feeding was more in swamp buffalo than in Brahman cattle. On the other hand, an increase in NEFA content in blood serum during fasting in comparison with during feeding was more in Brahman cattle than in swamp buffalo. It would suggest that, while more energy was mobilized from body tissue protein in swamp buffalo during fasting, more energy was mobilized from fat in Brahman cattle. This might suggest a specific difference between swamp buffalo and Brahman cattle in energy mobilization during fasting. However, the amount of fat deposited in the animal body prior to the trial was not examined and the difference of body weight between the animals might have influenced the results. It requires further studies to conclude this.

Moran[16] indicated that swamp buffaloes have a total nitrogen balance either equal to or higher than that of Zebu cattle, and that this is generally the result of a higher nitrogen intake and/or a lower urinary nitrogen output rather than a lower fecal nitrogen output. These findings were supported by Devendra[5]. In the present study, both species were given almost the same amount of nitrogen and there was no difference in fecal nitrogen and urinary nitrogen outputs.

Urinary excretion of allantoin is considered to be a marker of microbial production in rumen. It tended to be lower in swamp buffalo than in Brahman cattle, although it was not statistically significant. This may suggest the difference of production in microorganisms in rumen between the two species. However, Samaraweera et al.[19] suggested that the endogenous purine derivative excretion is low in buffaloes.

Swamp buffaloes may have an ability to utilize fiber and energy better than cattle. However, it still requires further studies to clarify the difference. There are clear physiological differences, which were clarified when they were fasted in the present study. The characterization of digestion physiology in swamp buffaloes would contribute to the establishment of a strategy for sustainable development of local feeding management.

References

1. Agriculture, Forestry and Fisheries Research Council Secretariat (2001) Standard tables of feed composition in Japan. Ministry of Agriculture, Forestry and Fisheries, Japan, pp.245.
2. AOAC (1975) Official methods of analysis (12th ed.). Ed. Horwitz, W., Association of Official Analytical Chemists, Washington DC, pp.1094.
3. Agricultural Research Council (1980) The nutrient requirements of ruminant livestock. Commonwealth Agricultural Bureaux, Slough, pp.351.
4. Crutzen, P. J., Aselmann, I. & Seiler, W. (1986) Methane production by domestic animals, wild ruminants, other herbivorous fauna, and humans. *Tellus*, **38B**, 271–284.
5. Devendra, C. (1992) Nutrition of swamp buffaloes. *In* Buffalo production, eds. Tulloh, N. M. & Holmes, J. H. G., Elsevier, Amsterdam, 135–151.
6. Goering, H. H. & Van Soest, P. J. (1970) Forage fiber analysis (apparatus, reagents, procedures and some applications). Agric. Handb. No. 379, USDA.
7. Homma, H. (1994) Liquid turnover rate and water flux rate in the rumen of cattle and buffaloes. *Anim. Sci. Technol.*, **65**(3), 258–260.
8. Kawashima, T. et al. (2001) Respiration trial system

using ventilated flow through method with a face mask. *JIRCAS J.*, **9**, 53–74.
9. Kearl, L. C. (1982) Nutrient requirements of ruminants in developing countries. International Feedstuffs Institute. Utah State University, Logan, Utah, pp.381.
10. Khan, M. Y. et al. (1988) Energy requirement of Murrah buffalo for maintenance. *In* Proc. of 2nd world buffalo congress, New Delhi, Vol. II, Indian Council of Agricultural Research, New Delhi, 238–243.
11. Krishna, G., Razdan, M. N. & Ray, S. N. (1978) Effect of nutritional and seasonal variations on heat and methane production in *Bos indicus*. *Indian J. Anim. Sci.*, **48**(5), 366–370.
12. Kurihara, M. et al. (1999) Methane production and energy partition of cattle in the tropics. *Br. J. Nutr.*, **81**, 227–234.
13. McLean, J. A. (1972) On the calculation of heat production from open-circuit calorimetric measurements. *Br. J. Nutr.*, **27**, 597–600.
14. Mohini, M. & Singh, G. P. (2001) Methane production on feeding Jowar fodder based ration in buffalo calves. *Indian J. Anim. Nutr.*, **18**(3), 204–209.
15. Mohini, M. & Singh, G. P. (2003) Methane production on maize fodder based rations in buffalo calves. *In* Proc. 3rd int. methane and nitrous oxide mitigation conference, 93–102.
16. Moran, J. B. (1983) Aspect of nitrogen utilization in Asiatic water buffalo and Zebu cattle. *J. Agric. Sci.* (*Cambridge*), **100**, 13–23.
17. Norton, B. W., Moran, J. B. & Nolan, J. V. (1979) Nitrogen metabolism in Brahman cross, buffalo, banteng and Shorthorn steers fed on low-quality roughage. *Aust. J. Agric. Res.*, **30**, 341–351.
18. Ranjhan, S. K. (1992) Nutrition of river buffaloes in southern Asia. *In* Buffalo production, eds. Tulloh, N. M. & Holmes, J. H. G., Elsevier, Amsterdam, 111–134.
19. Samaraweera, L., Orskov, E. R. & Chen, X. B. (1994) Preliminary studies on purine derivative excretion in buffaloes. *In* Proc. first Asian buffalo association congress, eds. Wanapat, M. & Sommert, K., Khon Kaen University, Thailand.
20. SAS Institute (1989) SAS/STAT User's guide, version 6, 4th ed., vol. 2. SAS Institute Inc., Cary, NC.