Nitrogen excretion in growing buffaloes (*Bubalus bubalis*) of different feed conversion rates

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Abstract:
A study was carried out to evaluate nitrogen use efficiency traits in growing buffaloes coming from no milking (NM), or dual purpose (DP) systems. In NM systems, animals have high weaning weights and reach slaughter weight at an early age, whereas DP animals, whose mothers are milked, have lower weaning weights and reach slaughter weights later than NM animals. three performance tests were conducted, two with NM animals (45 buffaloes, initial weight 288 ± 28.80 kg and age 293 ± 25 d) and one with DP animals (33 buffaloes, initial weight 249 ± 33 kg and age 426 ± 25 d). Animals were assigned to one of three groups according to their feed conversion and nutrient intake, excretion and digestibility and average daily weight gain was measured in all animals. Feed conversion (kg feed/kg of weight gain) differed greatly among the three animal groups, with the high conversion animals requiring only 50% of the feed required by the low conversion animals (P<0.001). Although there were no differences in body weight among animals in the three groups, there were significant differences in average daily gain, which the high conversion animal gaining 1.52X more weight than low conversion animals (P<0.001). Fecal excretion of DM and ADF was not different among animal groups, but there were significant differences in NDF and CP fecal excretion (P<0.05). In turn, the apparent digestibility of DM, ADF and CP was significantly greater in intermediate conversion animals than in high conversion animals (P<0.05). High conversion animals emitting the less N_2O (g/animal/day) than low conversion animals (P<0.05). Finally, there were differences in the estimated N_2O emissions from feces, with high conversion animals emitting the less N_2O (g/animal/day) than low conversion animals (P<0.05) and differences were more pronounced when estimating the intensity (g of N_2O/ kg weight gain) of N_2O emissions (P<0.001). It is concluded that selecting buffaloes for improved feed conversion can both allow to increase he system productivity as less feed resources can be devoted to produce meat, while at the same time, the carbon intensity of the buffalo-based meat production can be significantly reduced.
Key words: Degradation; Rumen; plant protein; *in situ*; chemical treatment; buffalo.

Introduction

The buffalo (*Bubalus bubalis*) has become an alternative for the production of meat and milk in the Colombian lowland tropics, as it performs well when grazing in flooded lands (Gutiérrez, 2001) and it produces high quality meat and milk (Oliveira, 2005). In recent years, the Colombian buffalo herd has had a high expansion in Colombia, growing at an annual rate of around 10%, a growth three times higher than the one observed for the Colombian cattle herd.

In Colombia, buffaloes are handled under two production systems: dual purpose (DP) and no milking (NM). In the DP system, the main objective is to produce milk, since given its high quality (high fat, protein and total solids content), buffalo milk is usually sold at a price that is 30% higher than that paid for bovine milk. In DP systems, the production of buffalo calves is a second priority; consequently animals are weaned at lower live weights and reach slaughter weights at later ages than in the NM system (Bolívar et al., 2014). In the NM systems, the objective is to produce buffaloes with high weaning weights that reach their slaughter weight at an early age, thus producing a high value meat, branded as "baby buffalo" in Colombia and other countries. In Colombia, baby buffaloes are harvested at around 24 and 26 months of age, with an average liveweight of 450 kg.

Although it has been reported that buffaloes are capable of utilizing efficiently low- quality, high-roughage diets, there is still the need to further characterize their ability to utilize these diets. High feed prices and the potentially negative environmental impact of meat production implies that the efficiency of feed utilization is an economically important trait.

Livestock farming systems convert crop protein into animal protein with an efficiency ranging from 5% to 45%, depending on animal type, system and management (Oenema, 2006). The nitrogen in the remaining fraction (55–95%) is in urine and dung, and is conducive to N losses (Oenema, 2006). As with any production system, it is necessary to characterize fecal and urinary nitrogen loses in buffalo production systems in the tropics, as this is associated with their economic and environmental sustainability.

Materials and Methods

The study was conducted at the El Progreso Experimental Station in Barbosa, Antioquia, Colombia and chemical analyzes were performed at the Integrated Animal Nutrition, Biochemistry, and Forage Laboratory, both of the University of Antioquia. Determination of *in situ* indigestible acid detergent fiber (in ADF) was conducted at the Paysandú Production Center of the National University of Colombia.

Three performance tests were conducted, two for NM buffaloes using 45 animals and one with 33 buffaloes from DP systems. Buffaloes from NM systems had an average initial weight and age of 288 ± 28.80 kg and 293 ± 25 d, respectively. Buffaloes from DP systems had an average initial weight and age of 249 ± 33 kg and 426 ± 25 d, respectively. All animals were either pure or at least 75% Murrah intact males. The tests lasted 112 days, with the first 28 days serving as adaptation to the facilities and diet, and the remaining 84 days used for data collection. Animals were assigned to one of three groups according to their feed conversion and growth, feed intake, and nutrient excretion data were measured in all animals.

Animals were housed in individual pens (16 m2). Pens had concrete floor, no bedding, and were partially roofed (4 m^2), and each had a feeder and a water dispenser. The diet consisted of fresh Maralfalfa grass (*Pennisetum sp*.) offered *at libitum* and two kg of a concentrate supplement per day. Concentrate ingredients were corn (50%), extruded soybeans (15%), soybean meal (10%), extruded corn (10%), homogeneous mixture of extruded corn and soybean meal (10%) and a mixture of mineral salt containing of 8% phosphorus, calcium carbonate, and a vitamin-micromineral premix (5%). The chemical composition of Maralfalfa grass and concentrate supplement were previously reported (Bolívar 2012; Bolívar et al., 2014).

Body weight was measured every 14 days after 12 hours of feed withdrawal. The DMI was evaluated every 11 days for three consecutive days before each weighing. To determine DMI throughout the test, DMI obtained at each measurement period were added together (calculated for each period as the average of the current and the next measurement, multiplied by the number of days in the period). Daily DMI was calculated by dividing total DMI by the number of days in the test.

Feed conversion for each animal was computed as the ratio of daily DMI to ADG. Apparent digestibility of nutrients (ND) was evaluated during the last four days of each experimental period and included the estimation of dry matter (DMD), crude protein (CPD), neutral detergent fiber (NDFD), and acid detergent fiber (ADFD) digestibility. The feed offered and refused was weighed and DM, CP, ADF and NDF contents were determined so as to estimate consumption of these fractions. The apparent digestibility of DM, CP, NDF, and ADF was estimated according to Bondi (1989).

To estimate fecal output -needed to determine excreted nutrients-, indigestible acid detergent fiber (inADF) was used as an internal marker (Correa et al., 2009). The inADF was measured in residues recovered after 144 hours of in situ ruminal incubation (Berchielli et al., 2000) of feces, forage, and feed supplements (Correa et al., 2009). Fecal samples were taken directly from the rectum every six hours during a four-day period (Correa et al., 2009), for a total of 16 samples per animal. Samples were kept frozen until the end of the collection period. Subsequently, after being dried at 60 °C for 72 hours, these samples were mixed to obtain a single sample per animal which was stored until chemical analyzes.

Fecal production (F) was estimated using the following equation:

$$F = (\text{inADF intake} * \%\ \text{inADF recovery in feces})/(\%\text{in ADF feces})$$

To estimate nitrous oxide emissions, an emission factor of 0.02 kg of N_2O-N volatilized /kg of N in both urine and feces (IPCC, 2006) was utilized. The conversion of emissions of N2O–N to emissions of N_2O was done as:

$$N_2O = N_2O\text{–}N \bullet 44/28 \text{ (IPCC, 2006)}$$

Results and Discussion

The mean performance and nutrient intakes of growing buffaloes with different (high, intermediate and low) feed conversion rates are shown in Table 1. There were huge differences in feed conversion (kg feed/kg of weight gain) among the three animals groups, with the high conversion animals requiring only 50% of the feed required by the low conversion animals ($P<0.001$). Comparing to the feed conversion of steers, the conversion of 68% of the buffaloes in this trial is highly promising. For example, Sossa et al. (2015) reported that steers fed a high quality diet composed of *Cenchrus clandestinus* had a feed conversion of 12.35 kg feed/kg of weight gain. In turn, Gaviria et al. (2015) reported that the mean dry matter of Zebu steers 380 kg grazing on a *Leucaena leucocephala* intensive silvopastoral system and also receiving energy supplementation was 10.1 kg and that their feed conversion was 16.58 kg feed/kg of weight gain.

In spite of differences in feed conversion, there were no significant differences in body weight among the three groups, which meant that differences in feed conversion were mostly related to differences in voluntary intake of the forage component of the diet, which varied from 3.79 to 4.93 kg/day, being lower in the high conversion animals ($P<0.001$) and to differences in the ability of animals to metabolize and efficiently utilize absorbed nutrients. In turn, although there were no differences in body weight among animals in the three groups, there were significant differences in ADG ($P<0.001$), which the high conversion animal gaining 1.52X more weight than low conversion animals, which points towards differential genetic ability among animals to convert feed into body mass.

Table 1: Mean performance and nutrient intakes in growing buffaloes of different (high, intermediate and low) feed conversion rates

	High	**Intermediate**	**Low**
Conversion, kg feed/kg of gain	7.75 [c]	10.44 [b]	14.46 [a]
Initial BW, kg	263.9	258.9	271.4
Final BW, kg	346.8	328.7	330.4
Average daily gain, kg	0.719 [a]	0.594 [b]	0.472 [c]
Intake, kg/ animal/ day			
Maralfalfa grass	3.79 [c]	4.42 [b]	4.93 [a]
Concentrate	1.74	1.76	1.76
Total DMI	5.52 [c]	6.18 [b]	6.69 [a]
NDF	2.90 [c]	3.21 [b]	3.56 [a]
ADF	2.10 [c]	2.40 [b]	2.63 [a]
CP	0.483 [c]	0.595 [b]	0.647 [a]
Intake, g/ kg of metabolic weight			
Maralfalfa grass	51.96 [c]	63.35 [b]	68.62 [a]
Concentrate	23.89	25.16	24.57
Total DMI	75.85 [c]	88.50 [b]	93.19 [a]
NDF	39.80 [c]	46.00 [b]	49.62 [a]
ADF	28.87 [c]	34.37 [b]	36.62 [a]
CP	6.63 [c]	8.55 [b]	9.02 [a]

Means within rows with different superscripts are different (P<0.05).

The mean fecal excretion of DM and nutrients and estimated N_2O emissions from feces in growing buffaloes of different (high, intermediate and low) feed conversion rates is shown in Table 2. Fecal excretion (kg/animal/day) of DM and ADF was not different among animal groups, but there were significant differences in NDF and CP fecal excretion (P<0.05). Interestingly enough, the apparent digestibility of DM, ADF and CP was significantly greater in intermediate conversion animals than in high conversion animals (P<0.05). This supports the idea that a significant portion of the difference in feed conversion among the three groups is related to differences in the ability of animals to metabolize and efficiently utilize absorbed nutrients, as it was reported by Bolívar et al. (2014).

Finally, there were differences in the estimated N_2O emissions from feces, with high conversion animals emitting the less N_2O (g/animal/day) than low conversion animals (P<0.05; Table 2). Differences were more notorious when estimating the intensity (g of N_2O / kg weight gain) of N_2O emissions, with the estimated N_2O emissions being significantly different among all groups (P<0.001). Opio et al. (2013) estimated that at global scale, the production of buffalo meat is associated with an emission of 143.9 kg CO_2-eq/kg product (meat) of which 13.8% (19.85 kg CO_2-eq) was estimated to come from N_2O emissions from applied and deposited manure. The values estimated here are much lower, even after correcting from the fact that our estimations are only based on fecal nitrogen excretion, which was in in average 41% on N intake, and this points to the fact that if adequate diet formulation is employed and buffaloes are of the proper genetic potential, great improvements can be made both in increasing system productivity and in reducing the carbon footprint of the products. Clearly, this points to the need of having local emissions factors for the animal production systems in the tropics (Rivera et al., 2016).

Table 2: Mean fecal excretion of DM and nutrients and estimated N_2O emissions from manure patches in growing buffaloes of different (high, intermediate and low) feed conversion rates

	High	Intermediate	Low
Fecal excretion, kg/animal/day			
Dry matter	2.44	2.42	2.71
NDF	1.53 [b]	1.59 [b]	1.84 [a]
ADF	1.19	1.17	1.34
Crude protein	0.211 [b]	0.221 [ab]	0.242 [a]
Fecal excretion, g/ kg of weight $^{0.75}$			
Dry matter	33.60	33.24	37.80
NDF	21.07 [b]	21.89 [b]	25.71 [a]
ADF	16.34	16.13	18.73
Crude protein	2.91	3.05	3.38
Apparent digestibility, %			
Dry matter	56.36 [b]	61.30 [a]	59.65 [ab]
NDF	47.68	50.98	48.42
ADF	44.23 [b]	51.66 [a]	49.16 [ab]
Crude protein	55.99 [b]	62.64 [a]	62.55 [a]
Estimated N_2O emissions			
Fecal N_2O, g/animal/day	1.060 [b]	1.113 [ab]	1.219 [a]
Fecal CO_2 equiv., kg	0.329 [b]	0.345 [ab]	0.378 [a]
Fecal N_2O, g/ kg weight gain	1.482 [c]	1.821 [b]	2.643 [a]
Fecal CO_2 equiv., kg/ kg weight gain	0.459 [c]	0.565 [b]	0.819 [a]

Means within same column having different superscripts are different ($P<0.05$).

Conclusions

Selecting buffaloes for improved feed conversion can both allow to increase the system productivity as less feed resources can be devoted to produce meat, while at the same time, the carbon intensity of the buffalo-based meat production can be significantly reduced.

References

Berchielli, T. T., P. Andrade, C. L. Furlan. 2000. Avaliação de indicadores internos em ensaios de digestibilidade. Rev Soc Bras Zootec. 29:830-833.

Bolívar, D. M. 2012. Desempeño productivo y variabilidad genética de búfalos (*Bubalus bubalis*) en diferentes sistemas de producción para características de crecimiento y eficiencia en la utilización de nutrientes. Tesis de Doctorado, Universidad de Antioquia, Medellín, Colombia.

Bolívar, D. M., Cerón-Muñoz, M. F., & Barahona-Rosales, R. 2014. Feed efficiency traits and productive performance in fifteen-month old buffaloes (*Bubalus bubalis*) from a dual-purpose system. Liv Res Rur Dev. 26 (5).

Bondi, A. A. 1989. Nutrición Animal. Editorial Acribia, S. A. Zaragoza, España. 546 p.

Correa, H. J., M. L. Pabón y J. E. Carulla. 2009. Estimación del consumo de materia seca en vacas Holstein bajo pastoreo en el trópico alto de Antioquia. Liv Res Rur Dev. 21 (4).

Gaviria-Uribe, X., Naranjo-Ramírez, J. F., Bolívar-Vergara, D. M., & Barahona-Rosales, R. 2015. Consumo y digestibilidad en novillos cebuínos en un sistema silvopastoril intensivo. Archivos de Zootecnia, 64(245), 21-27.

Gutiérrez, M. 2001. Buffalo production perspectives in Colombia. In: Proceedings VI World Buffalo Congress: an alternative for animal agriculture in the third millenium. Maracaibo, Venezuela. 677-697 p.

IPCC 2006 Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and Other Land Use. Prepared by the Nacional Greenhouse Gas Inventories Programme. Eggleston H S, Buendia L, Miwa K, Ngara T and Tanabe K (Editors). The Intergovernmental Panel on Climate Change. Institute for Global Environmental Strategies (IGES), Hayama, Japan. 595p.

Oenema, O. 2006. Nitrogen budgets and losses in livestock systems. In International Congress Series (Vol. 1293, pp. 262-271). Elsevier.

Oliveira, A. 2005. Búfalos: produção, qualidade de carcaça e de carne. Alguns aspectos quantitativos, qualitativos e nutricionais para promoção do melhoramento genético. Revista Brasileira Reproducción Animal; 29 (2): 122-134.

Opio, C., Gerber, P., Mottet, A., Falcucci, A., Tempio, G., MacLeod, M., Vellinga, T., Henderson, B. & Steinfeld, H. 2013. Greenhouse gas emissions from ruminant supply chains – A global life cycle assessment. Food and Agriculture Organization of the United Nations (FAO), Rome.

Rivera, J. E, Chará, J. & Barahona, R. 2016. Análisis del ciclo de vida para la producción de leche bovina en un sistema silvopastoril intensivo y un sistema convencional en Colombia. Tropical and Subtropical Agroecosystems, 19(3), *in press*.

Sossa Sánchez, C. P., Correa Londoño, G. A., & Barahona Rosales, R. 2015. Consumo y excreción de nutrientes en novillos de carne pastoreando en trópico de altura con y sin suplementación energética. Zootecnia Tropical, 33(2), 117-128.