Fasting Heat Production of Growing Buffalo Calves

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ABSTRACT : Fasting heat production (FHP) of growing buffalo calves (*Bubalus bubalis*) in the body weight range of 76 to 236 kg was determined using open circuit respiration chamber. The details of the chambers, calibration of gas analysers and operation of the systems are described. Animals were fasted for 96 hrs during which only water was provided. FHP was determined during next 24 hrs. The mean oxygen consumed, carbon dioxide and methane produced and urinary N excretion per 24 h was 17.03 ℓ, 11.70 ℓ, and 0.12 ℓ and 0.35 g respectively. The mean respiratory quotient ranged from 0.68 to 0.71, which indicated that post absorptive stage is reached after 96 hrs in growing buffalo calves previously fed ammoniated straw-based ration. Mean FHP of calves was 331.4 kJ/kg $W^{0.75}$. FHP of calves with range of mean body weights of 167 to 235 kg, although nonsignificant but, was almost 12% higher than of calves having mean body weight of 101 kg. Suitable exponent to body weight to describe FHP of buffalo calves was 0.87. (*Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 3 : 307-312*)

Key Words : Growing Buffalo Calves, Fasting Heat Production, Respiration Calorimetry

INTRODUCTION

The energy expended in the fasting animal is represented by the fasting heat production, which can be measured in the respiration chamber. The first determination of fasting metabolism of steers was carried out by Ritzman and Benedict (1938) at Durham, New Hampshire.

Buffaloes occupy an important position (79 million, FAO, 1997) among domesticated ruminant livestock and constitute 28 percent of total bovine population, and contribute about 52 percent of total milk production, in addition to their well recognised draft capability and meat production potential. Reports on fasting heat production of adult buffaloes are scanty (Lawrence, 1980; Khan et al., 1988a) and of growing buffalo calves do not seem to be available in literature. In the present paper, we report fasting heat production of growing buffalo calves of different body weights measured by calorimetry technique along with details of the respiration chamber at the Institute.

MATERIALS AND METHODS

Eighteen healthy, intact, male Murrah buffalo calves were procured from Livestock Production Research Division of the Indian Veterinary Research Institute. The animals were already vaccinated against important bacterial and viral diseases according to the schedule followed at the institute. Animals were dewormed using Panacur @10 mg per kg body weight and housed in animal shed with *pucca* floor with adequate ventilation and arrangements for individual feeding. Adequate clean drinking water was made available. All buffalo calves were fed on a balanced concentrate mixture and ad lib urea ammoniated wheat straw (UAS) for three weeks period.

Then the animals were distributed randomly into three groups of six animals each with similar body weights following completely randomized design. They were fed on *ad lib.* urea-ammoniated wheat straw ad lib supplemented with different concentrate mixtures for each group. Feeding was done as per recommendations of Kearl (1982) for a daily gain of 400 g per head per day. Concentrate mixture for animals of group 1, 2 and 3 contained 8% of deoiled groundnut cake (GNC), formaldehyde GN cake and fishmeal, respectively. During extended growth period, fasting heat production (FHP) of calves was determined. For this purpose one calf from each group was used at different body weights. In all nine animals (3 animals $\times$3 periods) were used for the FHP studies. Before recording gaseous exchange, calves were adapted to chamber conditions. Fasting heat production was calculated using the data of gaseous exchange (O_2 consumed, CO_2 and methane produced) and nitrogen excreted (g) in 24 hours following Brouwer's (1965) equation.

Respiration chamber

At Energy Metabolism and Respiration Calorimetry

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Laboratory of the Indian Veterinary Research Institute, the respiration chambers for large animals are open circuit type. They consist of two independent climatically controlled units with arrangements for recirculation of air within the chamber. The temperature of the chamber was maintained at 25 ± 1°C by the air conditioning device with controls, installed in adjacent room. The relative humidity was maintained at 65 ± 10% in the chamber. A metabolism cage was fixed inside the chamber for separate collection of urine and faeces. There was arrangement for feeding and watering the animal from outside without affecting the temperature and gases from the chamber. The chamber was provided with a centrifugal exhauster, model 4MS 11/180 (Air control Installation Co. (Chard) Ltd., Somerset, England) with a maximum capacity of airflow of 170 m 3 per hour. The rate of airflow through the chamber could be controlled with the help of a gate valve. A Hasting's Mass flow meter was fitted in the pipeline between the chamber and exhauster. It recorded the flow rate as well as the total volume of air passing through it very precisely. The pipeline to the outgoing air was provided with a filter to remove dust particles from the air before it passed through the flow meter. Both the ingoing and outgoing air from the chamber could be sampled continuously with the help of small sampling pumps with capacity of a 3 liters/minute (Charles Austen pump, Surrey, England Model DYMAX2). The samples of air were passed through another filter and dried before it entered into the gas analysers. Arrangements for the measurement of dry and wet bulb-temperature have been made by the use of a digital temperature indicator (Decibel India, Ltd.) with electronic output for continuous recording of observations.

Infra-red gas analyser (Analytical Development Co., Hoddesdon, Hetts, England) were used for the analysis of methane (0.01-0.1%) and carbon dioxide (0.1-1.0%) of the air samples (in-coming and out-going). A dual channel para-magnetic oxygen analyser type OA184 (Taylor Instrument Co., England) was used for the measurement of oxygen in the air samples. The dual channel analyser measures the differences in the concentration of oxygen between the in-coming and out-going samples of air directly and it also overcomes the problem of fluctuations in barometric pressure (Brockway et al., 1971). The analysers were connected with a 12-point speedomax W recorder (Leeds and Northrup Ltd., UK.) for continuous recording of the percentage of methane, carbon dioxide and oxygen in the out-going air. The analysers were calibrated with a standard gas mixture. Gravimetric calibration of the chamber was done using methane lecture bottle by the standard method (Brockway et al., 1971).

Measurement of respiratory (gaseous) exchange

Animals housed in chamber-2 were used for measurement of respiratory exchange. These animals were fasted for 96 hrs continuously with only water provided to them. Recording of gaseous exchange was done between 96 to 120 hrs. (24 hrs.). Before recording, chamber was closed airtight and associated equipment were put on (air conditioning device and main pump and chamber was allowed to run for an hour to stabilize the chamber conditions.

Simultaneously flow rate, dry and wet bulb temperature and barometric pressure were noted down. Samples of air both in-coming and out-going (respiration chamber) were collected separately in Douglas bags, in two periods, each of 12 hr duration. Chamber was opened after 24 hrs and the volume of urine excreted was measured and suitable aliquot of urine was taken for nitrogen estimation.

Respiration calorimetry techniques

A brief description of respiration calorimetry technique adopted during the course of experiments is given below. To achieve accuracy in respiration calorimetry trial measurements, it is essential to calibrate the associated equipment viz., flow meter, gas analyser etc. The procedure followed for calibration of some of the equipment is given below.

Calibration of flow meter

The flow meter with totaliser was frequently calibrated by a standard dry gas meter supplied under UNDP programme to EM and RC Laboratory of this Division. The standard dry gas meter was fitted between animal chamber and flow meter to be calibrated. The respiration chamber was run for 4 hr and the volume of air coming out of chamber was recorded in both the equipments and a factor was obtained for the difference in the reading of the two. Mean of four such factors was used for correction of the flow rate of total volume of air passed through the chamber in 24 hrs.

Calibration of gas analysers

1) Infrared methane analyser

At first, the infra red analyser for methane was started and run for 60 minutes. There after, nitrogen gas was passed through it and the indicator was set to zero. Finally a standard gas mixture of known methane concentration was passed at the rate of 0.5 l/minute and the indicator was adjusted according to standard value. By this way, the methane analyser was adjusted to give accurate concentration in atmospheric and sample air. Sample of air was sucked by a sampling pump and was dried by passing through a gas blower containing anhydrous calcium chloride,

before it was received by the gas analyser for measuring the concentration of methane.

2) Oxygen analyser

First nitrogen gas was passed through both the channels of the analyser and simultaneously indicator was adjusted to zero. Then atmospheric air was passed and indicator was adjusted at 20.95 percent in both the channels. The recorder was set to read 95% difference between the two channels. Samples of air going-in and coming-out from the respiration chamber were connected to the two channels and the differences in concentration were recorded on a automatic recorder.

Calculations

Using the data of gaseous exchange and nitrogen excreted in urine (g per d), heat production was calculated. The steps followed in calculations are given below.

1) Conversion of volume of air at room temperature to STP condition (0℃, 760 mm Hg):

The total volume of air passed through the chamber in 24 hr period was obtained from mass flow meter with totalizer (Hasting's). Then this volume of air, at room temperature was corrected using correction factors for temperature and pressure, to obtain the volume of air at STP conditions. The following formula was used:

$$V_{STP}\ (l/24\ hr) = [V\ (273)/273+t] \times [P-V_p/760]$$

Where;

V = Volume of air (litre) passed through chamber at room temperature and pressure.
P = Atmospheric pressure, mm Hg.
V_p = Vapour pressure, which was read from a psychometric chart using dry and wet temperature (0℃).
t = Average dry bulb temperature (℃).
V_{STP} = Volume of air (litre) at standard temperature and pressure.

2) Oxygen consumption

The total volume of oxygen consumed by the animal in 24 hr was computed as per the following formula.

Oxygen consumed (l/d) = $V_{STP} \times$ Difference in the concentration of oxygen in in-coming and out going air from the chamber.

3) Carbon dioxide production

The total volume of carbon dioxide produced in 24 hr was obtained by using the following formula:

$$CO_2 \text{ produced (l/24 hr)} = V_{STP}\ (Cf-Ci)$$

Where,

Cf = Average CO_2 concentration in out-going air from chamber.
Ci = Average CO_2 concentration in in-coming air to the chamber.
V_{STP} = Volume of air at standard temperature and pressure.

4) Methane production

Methane production was computed using following formula.

$$\text{Methane production (l/24 hr)} = V_{STP}\ (Mf - Mi)$$

Where,

Mf = Average concentration of methane in out-going air from the chamber.
Mi = Average concentration of methane in in-coming air to chamber.

5) Heat production

The heat production was calculated by using data of respiratory (gaseous) exchange and urinary nitrogen excretion (g/d) using Brouwer's (1965) equation

$$\text{Heat production (kJ/day)} = 16.18\ VO_2 + 5.02\ VCO_2 - 2.17\ VCH_4 - 5.99\ N$$

Where,

VO_2 = Volume of oxygen consumed (l) in 24 hr
VCO_2 = Volume of Carbon dioxide produced (l) in 24 hr
VCH_4 = Volume of methane produced (l) in 24 hr
N = Amount of nitrogen excreted through urine (g/d)

Respiratory quotient

Respiratory quotient (RQ) is used as an indicator of *in situ* energy metabolism (state) of the animal, and was calculated by dividing volume of CO_2 produced (l) by volume of O_2 used (l).

RESULTS AND DISCUSSION

Data obtained on gaseous exchange, urinary-N excretion and heat production on different dietary treatments during FHP studies is presented in table 1. The body weight range in group I, II and III were 76-116, 140-189 and 235-236 kg, respectively. The overall daily means per unit metabolic body weight (kg $W^{0.75}$) for oxygen consumption, carbon dioxide and methane production, urinary-N excretion and fasting heat production were 17.03 liters, 11.7 ℓ, 0.12 ℓ, 0.35 g and 331 kJ/kg $W^{0.75}$, respectively. With

Table 1. Gaseous exchange, urinary N excretion (per kg$W^{0.75}$) and fasting heat production in growing buffalo calves after 96 h of fasting/d

Group		Fasted wt. (kg)	Fasted kg $W^{0.75}$	O_2 (ℓ)	CO_2 (ℓ)	CH_4 (ℓ)	Urinary N (g/d)	Heat production (kJ/d) Total	Heat production (kJ/d) kg $W^{0.75}$	RQ
		76	25.74	15.63	10.78	0.16	0.43	7827	304.2	0.69
I		112	34.43	13.86	10.11	0.13	0.38	9379	272.4	0.73
		116	35.35	16.96	11.98	0.11	0.39	11728	331.8	0.71
	Mean ± SE	101.3 ± 12.72	31.93 ± 3.06	15.44 ± 0.89	10.95 ± 0.54	0.13 ± 0.01	0.40 ± 0.01	9645 ± 1134	302.0 ± 17.7	0.71 ± 0.01
		140	40.70	19.66	13.03	0.09	0.25	15542	382.0	0.66
II		150	42.86	17.16	11.73	0.15	0.39	14310	333.9	0.68
		189	50.97	16.01	10.88	0.09	0.28	15896	311.8	0.68
		189	50.97	19.11	13.04	0.13	0.39	18960	372.0	0.68
	Mean ± SE	166.7 ± 12.72	46.32 ± 2.66	18.00 ± 0.83	12.14 ± 0.51	0.11 ± 0.01	0.33 ± 0.03	16177 ± 988	350.2 ± 16.15	0.68 ± 0.00
III		235	60.0	17.37	12.39	0.19	0.30	20460	341.0	0.71
		236	60.21	17.42	11.32	0.05	0.31	20270	336.8	0.65
	Mean ± SE	235.5 ± 0.50	60.0 ± 0.10	17.40 ± 0.02	11.86 0.54	0.12 ± 0.07	0.31 ± 0.01	20368 ± 98.5	338.9 ± 2.09	0.68 ± 0.03
	Grand mean ± SE		45.06 ± 3.95	17.03 ± 0.58	11.70 ± 0.33	0.12 ± 0.01	0.35 ± 0.02	14930 ± 1530	331.4 ± 11.08	0.687 ± 0.01

increase in body weight, the urinary -N excretion per unit metabolic body size tended to decrease from group I to group III (0.4 to 0.31 g).

The value is higher than 200 mg N/kg $W^{0.75}$ for Zebu cattles and their crosses (Osuji et al., 1996) and lower than 429 mg N/ kg $W^{0.75}$ in sheep sustained on intragastric infusion of VFA and casein (Ørskov et al., 1979; Hovell et al., 1983). Thus like zebu animals buffalo seems to have evolved a methods of conserving N and utilisation in environment where there is scarcity of N availability and with fluctuating supply.

The total heat production (9.6 to 20.4 MJ/d) increased with the increase in body weight from group I to group III. Similarly the FHP (kg $W^{0.75}$) increased from 302 to 339 kJ with a grand mean of 331 kJ. However, increase was not consistent. Based on nine observations, suitable exponent to body weight was found out by power equation regression of total production on body weight. It was FHP (kJ/d)=199.3 $W^{0.87}$ (r=0.96). The power was higher than 0.75 reported by Kleiber (1975).

The respiratory quotient (RQ) ranged from 0.68 to 0.71 with mean of 0.687. This indicated that post-absorptive stage is attained after 96 hrs of fasting. However, Khan et al. (1988a, b), Ghosh (1990), Prakash (1990) and Rane (1990) found 72 hours of time as sufficient to attain post absorptive stage in adult buffaloes and cattles. Ortigues et al. (1990) determined FHP for 24 hrs. after a fast of 90 hrs. The possible reason for variation of time in obtaining-reaching post-absorptive stage is the type of basal roughage fed to the animals. Since in the present study ammoniated straw was fed as basal ration, which has higher evacuation time, it was found appropriate to study fasting heat production between 96 to 120 hrs.

The reported FHP of cattle and buffalo is summarized in table 2. The observed value is higher than the value 286.2 kJ/kg $W^{0.75}$ in adult Murrah buffaloes reported by Khan et al. (1988a). The differences could be attributed to the differences due to physiological status of the animals (growing vs adult). In growing animals, protein retention is the main form of energy retention as against fat retention in adult. Protein synthesis which involves high turn over of amino acids, is associated with heat loss. Cost of 1-g protein synthesis is 68 kJ as against 47.9 kJ for 1 g fat (Ørskov and McDonald, 1970). This may be one of the main causes for differences in fasting heat production of growing and adult animals. The animals used in the experiment were growing but about to mature in group III. So, as animal matures there is deposition of fat in the body. But in this experiment, this factor is unlikely to have effect on FHP. Secondly, McNiven (1984) reported that the fasting heat production remains constant when expressed as multiple of maintenance in thin, medium and fat sheep. Heat production is higher for lean than fatty animals. This is because lean tissue is metabolically more active. When FHP between groups was compared by 't' test, the difference was almost nonsignificant at 5% level of significance. However, FHP of calves of body weights in the range of 167 to 235 was almost 12% higher than that of calves with mean body weight of 101 kg.

Table 2. Fasting heat production (FHP) in cattle and buffaloes by calorimetry

Authors	Species	Time of determination	FHP (kJ/$W^{0.75}$/d)
Brody (1945)	Interspecies mean	-	288.7
Kleiber (1961)	-do-	-	295.0
Colovos (1961)	Steers	-	407-353
Flatt & Cappock (1963)	Non lactating Holstein cow	-	307.5
Hashizume et al. (1965)	Holstein cow	-	318.0
Lawrence (1980)	Swamp buffalo steer	-	334.7
Ortigues et al. (1980)	Dairy Heifer	90-114 h	319.7
Shibata et al. (1983)	Non pregnant Holstein cow	-	355.6-399.3
IVRI (1986)	Holstein cow	72-96 h	336.0
IVRI (1986)	Crossbred cow	-do-	307.9
MacRae (1987)	Growing steers	-	341.4
Khan et al. (1988a)	Adult Murrah buffalo	72-96 h	400-327
Khan et al. (1988b)	Nonlactating desi cow	-do-	286.2
Ghosh (1990)	Nonlactating crossbred cow	-do-	318.0
Prakash (1990)	Male Murrah buffalo	-do-	338.9
Rane (1990)	Adult crossbred male cattle	-do-	301.0
Present study	Growing calves of Murrah buffalo	96-120 h	302-339
			Mean 331.4

The present FHP value is similar to the value of 319.7 kJ /kg $W^{0.75}$/d observed in Swamp Buffalo by Lawrence (1980). The value is also similar to FHP value reported by Rane (1990) for adult crossbred male cattle and by Ghosh (1990) for non-lactating crossbred cows. The present finding of increase in FHP of growing buffalo calves with increase in body weight is contrary to the finding of Mac Rae (1987) who observed a decreasing trend in the FHP with increasing body weight (100-345 kg) of growing steers. Colovos (1961) also reported decrease in FHP from 407 to 353 kJ/$W^{0.75}$/d with increase of body weight from 260 to 334 kg. The variation in the FHP of growing animals besides age, sex and breed can be assigned to the calorimetry training, stage of growth and more specifically to fat free mass i.e. body composition. The calves were trained for the sufficient period of time in these studies before recording actual gaseous exchange. Of the two respiration chambers, one was used for adaptation and other for actual gaseous exchange measurements. Moreover the calves were in continued growing phase (76 to 236 kg) and must have high fat free mass causing increased FHP.

REFERENCES

Agricultural Research Council. 1980. The nutrient requirements of livestock. Commonwealth Agricultural Bureaux, Farnham Royal, UK.

Blaxter, K. L. 1967. Energy Metabolism of Farm Animals (2nd Ed). Hutchinson, London.

Brockway, J. M., A. W. Boyne and J. G. Gordon. 1971. J. Appl. Physiol. 31:296-97 (c.f. M. Y. Khan. 1991). Energy Measurements of Feeds for Ruminants. In: 1st International Animal Nutrition Workers Conf. for Asia and Pacific (Sep. 23-28, 1991), Bangalore India. pp. 46-50.

Brody, S. 1945. Bioenergetics and growth. Reinhold Publ. Corp. NY, USA.

Brouwer, E. 1965. Report to sub committee on constants and factors. Energy Metabolism. (Ed. K. L. Blaxter) Academic Press. pp. 641-643.

Colovos, N. F. 1961. Energy studies and their application to dairy cattle feeds. 2. Symposium on Energy Metabolism. Methods and Results of experiments with animals. Wageningen, Sep. 11-15 1961. EAAP Publ. 10. p. 147.

FAO. 1997. In: FAO Yearbook, Food and Agricultural Organisation of United Nations 1997.

Flatt, W. P. and C. E. Cappock. 1963. Fasting metabolism of dry, non-pregnant adult dairy cows. J. Dairy Sci. 46:638.

Ghosh, A. 1990. Studies on energy requirements of adult non-lactating crossbred cows for maintenance. M.V. Sc. Thesis. IVRI, Izatnagar, India.

Hashizume, T., H. Morimoto, T. Masubuchi, M., Abe, S. Horri, T. Hamada, K. Tanaka, S. Takahashi, Y Kaishio and S. Ambo. 1968. Studies on the feeding standard for dairy cattle maintenance requirement of energy and protein for dairy cattle. Nutr. Abstr. Rev. 35:Abstr. No. 1270.

Hovell, F. D. Deb, E. R. Ørskov, D. A. Grubb and N. A. MacLeod. 1983. Basal urinary nitrogen excretion and growth response to supplemented protein by lambs close to energy equilibrium. Br. J. Nutr. 50:173-183.

Indian Veterinary Research Institute. 1986. Annual Report, Animal Nutrition Div., IVRI, Izatnagar, India.

Kearl, L. C. 1982. Nutrient Requirement of Ruminants in Developing countries. International Feedstuffs Institute. Agric. Expt. Station, Logan, Utah. p. 82.

Khan, M. Y., Jaikishan, Murarilal and D. C. Joshi. 1988a. Energy requirements of Murrah buffalo for maintenance. Proc. II World's Buffalo Cong., New Delhi, India (Dec 12-16). pp. 238-243.

Khan, M. Y., Jaikishan, Murarilal and D. C. Joshi. 1988b. Fasting heat production of Indian livestock In: 3rd Symp. on Latest Trends in Livestock and Poultry Nutrition held at Varanasi, March 23-26 p. 1.

Kleiber, M. 1975. Body size and metabolic rate. Physiol. Rev. 27:11.

Lawrence, P. R. 1980. The nutritional requirement and work output of drought cattle. Drought Animal News. 1:2.

Mac Rae, J. C. 1987. In: Advanced Animal Nutrition for Developing Countries (Ed. U. B. Singh). Indo-vision Publ. Pvt. Ltd., Ghaziabad, India. p. 122.

McNiven, Meirry, A. 1984. The effect of body fatness on energetic efficiency and fasting heat production in adult sheep. Br. J. Nutr. 51:297-304.

Ørskov, E. R. and I. McDonald. 1970. The utilisation of dietary energy for maintenance and for fat deposition of young rowing sheep In: Energy Metabolism of farm animals (EAAP Publ. No. 13) Zurich, Juris. p. 121-124.

Ørskov, E. R, D. A. Grubb, G. Wemham and W. Corrigull. 1979. The sustenance of growing and fattening ruminants by intragastric infusion of volatile fatty acids and protein. Br. J. Nutr. 51:553-558.

Ortigues, I., T. Smith, M. Gill, S. B. Cammell and N. W. Yarrow. 1990. The effect of fish meal supplementation of a straw based diet on growth and calorimetric efficiency of growth in heifers. Br. J. Nutr. 64:639-651.

Osuji, P. O., I. V. Nsahlal and H. Khalili. 1996. Effect of fasting on the urinary excretion of nitrogen and purine derivatives by Zebu (*Bos indicus*) and crossbred (*Bos indicus* × *Bos taurus*) cattle. J. Appl. Anim. Res. 10(1): 39-48.

Prakash, H. G. 1990. Energy balance studies in Murrah male buffalo calves. Ph.D. Dissertation. IVRI, Izantagar, India.

Rane, A. S. 1990. Studies on metabolisable energy content of common feedstuffs for ruminants. Ph.D. Dissertation. IVRI, Izatnagar, India.

Ritzman, E. G. and F. G. Benedict. 1938. Publ. Carnigic Institute no 494 (c.f. K. L. Blaxter and F. W. Wainmann, 1966).

Shibata et al. 1983. Effect of environmental temperature on fasting metabolism of cows. Proc. 5th World's Conf. on Anim. Prod. Vol. 2. Jpn. Soc. Zootech. Sci. Tokyo.