



Energy Expenditure in Crossbred Cattle Fed Paddy Straw of Different Form

Raghavendra Bhatta*, Vijay Kumar, Manpal Sridhar and Khub Singh

Bioenergetics and Environmental Sciences Division

National Institute of Animal Nutrition and Physiology (ICAR), Bangalore 560 030, India

ABSTRACT: Studies were carried out at the National Institute of Animal Nutrition and Physiology, India to determine the effect of feeding chopped paddy straw (*Oryza sativa*) on the energy expenditure in crossbred cattle. Four crossbred cattle male, aged 5-6 years and weighing about 450 kg were used for this study. Three experimental trials, one each for the feeding of un-chopped paddy straw offered *ad libitum* (UCA), chopped paddy straw fed at restricted level (CR) and chopped paddy straw offered *ad libitum* (CA) were conducted. The quantity of un-chopped paddy straw consumed during UCA was assumed as the voluntary intake by the cattle and the same quantity was offered after chopping during CR. Each trial comprised of 21 d preliminary feeding period and 5 d of observation recording period. Expired gas was collected in Douglas bags using a face-mask and three-way valve at 6 hourly intervals i.e., at 09.30, 15.30, 21.30, and 03.30 h throughout the observation period. Expired gas and ambient air inspired by the animals were analyzed for the oxygen content through paramagnetic oxygen analyzer. Energy expenditure (EE) by the animals was calculated by determining the volume of oxygen consumed per minute (STP) and multiplying by 4.825. Paddy straw used in all the three trials contained (g/kg DM) 90.0 CP, 786 OM, 700 NDF, 489 ADF, 357 Cellulose and 60.0 ADL. Metabolizable energy (ME) was 6.9 MJ/kg DM. Dry matter intake (DMI) both in UCA and CR was about 6.8 kg, except that it was chopped in CR. Chopping has resulted in 32% improvement (9 kg) in DMI of CA as compared to that of UCA. Although ME intake was similar in UCA and CR (47.2 MJ/day), energy expenditure (EE) was higher in UCA (23.3 MJ) when compared to that of CR (19.5 MJ). The ME intake (63.3 MJ) as well as EE (27.1 MJ) was highest in CA. Energy expenditure when expressed as MJ/kg DMI was 3.48, 2.90 and 3.12; whereas as per cent of ME intake it was 50, 41 and 44 in UCA, CR and CA respectively. Our study has unequivocally confirmed that chopping of poor quality roughages like paddy straw has definite advantages not only in terms of improving the intake by decreasing the time taken for ingestion but also in reducing the energy cost of eating. (**Key Words** : Paddy Straw, Chopping, Intake, Energy Expenditure, Cattle)

INTRODUCTION

Time that cattle spends for eating and ruminating amounts to 13 to 17 h/d when animals are given *ad libitum* access to diets that contain a high proportion of roughage (Teller et al., 1993; Susenbeth et al., 1995). The capacity of ruminants for mechanically reducing feed particle size could be a limiting factor for feed intake (Bosch et al., 1992). In addition, the energy requirement for chewing accounts for a considerable proportion of the total energy requirement. In low-quality roughages (like paddy straw), the energy requirement for eating could amount to substantial proportion of the ME. Energy needed for chewing thus reduces the amount of ME available for

production, and this could have a substantial effect on productivity, particularly at low levels of production in tropical countries like India. This fact might be mainly responsible for the lower efficiency of utilization of ME in roughages than in other feedstuffs (Ørskov and Macleod, 1990).

In large parts of southern India, un-chopped dry roughage is offered to the ruminants. The activity of various muscles involved in chewing activity and rumination is a potential mechanism to reduce the particle size of feed to the threshold size which, for cattle is around 1.0-1.18 mm (Poppi et al., 1981). Although some chewing and rumination is essentially required for proper mixing of the saliva with the feed particles, in addition to reducing the particle size, excessive chewing and rumination needs extra energy expenditure, resulting in wastage of biological energy. This study was therefore conducted to study the effect of chopping paddy straw, a commonly used

* Corresponding Author: Raghavendra Bhatta. Energy Metabolism Laboratory, National Institute of Livestock and Grassland Science, Tsukuba, Japan. Tel: +81-29-838-8655, Fax: +81-29-838-8553, E-mail: ragha0209@yahoo.com

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agricultural byproduct for animal feeding on the dry matter intake and energy expenditure in crossbred cattle.

MATERIALS AND METHODS

Experimental animals and feeding protocol

Four Holstein Friesian \times *Bos indicus* crossbred cattle aged 5-6 years and weighing about 450 kg were used in this study. The animals were healthy as verified by the clinical history and physical examination. They were housed in a fly proof enclosure and trained for a month for experimental procedures like collection of expired gas through face-mask and *ad libitum* feeding of the paddy straw and availability of water. Three experimental trials (26 days each), one each for the feeding of un-chopped paddy straw fed *ad libitum* (UCA), chopped paddy straw fed at restricted level (CR) and chopped paddy straw fed *ad libitum* (CA) were carried out. In each trial, all the 4 experimental animals were fed the same straw as per the protocol (chopped or un-chopped) and expired gas was collected from all the animals for measuring the EE. The quantity of un-chopped paddy straw consumed during the *ad libitum* feeding was assumed as the voluntary intake by the cattle and the same quantity was offered after chopping during the second trial (restricted). The length of the chopped paddy straw was about 2 inches as against 2.5 to 3.0 feet for the un-chopped paddy straw. Each trial comprised of 21 days preliminary feeding period and 5 days of observation recording period. Around one month interval was allowed in between the trials. The weighed quantity of straw was offered in large individual feeding troughs immediately after the expired gas collection, in the morning (9.30 h). The animals were allowed feeding of paddy straw at all times as per the protocol except during restricted feeding (weighed quantity was offered periodically until the entire amount was consumed) with free access to drinking water. Since the straw was deficient in calcium, about 10-15 g di-calcium phosphate was added to the water as a source of mineral.

Experimental measurements

Expired gas was collected in Douglas bags using a face-mask and three-way valve (Harvard Apparatus Ltd., Kent, England) at 09.30, 15.30, 21.30, and 03.30 h from all the four animals throughout the recording period. The capacity of the Douglas bag was 150 L; the expired air was collected until the bag was completely filled but not distended. The duration of the collection varied from 2 to 6 minutes, depending upon the measurement period. The volume of the expired air was measured with a dry gas meter (Harvard Apparatus Ltd., Kent, England); volume of air collected in the bag per unit time was determined and corrected for standard temperature and pressure (STP). The expired air and the ambient air inspired by the animal were analyzed

for the oxygen content through paramagnetic oxygen analyzer (Paramax-101, Columbus Instruments, Ohio, USA).

Respiration rate (RR) was recorded by counting the thoracic and flank movements and rectal temperature (RT) using a digital thermometer. Dry and wet temperatures were also recorded simultaneously using a wet and dry bulb-thermometer hung in the animal enclosure.

The ort was weighed every morning to determine the daily straw intake. The dry matter was estimated every day during the experimental period. Nitrogen was determined by the Kjeldahl method (AOAC, 1995). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined by the method of Van Soest et al. (1991). Metabolizable energy was estimated by *in vitro* gas production test (Menke and Steingass, 1988). Pre and post experimental period body weights of all the animals were also recorded for each trial.

Calculations

The energy expenditure (kcal) was calculated by determining the volume of oxygen consumed (at STP) by the animal per minute and multiplying it by 4.825 (Brody, 1945). The energy expenditure thus calculated in kcal was then converted to MJ.

Statistical analysis

The data recorded on energy expenditure at every six hour interval for each of the 5 days in the experimental periods for each of the three treatments: un-chopped paddy straw and chopped paddy straw fed to individual animals, was subjected to analysis of variance (Harvey, 1990) with multiple observations per cell and Duncan's Multiple Range Test (DMRT) was used to determine the difference between means (Montgomery, 1976) using Systat 8.0 statistical software (SPSS Inc., USA).

RESULTS AND DISCUSSION

Meteorological observations

Meteorological observations recorded during the experimental periods and the physiological responses of the animals are presented in Table 1 and 2, respectively. Maximum dry bulb temperature (DBT) was recorded at 15.30 h followed by 09.30, 21.30 and 03.30 h, respectively. Similar trend was also observed in wet bulb temperature (WBT), temperature-humidity-index (THI), minimum and maximum temperatures. During the third experiment (CA) DBT was slightly higher as compared to the earlier two. However, there was no significant ($p > 0.05$) difference in the meteorological observations during different trials.

Physiological responses

Rectal temperature followed a trend almost similar to

Table 1. Meteorological observations during the experimental period

Time of recording (h)	UCA	CR	CA
Dry bulb temperature (°C)			
9.30	23.33	21.17	23.33
15.30	24.30	25.10	26.30
21.30	22.00	20.20	21.40
03.30	19.30	19.00	19.40
Wet bulb temperature (°C)			
9.30	20.00	18.92	19.50
15.30	20.20	19.90	20.90
21.30	19.30	18.70	18.90
03.30	18.10	18.10	18.10
Temperature humidity index (THI)			
9.30	71.80	69.46	70.72
15.30	72.64	73.00	75.74
21.30	70.34	68.61	69.62
03.30	67.53	67.31	67.60
Minimum temperature (°C)			
9.30	24.50	22.60	23.80
15.30	26.60	26.80	29.60
21.30	22.80	21.70	22.90
03.30	20.70	20.30	20.80
Maximum temperature (°C)			
9.30	25.25	23.17	24.30
15.30	27.20	27.40	30.10
21.30	23.50	22.10	23.30
03.30	21.10	21.00	21.20

UCA: un-chopped paddy straw offered *ad libitum*.

CR: chopped paddy straw fed at restricted level.

CA: copped paddy straw offered *ad libitum*.

that of DBT, maximum being at 15.30 h during all the trials. Cattle, like other mammals, must maintain their core body temperature (about 38°C). Thermoregulation is the means by which an animal maintains its body temperature by either heat gain or heat loss. When cattle are stressed by the cold, their metabolic rate increases in an effort to maintain body temperature. Environmental factors can also influence the nutrient requirements and the subsequent performance of cattle. The most important variable is the environmental temperature. When animals are exposed to intense solar radiation, they resort to thermo-regulatory mechanisms to dissipate body heat. Cattle are reported to have a comfort zone of approximately 15°C to 25°C where they are content and consume feed normally. Above this temperature range or the upper critical temperature, intake starts to decrease and below this temperature range or lower critical temperature (LCT), intake starts to increase. Below the LCT, the amount of energy required by the animal to maintain core body temperature increases. Berman et al. (1985) suggested that 25-26°C as the upper critical temperature for high-yielding dairy cows. In our experiment, the experimental animals were adult male and the enclosure was well ventilated with sufficient drinking water supply.

Table 2. Physiological responses of crossbred cattle fed un-chopped and chopped paddy straw

Time of recording (h)	UCA	CR	CA	SEM	P
Rectal temperature (°C)					
9.30	37.3	37.2	37.3	0.17	0.7864
15.30	38.1	38.0	38.2	0.16	0.9124
21.30	37.9	38.0	38.1	0.13	0.8623
03.30	37.5	37.5	37.3	0.11	0.4537
Respiration rate (number/min)					
9.30	11.0	8.2	9.8	2.2	0.1627
15.30	13.5	10.2	14.9	2.0	0.3735
21.30	11.8	9.8	12.3	2.1	0.2536
03.30	10.5	9.2	11.3	1.9	0.3745

UCA: un-chopped paddy straw offered *ad libitum*.

CR: chopped paddy straw fed at restricted level.

CA: copped paddy straw offered *ad libitum*.

Since the temperature variations during the three trials were minimal, the recorded difference in the energy expenditure was solely attributed to paddy straw intake. Respiration rate was slightly higher in the third trial because of the combined effect of higher temperature as well as intake compared to the earlier two trials. However, these variations were non-significant ($P>0.05$) and within the physiological limits of cattle.

Energy intake and expenditure

Paddy straw from a single source/batch was used in all the three trials in order to maintain uniform nutritive composition and it contained (g/kg DM) 90.0 crude protein (CP), 786 organic matter (OM), 700 NDF, 489 ADF, 357 Cellulose and 60.0 ADL. Metabolizable energy (ME) was 6.9 MJ/kg DM. Dry matter intake (DMI) both in UCA and CR was about 6.8 kg, except that it was chopped in CR. In the active hours of a day, this seemed to be the amount of paddy straw that cattle could consume (UCA). When expressed as per cent of the body weight it was 1.5 which is low when compared to the maintenance requirement for adult cattle. Chopping resulted in 9.1 kg DMI in CA (about 2% of the BW) or 32% increment as compared to that of un-chopped paddy straw. In an earlier study, Vijay Kumar (unpublished) recorded 49% improvement in DMI in crossbred cattle fed finger millet (*Eleusine coracana*) straw after chopping. Retter (1978) also reported an increase in DMI with decrease in the length of chopped grass silage. Deswysen et al. (1979) observed a significantly higher voluntary intake of silage by heifers (10.4%) with chopped (1.5 cm) than un-chopped (9 cm) silage. The rate of ingestion is influenced by several factors such as animal species, appetite, bite size and type of feed (Adam et al., 1984). There appears to be a limit to the amount of rumination chewing an animal will perform each day. The intake of un-ground roughages might be related to how efficiently they could be broken down by rumination during

Table 3. Energy intake and expenditure of crossbred cattle fed un-chopped and chopped paddy straw

	UCA	CR	CA	SEM	P
Body weight (kg)	462 ^b	445 ^a	451 ^a	2.801	0.0443
DM intake					
kg/day	6.75 ^a	6.76 ^a	9.05 ^b	0.442	0.0213
g/kg BW	14.6 ^a	14.6 ^a	19.8 ^b	0.991	0.0276
g/kg W ^{0.75}	67.7 ^a	67.7 ^a	91.4 ^b	4.550	0.0362
ME intake					
MJ/day	47.2 ^a	47.2 ^a	63.3 ^b	3.104	0.0165
MJ/kg BW	0.102 ^a	0.102 ^a	0.138 ^b	0.007	0.0234
MJ/kg W ^{0.75}	0.474 ^a	0.474 ^a	0.639 ^b	0.032	0.0318
Energy expenditure					
MJ/day	23.3 ^b	19.5 ^a	27.1 ^c	1.262	0.0125
MJ/kg BW	0.05 ^b	0.04 ^a	0.06 ^c	0.003	0.0243
MJ/kg W ^{0.75}	0.24 ^b	0.20 ^a	0.28 ^c	0.013	0.0341
MJ/kg DMI	3.48 ^b	2.90 ^a	3.12 ^c	0.098	0.0345
MJ/ MJ of MEI	0.50 ^b	0.41 ^a	0.44 ^c	0.015	0.0172
% of MEI	50.0 ^b	41.0 ^a	44.0 ^c	1.528	0.0182

UCA: un-chopped paddy straw offered *ad libitum*. CR: chopped paddy straw fed at restricted level. CA: copped paddy straw offered *ad libitum*.

the limited time available (Welch, 1982). This limit may be determined by the time available for chewing, because fatigue of the jaw muscles does not appear to limit chewing (Campling and Balch, 1961). The longer roughage size causes difficulty in prehending, forming a bolus or chewing compared to chopped ones. One of the factors controlling the voluntary intake by ruminants is the rate at which large food particles are reduced to a size small enough to leave the rumen (Freer et al., 1962). Eating and rumination are the main contributors to this process and both are affected by the fibre level of the diet (Fujihara and Nakao, 1982) and length of the forage. McLeod and Smith (1989) reported a negative relationship between rate of ingestion and fibre level. The higher rate of eating was related to the lower ADF and ADL levels and vice versa. Regulation of DM intake by the fibre level is not a point of discussion here, since the nutritive composition of the straw was same in all our experimental trials.

Although ME intake was similar in UCA and CR (47.2 MJ/day), EE was higher in UCA (23.3 MJ) as compared to CR (19.5 MJ). The ME intake (63.3 MJ) as well as EE (27.1 MJ) was maximum in CA due to higher DMI. The EE when expressed as MJ/kg DMI was 3.48, 2.90 and 3.12 in UCA, CR and CA, respectively. Adam et al. (1984) reported that the act of eating accounts for an energy cost of about 1-5% of the ME ingested in cattle. This was based on the values for energy cost of eating (J/g DM per kg BW) as 1.48 and 0.79, respectively for long dried forage and chopped dried forage. Assuming these values, the energy cost of eating was calculated in our study and were 4.61 MJ (1.48 J×6,750 g×462.25 kg BW), 2.38 MJ (0.79 J×6,760 g×445.75 kg BW) and 3.23 MJ (0.79 J×9,054 g×451.25 kg BW) for UCA, CR and CA, respectively. When expressed as per cent of MEI it was 9.77, 5.05 and 5.10, respectively for the three groups. High energy cost of eating (>5% in UCA) was

attributed to the quality of the paddy straw used in terms of ADF (489 g/kg DM) and ADL (60 g/kg DM). In India, paddy straw is an agricultural byproduct obtained after harvesting the grain. High energy cost of eating in UCA was expected because of the maturity and subsequent lignification of straw.

The interesting finding of this study was the difference in the energy cost of eating calculated in cattle of CR and CA. Although animals in CA consumed an additional 2,300 g (9,054-6,760) of paddy straw DM as compared to that of CR however, energy cost of eating was almost similar (5% of MEI). Adam et al. (1984) reported that the physical form of a diet influence the rate at which animals ingest a diet and, furthermore, the total energy cost of eating is more a function of the time spent eating than of the weight of feed consumed. That means in our study, cattle in CA consumed 9,054 g paddy straw in almost at same duration as that of 6,760 kg in CR (indicating more idle time in CR) i.e. when cattle were offered un-chopped paddy straw they spent 50% of the MEI and only 41% of MEI for the same quantity, if chopped (Table 3) i.e. for 47 MJ of MEI there will be a net saving of 4.23 MJ. Chopping helped not only in improving the intake but also in minimizing the energy spent on chewing. Therefore, it is imperative that material which could be consumed slowly, like for example long un-chopped paddy straw, would require significantly more energy for eating than readily available feeds such as chopped straw (Bhatta et al., 2004). Thus for an animal grazing pasture of low quality, the rate of ingestion is likely to be relatively low and the energy cost of feeding activity might be a significant fraction of the maintenance energy requirement of cattle (Adam et al., 1984). Shinde et al. (1998) reported 43% higher energy expenditure (421 kJ/kg W^{0.75}) in sheep grazing on a semi-arid region of India as compared to that of stall fed (295 kJ/kg W^{0.75}) sheep. Bhatta

et al. (2005) recorded significant effect of housing on energy expenditure in sheep. Sahlu et al. (1989) reported lowest EE in sheep grazing high quality temperate pasture and increase as the quality deteriorated; however, Shinde et al. (2002) recorded contrasting observation in goats browsing on a semi-arid rangeland of India. Webster (1972) concluded that the energy cost of eating is too great to be simply the result of the cost of chewing and salivating, as these activities are common to eating and rumination. The most obvious difference between eating and rumination is that during eating the animal is standing and alert whereas during rumination it is usually lying down and at rest. Osuji et al. (1975) indicated that one of the many beneficial aspects of rumination is that it enables the ruminant to harvest feed relatively fast and then comminute it literally at its leisure, and at negligible cost in terms of energy. The results of our study confirmed that chopping of coarse straws has significant beneficial effect on the rate of consumption as well as energy cost of eating - two factors that influence the efficiency of utilization. Further, since the total energy cost of eating is more a function of the time spent eating than of the weight of feed consumed (Adam et al., 1984) our results also demonstrated that if the time spent for ingestion of the chopped forage is similar to that of un-chopped forage, then chopping such forages may have little or no impact on energy cost of eating.

Energy required for the activity associated with eating and ruminating can account for one-third of the ME in low quality roughages, which leads to a significant reduction in the proportion of ME available for maintenance and production (Susenbeth et al., 1998). With decreasing quality of roughages, energy requirement for eating and ruminating can increase from 10 percent to approximately 30 percent of the ME provided by the feedstuff. Energy requirement for this activity should be taken as an important criterion among others for evaluating methods for improving roughage quality. The lower efficiency of ME utilization in roughage compared with that of other feedstuffs seems to be mainly caused by heat production associated with eating. Therefore, energy requirement for this activity should be considered as a quantifiable component of the total energy budget instead of an indefinite consequence of feed composition or processing (Susenbeth et al., 1998). This is more relevant particularly in tropical countries like India, where majority of the ruminants are fed on agricultural byproducts like straws and stovers.

CONCLUSION

From the results of this study it could be concluded that chopping of poor quality roughages like paddy straw has definite advantages in terms improving the intake by

decreasing the time taken for ingestion as well as in reducing the energy cost of eating in ruminants.

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