



Variability in residual feed intake, nutrient utilisation and blood parameters in Murrah buffalo calves fed on total mixed ration

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ABSTRACT

The present study was conducted on 18 female Murrah buffalo calves divided into two treatment groups to determine the residual feed intake, nutrient digestibility and blood metabolite parameters when fed with ration containing wheat (*Triticum aestivum*) straw, berseem (*Trifolium alexandrinum*) fodder as roughages and concentrate mixture to meet their requirements. Regular recording of body weight and feed intake was done during 90-day trial period. Residual feed intake (RFI) values were determined for individual animals based on which they were divided into low and high RFI groups. DM intake was lower in low RFI animals than high RFI animals. The blood glucose level and growth hormone level in low and high RFI group was comparable in both groups. Low RFI group had greater concentration of creatinine (1.62 vs. 1.21 mg/dL) as well as IGF-1 (136.70 vs. 120.38 ng/mL) whereas, concentration of total plasma protein level (6.80 vs 7.43 g/dL), albumin (3.46 vs 3.71 g/dl), aspartate aminotransferase (102.20 vs. 122.60 IU/L) and cortisol (3.48 vs. 5.32 ng/mL) were lesser in low RFI group with respect to high RFI group, indicating a positive correlation of RFI with total plasma protein, albumin, aspartate aminotransferase and cortisol and a negative correlation with plasma creatinine and IGF-1 levels in female Murrah buffalo calves. It was concluded that low RFI group of female Murrah buffalo calves showed better performance when fed with total mixed ration.

Keywords: Blood parameters, Murrah buffalo calves, Nutrient utilisation, Residual feed intake

The population is increasing at an alarming rate globally which in turn would increase the expected demand for food in 2050 by approximately 70% more than that in 2010 (FAO 2019). This demand can only be met by increasing the food production efficiency of agricultural as well as animal sector. As the feed cost contributes about 60-70% of total cost of livestock production, there is a need to select energetically efficient animals in order to efficiently utilize the scarce feed resources particularly in developing countries (Sharma *et al.* 2012, Sharma *et al.* 2013). Residual feed intake (RFI) is a measure of feed efficiency which is the difference between actual feed intake and the feed which an animal is expected to consume based on its body size and growth rate (Sharma *et al.* 2021). The heritability of Residual feed intake ranges from 0.14 to 0.58 indicating moderate heritability (Fan *et al.* 1995, Crews *et al.* 2003, Sharma *et al.* 2021) and it is phenotypically independent of growth rate and body weight in growing cattle (Archer *et al.*

1999, Herd *et al.* 2003). The scientific basis for using RFI as a selection tool is that individuals having same body weight require feed of varying amount for the similar level of production (Sainz and Paulino 2004, Nkrumah *et al.* 2006, Hegarty *et al.* 2007). Measurement of RFI is expensive, time-consuming and tedious as it requires records of animal's feed intake and body weight for a minimum of 70 days. The plasma IGF-1 levels are correlated to RFI ($r=0.56$) (Johnston *et al.* 2002) and can be used as a selection criterion for RFI (Wood *et al.* 2004, Bhong *et al.* 2014). Dudi *et al.* (2015) found that RFI was positively correlated with total plasma protein ($r=+0.66$), BUN ($r=+0.95$) and AST ($r=+0.44$) and negatively correlated with plasma creatinine ($r=-0.51$) and IGF-1 ($r=-0.57$). Angus heifers and bulls with low RFI showed higher DM digestibility compared to high RFI Angus bulls and heifers (Richardson *et al.* 1996). As no work has been undertaken in buffalo calves and buffalo which have different RFI from cattle, hence, this study was undertaken.

MATERIALS AND METHODS

The present research work was carried out at the Livestock Research Centre of ICAR-National Dairy Research Institute (NDRI), Karnal which is situated at latitude and longitude position being 29°42' N and 79°54'

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E, respectively. The ambient temperature ranges from 45°C in summer to 4°C in winter.

Feeds and feeding regimen: A total of 18 female Murrah buffalo-calves were selected from Livestock Research Centre of NDRI, Karnal and were given ration in TMR (total mixed ration) form to meet their nutritional requirements (ICAR 2013). The animals were fed with Concentrate mixture, berseem (*Trifolium alexandrinum*) and wheat straw (*Triticum aestivum*) in the ratio of 40: 40: 20 dry matter basis (DMB). Ingredient composition of concentrate mixture has been given in Supplementary Table 1.

Housing and management: All the animals were housed in clean, well-ventilated and spacious sheds having provision for individual feeding and were dewormed and vaccinated prior to the start of the study. Thereafter, animals were shifted to metabolism cages for conducting metabolism trial and animals were divided into two groups on the basis of their RFI values.

Periodical studies: The blood samples were collected in heparinised vacutainer at the start and end of the trial by jugular puncture and centrifuged at 3000 rpm for 15 min to separate plasma which was stored at -20°C to estimate AST, glucose, total protein, albumin, creatinine, insulin like growth factor (IGF-1), growth hormone and cortisol.

The feed offered and its residue and hence DMI were recorded daily. Weekly recording of the body weight of individual animals was carried out in the morning hours before feeding and watering.

Methodology for measuring RFI in female Murrah buffalo calves: Residual feed intake was calculated using mean feed intake and body weight gain data of the 90-days trial period. Growth was modelled by linear regression of body weight data against time. Regression coefficients were used to describe individual animal's growth (Archer *et al.* 1997) and for individual animal's every test a separate regression was fitted. Equation fitted was:

$$Y_i = b_0 + b_1 X_i + e_i$$

Where, Y_i , weight of animal at observation i ; B_0 , intercept (weight at start of test); B_1 , regression coefficient (i.e., average daily gain); X_i , number of days on test at observation i .

Regression coefficients estimates were used to calculate ADG and mid-test metabolic body weight. Average 90-days DMI was regressed on mid-test metabolic BW ($BW_{0.75}$) and ADG (Archer *et al.* 1997). Residual feed intake was computed for each animal and was assumed to represent the residuals from a multiple regression model regressing

DMI on ADG and mid-test metabolic BW ($BW_{0.75}$). The base model used was:

$$Y_j = \beta_0 + \beta_1 MBW_j + \beta_2 ADG_j + e_j$$

Where, Y_j , DMI of j th animal; β_0 , regression intercept; β_1 , regression coefficient on MBW; β_2 , regression coefficient on ADG; e_j , uncontrolled error of j th animal (RFI).

The predicted DMI subtracted from actual DMI represents RFI which means more efficient animal has a negative RFI and vice-versa.

Metabolism trial: After feeding trial of 2 months, animals were transferred to metabolism cages and given adaptation period of 2 days. Weight of individual animal was recorded consecutively for 2 days before the start and at the end of the trial. The animals were fed ration stated earlier with provision of potable water.

Sampling, processing and storage of feed samples: The samples of feeds offered, residues and faeces were dried, ground and pooled for analysing proximate principles (DM, CP, total ash and EE) and cell wall constituents (NDF, ADF, cellulose and lignin). An aliquot of faeces and urine voided were taken daily in plastic containers containing 25 ml of 10% H_2SO_4 for nitrogen estimation. The blood was collected using 16-gauge for determining hemato-biochemical parameters.

Statistical analysis: The data obtained during this research was analysed using software package SAS.

RESULTS AND DISCUSSION

Chemical composition of the ration: Chemical composition of the ration fed to the animals is given in Table 1.

Grouping of animals in low and high RFI groups: A 90-days feeding trial was conducted and RFI value was determined for each animal followed by calculation of average value and standard error. Each animal was recorded for various parameters followed by categorisation of animals into low and high RFI groups depending on negative or positive RFI values, respectively. Predicted DMI subtracted from actual DMI presented RFI indicating that a more efficient animal has negative RFI (observed DMI is less than predicted DMI) and a less efficient animal has a positive RFI (observed DMI is greater than predicted feed intake) and this formed the basis of grouping (Fig. 1). Average RFI values were -0.13 and +0.10 kg/d, in low and high RFI groups, respectively. Bose *et al.* (2014) and Bhong *et al.* (2014) have reported mean RFI values varying from -0.01 to -0.31 and +0.01 to +0.44 in low and high RFI group of animals in Murrah and Sahiwal calves.

Table 1. Chemical composition of feeds (% DM basis)

Feed	Composition						
	DM	OM	CP	EE	Total ash	NDF	ADF
Concentrate mixture	87.0	93.20	20.73	4.25	6.80	31.20	14.60
Berseem fodder	14.38	88.36	15.35	2.20	11.64	51.31	35.50
Wheat straw	91.30	89.18	3.50	0.75	10.82	76.10	53.89

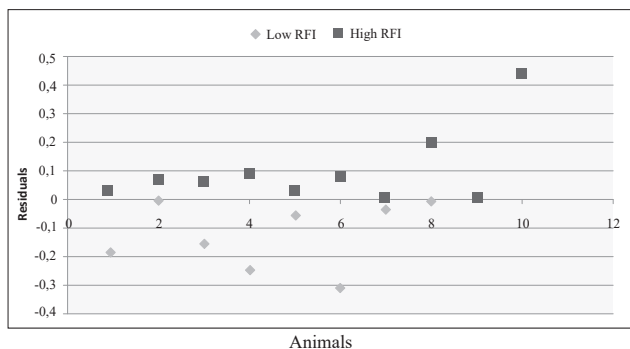


Fig. 1. Partitioning of animals in low and high RFI.

Relationship between RFI and FCR: The correlation between RFI and FCR and feed intake is presented in Supplementary Table 2 which shows that the average FCR values were 7.3 ± 0.22 and 8.5 ± 0.43 in low and high RFI groups, respectively, indicating significantly ($P < 0.05$) lower FCR values in low RFI group as well as lesser feed intake by low RFI group per kg BW gain. 15.19% lesser FCR was observed in low than high RFI group. Low RFI steers had 9.4% lower FCR with no differences in BW or ADG (Basarab *et al.* 2003). Nkrumah *et al.* (2006) reported 7.98 and 6.53 FCR for high and low RFI groups, respectively.

Fortnightly DM intake (kg/d and kg/100 kg BW) in low and high RFI groups: Mean DMI (kg/d) and mean DMI (% BW) of both groups is given in Supplementary Table 3 and 4 which represents that the average DMI was 4.87 ± 0.38 and 4.96 ± 0.47 kg/d whereas average DMI (%BW) was 2.51 and 2.72 kg/100 kg BW in low and high RFI groups, respectively. The DMI expressed as kg/100 kg BW was 8.02% greater in high RFI group with respect to low RFI group indicating significant ($P < 0.05$) correlation was between RFI and DMI (kg/100 kg B. wt.). Hafla *et al.* (2013) reported that low RFI heifers consumed 20% less feed while maintaining same body weight. Low RFI calves had 15-21% lesser feed intake than high RFI calves (Herd and Bishop 2000). Lancaster *et al.* (2009) also found that more efficient animals had 16% lower feed intake when compared to less efficient animals.

Digestibility of nutrients in low and high RFI groups: The digestibility coefficients of various nutrients for both groups is given in Table 2. The digestibility of EE and CP

Table 2. Digestibility coefficients (%) of nutrients in low and high RFI groups of female Murrah female calves

Parameter	Group	
	Low RFI	High RFI
DM	62.63 ± 0.57^a	58.32 ± 1.02^b
OM	65.68 ± 0.56^a	61.60 ± 0.97^b
EE	75.86 ± 2.56	76.84 ± 3.88
CP	65.58 ± 1.18	62.65 ± 1.89
NDF	56.50 ± 0.70^a	51.92 ± 1.44^b
ADF	49.86 ± 0.78^a	45.17 ± 0.89^b

^{a,b}Values bearing different superscripts in a row differ significantly ($P < 0.05$).

Table 3. Nitrogen balance in female Murrah buffalo calves having low and high RFI values

Parameter	Group	
	Low RFI	High RFI
N intake (g/d)	123.61 ± 9.09	112.77 ± 11.33
Faecal N outgo (g/d)	43.15 ± 3.84	41.83 ± 4.74
N absorbed (g/d)	57.69 ± 5.64	50.65 ± 5.82
N absorbed (% of intake)	80.40 ± 6.08	70.94 ± 7.19
Urinary N outgo (g/d)	65.10 ± 1.48	63.05 ± 1.73
Total N loss (g/d)	100.84 ± 8.39	92.48 ± 9.80
N retained (g/d)	22.77 ± 1.13	20.29 ± 1.87
N retained (% of intake)	18.86 ± 1.07	18.41 ± 0.92
N retained (of absorbed)	29.12 ± 1.83	29.38 ± 1.66

was comparable in both the groups. The digestibility of DM, NDF and ADF was higher ($P < 0.05$) in low RFI group indicating negative correlation of RFI with DM ($r = -0.42$), OM ($r = -0.39$), CP ($r = -0.10$), NDF ($r = -0.33$) and ADF ($r = -0.61$).

There was a decrease in digestibility of feed as the level of feed intake with respect to maintenance increased (Oddy and Herd 2001), causing differences in digestibility between calves with different RFI. As per Richardson *et al.* (1996) there were significant differences, however small, in digestibility of feed between high and low RFI cattle and reported 1% higher apparent digestibility in low RFI calves with low RFI when given pelleted roughage-based diet. When calves are fed a high-grain diet, it was found that there were 28% lesser methane energy losses and 6% greater apparent digestibility in low RFI calves with respect to high RFI calves (Nkrumah *et al.* 2006). On the contrary, Lawrence *et al.* (2012) observed no variation in total digestibility between the two different high and low phenotypic RFI sub-populations. Higher digestibility % in low RFI calves maybe the reason attributed to their low feed intake and more weight gain.

Nitrogen balance in low and high RFI groups: The nitrogen balance of both groups is presented in Table 3 which shows that nitrogen intake (g/d) was 123.61 and 112.77 in low and high RFI groups, respectively. This indicated that RFI was negatively correlated with daily faecal loss, total N-loss, daily N-retention, N expressed as % of N-intake and N-retention expressed as % of N-absorbed while RFI was positively correlated with urinary N loss and N absorbed as % of intake. Total N retention (g/d or % of N-intake) was higher in low RFI group than high RFI group but did not differ significantly. Higher N retention in low RFI calves may be the reason attributed to their more weight gain as compared to high RFI group.

N intake, urinary N and faecal N were significantly ($P < 0.05$) greater in high RFI groups when compared to low RFI group, however, N-retention, (% intake and % absorbed) was greater in low RFI group in male Sahiwal calves (Sharma *et al.* 2014 and Bhong *et al.* 2014) which is in accordance with the findings of present study. According to Dudi *et al.* (2016), there was a positive correlation of

RFI with daily faecal loss; urinary N-loss and total N-loss however, negative correlation ($P<0.5$) with N-retention.

Blood biochemical and physiological parameters in low and high RFI groups

Blood metabolites: The mean blood glucose level was 60.86 ± 2.99 and 57.31 ± 2.72 mg/dL in low and high RFI group respectively and was statistically similar in both the groups. As per Kolath *et al.* (2006) high glucose level was observed in steers with high RFI values, on the other hand, studies by Richardson *et al.* (2004) showed that at the commencement of the RFI test period, there was a positive correlation between glucose concentration and RFI in Angus steers. The concentration of glucose did not associate with DMI, ADG, FCR and RFI (Kelly *et al.* 2010). Blood glucose levels were comparable in low and high RFI groups of Sahiwal calves (Bhong *et al.* 2014) and buffaloes (Sharma *et al.* 2016 and Sharma *et al.* 2017).

Average total protein levels in low and high RFI groups was 6.76 ± 0.16 and 7.37 ± 0.13 g/dL, respectively, showing higher total protein level ($P<0.05$) in high RFI group which indicates a positive correlation. Richardson *et al.* 1996) and Richardson *et al.* 2004) reported a phenotypic relationship between RFI and total plasma protein. The mean plasma total protein level in low and high group of Sahiwal calves was 7.32 and 7.54 (g/dL) respectively (Dudi *et al.* 2016).

The mean albumin level in low and high RFI group was 3.46 ± 0.08 and 3.71 ± 0.05 g/dL, respectively indicating higher ($P<0.05$) levels in high RFI group. This indicates a significant ($P<0.05$) association between RFI and plasma albumin levels. The correlation between serum albumin and the efficiency measures can be related to higher DMI by low RFI animals as described by Connell *et al.* (1997) who showed that serum albumin levels are closely associated with the level of feed consumption. The mean globulin level in low and high RFI group was 3.30 ± 0.20 and 3.66 ± 0.14 g/dL, respectively.

The average plasma creatinine concentration in low and high RFI group was 1.62 ± 0.10 and 1.21 ± 0.07 mg/dL, respectively, the concentration being greater ($P<0.05$) in low RFI group, indicating a significant ($P<0.05$) negative association of RFI with creatinine concentration. Plasma creatinine levels were found higher ($P<0.05$) in low RFI with respect to high RFI heifers (Lawrence *et al.* 2011). Similarly, Richardson *et al.* (2004) also observed a negative correlation of RFI with plasma creatinine level. As per Herd and Arthur (2009), there was a negative association of plasma creatinine concentrations with RFI in cattle. On the contrary, a positive relationship of RFI values with creatinine levels was found and the level of creatinine in low and high RFI group was 1.27 and 1.78 mg/dL respectively (Bhong *et al.* 2014).

Plasma AST: The average AST level in low and high RFI group was 102.25 ± 2.30 and 122.60 ± 2.48 (IU/L) respectively indicating a positive correlation between RFI values and AST level. Low concentration of AST was observed in heifers with low RFI (Lawrence *et al.*

2011). As per Bhong *et al.* (2014) AST concentration was significantly greater in high RFI group in male Sahiwal calves were significantly ($P<0.05$) higher in high RFI group when compared to low RFI group. The mean level of creatinine was 97.51 and 118.74 IU/L in low and high RFI groups, respectively, indicating a positive correlation between RFI and AST level as reported by Dudi *et al.* (2016).

Blood plasma hormones: Average IGF-1 levels in low and high RFI groups was 136.70 ± 1.48 and 120.38 ± 2.64 ng/mL, respectively which showed significant ($P<0.05$) negative correlation of RFI and IGF-1 as also reported by Moore *et al.* (2005) and Kahi and Hirooka (2007). The average GH level in low and high RFI group was 6.33 and 5.30 ng/mL, respectively indicating GH levels were statistically comparable in both groups which was also confirmed by Bhong *et al.* (2014). The mean cortisol level in low and high RFI group was 3.48 ± 0.14 and 5.32 ± 0.19 ng/mL, respectively implying that a high positive correlation of RFI with cortisol concentration which compliance with the results of Theis *et al.* (2002) and Knott *et al.* (2008). The mean Growth hormone level in low and high RFI group was 6.33 ± 0.34 and 5.30 ± 0.41 ng/mL, respectively.

In conclusion, a positive correlation of RFI with DMI was observed indicating that high RFI group consumed more DM than low RFI group for similar weight gain. The digestibility of DM, OM, NDF and ADF was significantly higher ($P<0.05$) in low RFI group indicating their negative correlation with RFI.

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