https://doi.org/10.56093/ijans.v90i10.111420

Indian Journal of Animal Sciences **90** (10): 1423–1429, October 2020/Article

Residual feed intake and related biochemical parameters in male Sahiwal calves

BHONG N BABAN[1], CHANDER DATT[2], PH. SURAJ SHARMA[3], KULDEEP DUDI[2] and VIJAY K SHARMA[4]✉

ICAR-National Dairy Research Institute, Karnal, Haryana 132 001 India

Received: 20 November 2019; Accepted: 10 February 2020

ABSTRACT

This study was conducted to evaluate the differences in efficiency of feed utilisation in Sahiwal calves with low and high residual feed intake (RFI) by comparing feed intake, nutrient digestibility, growth traits and blood biochemical parameters. Eighteen growing male Sahiwal calves (aged 12 months, average body weight 120.04 kg) were selected and fed individually total mixed ration as per their requirements for a period of 60 days. Fifty per cent of maize grains in concentrate mixture containing 33% maize grains were replaced by fresh potatoes (DM basis). Based on linear regression models involving dry matter intake (DMI), average daily gain (ADG) and mid test metabolic body size, calves were assigned into low and high RFI groups. Residual feed intake (RFI) values were calculated for individual calves and the calves were divided into low (–0.20) and high (+0.18) RFI groups. Low RFI animals consumed less dry matter than the expected or predicted one indicating their more efficiency of feed utilization. The intakes of DM and CP were 4.95 and 6.47% lower in low RFI animals compared to high RFI animals while average daily gain was higher in low RFI group. The digestibility of DM, OM, CP, EE, total carbohydrates, NDF and ADF were similar in low and high RFI groups, however, nitrogen retention was higher in low RFI group. Values of alanine amino transferase (25.85 vs. 35.72 IU/L), aspartate amino transferase (80.33 vs. 100.57 IU/L), total protein (7.34 and 8.24 mg/dL), blood urea nitrogen (15.45 and 22.22 mg/dL) and creatinine (1.27 and 1.78 mg/dL) were higher for high RFI as compared to low RFI group. The concentration of growth hormone, insulin and IGF-1 were similar in both the groups. From present study, it could be concluded that low RFI animals were more efficient in feed conversion.

Keywords: Biochemical parameters, Nutrient utilization, Residual feed intake, Sahiwal calves

Feed costs about 60–70% of total cost of production in bovines and improvement in feed efficiency will lead to reduction in input costs and increased profitability. Little attention has been given to improve feed efficiency and reducing feed cost while it is mainly focused on output traits (growth, milk production, fertility *etc*). Feed utilisation efficiency in farm animals calculated as a function of individual intake, body weight (BW) and weight gain can be appraised by several ways; one of them is gross feed efficiency. But, actions taken to improve gross feed efficiency can inadvertently lead to financial losses rather than gains (Gaines *et al.* 2012). This is due to the fact that single-minded actions taken to improve feed efficiency may affect other aspects of the enterprise and most important is the cost of feed. Gross feed efficiency also may reflect an animal's energy requirement for maintenance. In growing cattle, maintenance energy costs represent approximately 70–75% of the total annual energy requirements (ICAR 2013). Measurement of RFI gives more precise way of feed efficiency. By this measure, animals which eat less than expected have a negative RFI and are considered more efficient. It is expressed as the difference between actual feed intake and the feed an animal is expected to consume based on its body size and growth rate (Koch *et al*. 1963). Thus, RFI is a measure of the variation in feed intake beyond that which is needed for maintenance and growth requirements (Archer *et al.* 1999). Cattle identified as having low RFI have lower feed intakes and FCR when compared to cattle identified as having high RFI (Herd *et al*. 2002, Basarab *et al*. 2003) and have same level of production as high RFI cattle (Arthur *et al.* 2001, Nkrumah *et al*. 2007). Although negative consequences of selection for RFI are uncertain, like cattle selected for low RFI have shown small associations with a reduction in carcass fat content (Richardson *et al.* 2001). RFI can be used as a tool to identify the most efficient animals. Previous research reported that RFI influenced insulin and glucose concentrations in beef heifers (Yelich *et al.* 1996). Yambayamba *et al*. (1996) reported that serum concentrations of glucose, insulin, and IGF-I in beef heifers were elevated due to increased feed intake. Richardson *et al.* (2004) showed that RFI was correlated with blood concentrations of insulin, glucose, urea, leptin and

Present address: [1]Department of Animal Husbandry, Maharashtra. [2]ICAR-NDRI, Karnal, Haryana. [3]Saife Vet Med Private Ltd. India. [4]KVK Kathua, SKUAST-J, Jammu and Kashmir. ✉Corresponding author email: vjsharmandri@gmail.com

creatinine. Physiological changes can influence blood hormone and metabolite levels so the relationship of selected blood metabolites and hormones with RFI requires detailed investigation.

Accurate measurement of the RFI of cattle is time consuming, difficult and very expensive process to collect data on relatively large number of animals. By correlating with some biomarkers, we can differentiate between animal with high or low RFI within short period of time. So, it was pertinent to find out the differences in RFI in the different animals and study related biochemical parameters. This study compared the nutrient utilisation efficiency, growth performance and blood metabolites of Sahiwal calves during selection to identify individual calves with low RFI (more efficient calves) and high RFI (less efficient calves) and related biochemical parameters in male Sahiwal calves.

MATERIALS AND METHODS

The use of the animals and the experimental procedure were approved by the Institutional Animal Ethics Committee (IAEC).

Experimental site: Experiment was conducted at Livestock Research Centre, ICAR-NDRI, Karnal, Haryana, India situated at an altitude of 250 metre above mean sea level, latitude and longitude position being 29º 42′ N and 79º 54′ E, respectively. The maximum ambient temperature in summer goes up to 45ºC and minimum temperature in winter comes down to about 4ºC with a diurnal variation to the order of 15–20ºC. The average annual rainfall was 696 mm, most of which was received from early July to mid September**.**

Animals, management and feeding: Eighteen male Sahiwal calves of 12 months of age (average body weight =120.04 kg) were selected from Livestock Research Centre, ICAR-NDRI, Karnal, Haryana, India and housed in the experimental sheds of NDRI, Karnal with well ventilated individual pens to facilitate individual feeding. Proper cleanliness and healthy surroundings were ensured throughout the experimental period. Deworming of the animals was done before the start of feeding trial. All the animals were fed total mixed ration (TMR) comprising of green berseem (*Trifolium alexandrinum*) fodder, wheat straw and a concentrate mixture in a ratio of 40: 20: 40 to meet their nutrient requirements (NRC 2001). Concentrate mixture consisted of maize (*Zea mays*) grains 16.5%, potato (*Solanum tuberosum*) tubers 16.5%, soybean (*Glycine max*) meal 21%, mustard (*Brassica compestris*) oil cake 12%, wheat (*Triticum aestivum*) bran 20%, de-oiled rice (*Oryza sativa*) bran 6%, bajra 5%, mineral mixture 2% and common salt 1%. It is worth mentioning that 50% of maize grain was replaced by fresh potato on DM basis in the concentrate mixture. Refusals of feed were removed daily and weighed at 7:00 AM before supplying fresh feed for dry matter intake (DMI) calculation. All the animals were weighed at 9:00 AM at fortnightly intervals before giving access to feed and water. Clean and fresh drinking water was made accessible *ad lib.* twice daily at 11:00 h and 16:30 h. The feed offered was adjusted weekly to account for changes in DM and BW.

Metabolism study: A metabolism trial with an adaptation period of 4 d followed by a collection period of 7 d was conducted at the end of feeding trial. Animals were weighed before and after the trial consecutively for 2 days. Feeds were offered to meet their requirements. Fresh and clean drinking water was provided twice a day and the quantity was measured to calculate the total water intake. The feed, faecal and feed residue samples were dried at 65°C in hot air oven for two consecutive days and ground to pass through 1.0 mm sieve. Intake of feeds, output of faeces and urine were recorded daily for each animal. The faecal and urine samples were preserved using 25% H_2SO_4 for N estimation.

Laboratory analysis: The proximate principles (DM, OM, CP, EE and TA) and cell wall constituents (NDF and ADF) were determined in feeds, residues and faecal samples were determined using procedures of AOAC (2005) and Van Soest *et al.* (1991), respectively. Nitrogen content in faeces and urine samples were estimated (AOAC 2005). The digestibility coefficient of nutrient (DM, OM, CP, EE, total CHO, NDF and ADF) was calculated from the nutrient intake and nutrient outgo in faeces during metabolism trial as following:

$$\text{Digestibility [\%]} = \{(\text{Nutrient intake})[\text{kg}] - \text{Faecal excretion [kg]})/\text{Nutrient intake [kg]})\} \times 100$$

During 60 days of experimental period, blood samples (10 mL) were collected from all the animals by jugular puncture in heparinised vacutainer thrice (at the beginning, middle and end of feeding trial) and plasma was separated by centrifugation at 3,000 rpm for 15 min. The plasma samples were stored at –20°C for further estimation of different blood metabolites and hormones. The levels of total protein, glucose and BUN were estimated in blood plasma samples using GOD-POD kits (Span Diagnostics Ltd., India). The activity of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) in blood plasma was determined (Reitman and Frankel 1957). The concentration of creatinine was determined using an initial rate assay test kit (Span Diagnostics India, Ltd.). The concentration of plasma growth hormone was determined using Bovine GH ELISA test kit, Endocrine Technologies, New York, USA), insulin by Bovine Insulin ELISA test kit, Endocrine Technologies, New York, USA) and IGF-I by Bovine IGF-I ELISA test kit, Endocrine Technologies, New York, USA).

Calculation of residual feed intake: Growth of the Sahiwal calves was modelled by linear regression of body weight data against time and the regression coefficients were used to describe the growth of each animal (Archer *et al.* 1997).

The equation fitted was $Y_i = b_0 + b_1 x_i + e_i$

where Y_i, weight of the 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; e_i, error in weight at observation i.

The estimates of the regression coefficients obtained were used to calculate the average daily gain during the test and the mid-test metabolic body weight. Average DMI for the 60 days feeding period was regressed on mid-test metabolic BW ($BW^{0.75}$) and ADG (Archer *et al*. 1997, Kelly *et al*. 2010). 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 MBW. The base model used was:

$$Y_j = \beta_0 + \beta_1 MBW_j + \beta 2 ADG_j + e_j$$

where Y_j, DMI of the jth animal; β_0, regression intercept; β_1, regression coefficient on MBW; β_2, regression coefficient on ADG and e_j, uncontrolled error of the j^{th} animal (RFI).

The actual DMI minus the predicted DMI corresponded to the RFI meaning thereby that a more efficient animal had a negative RFI (observed feed intake was less than predicted feed intake) and a less efficient animal had a positive RFI (observed feed intake was greater than predicted feed intake).

Statistical analysis: The data were analyzed by general linear model procedure according to a complete randomized design using statistical software SPSS (version 16.0). Individual animals were considered as experimental units and RFI group as a fixed parameter. When ANOVA was significant (P<0.05), differences among means were examined by the Tukey 't' test.

RESULTS AND DISCUSSION

Chemical composition of diets, residual feed intake and nutrient intake: The chemical composition of feed/fodders used for the animal feeding are given in Table 1. After completition of 60 days, 18 growing male Sahiwal calves were divided into two groups, i.e. low and high RFI group (Fig. 1). The dots below line (Fig. 1) indicated that 9 animals were considered as low RFI animals whereas the dots above the line indicated that 9 animals were considered as high RFI animals. RFI value was –0.20 and 0.18 kg DM/d for low and high RFI, respectively (Table 2).

Table 1. Nutrient composition (% DM basis) of experimental diets

Item	Concentrate mixture	Potato tuber	Berseem fodder	Wheat straw
DM	88.20	16.52	17.50	88.91
CP	21.24	7.97	17.89	3.95
EE	4.14	1.99	2.81	2.08
NDF	41.54	28.27	43.49	77.26
ADF	21.55	9.04	24.46	53.34
TA	3.34	4.45	10.06	9.41

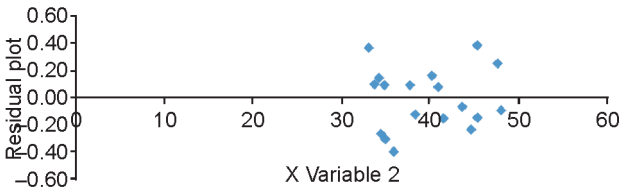

Fig. 1. Division of animals in low and high RFI groups

Table 2. Feed intake and feed conversion ratio in low and high RFI groups of Sahiwal calves

Parameter	Group	
	Low RFI	High RFI
No. of animals	9	9
RFI value	–0.20±0.07	0.18±0.08
Mean DMI (kg/d)	3.26±0.08	3.43±0.08
Mean DMI (kg/100 kg BW)	2.45[a]±0.10	2.77[b]±0.12
Initial body weight (kg)	124.23±14.78	115.85±15.83
Final body weight (kg)	154.89±16.91	144.20±18.09
Metabolic weight (kg $W^{0.75}$)	41.40±1.48	40.00±0.92
ADG (kg/d)	0.539±0.06	0.499±0.05
FCR (kg consumed/ kg of BW gain)	6.19±0.83	7.03±0.96

[a,b]Mean values bearing different superscripts in a column differ significantly (P<0.05).

The values of DMI during metabolic trial were 3.53 and 4.10 kg/d for low and high RFI groups, respectively (Table 4). It was found that low RFI group consumed 13.48% less DM than its requirement (NRC 2001) while high RFI group consumed 5.94% more DM than their expected. Also, the DMI (kg/100 kg BW/day) was lower (P<0.05) in low RFI (2.39) group compared to high RFI (2.63) group animals. The overall mean DMI during whole experimental period were 3.26±0.08 and 3.43±0.08 kg/d in low and high RFI groups, respectively (Table 2). Similar results of lower DMI in low RFI buffalo calves than that of high RFI group (1.9 kg/d vs 2.4 kg) has been reported (Sharma *et al*. 2016,

Table 3. Digestibility of nutrients (%) and nitrogen balance in low and high RFI groups of Sahiwal calves

Item	Group	
	Low RFI	High RFI
Nutrient digestibility		
DM	59.68±1.2	59.14±1.0
OM	61.38±3.6	60.61±1.4
CP	63.78±1.9	63.28±1.5
Total CHO	55.95±2.0	55.69±3.0
EE	64.43±4.1	63.18±1.5
NDF	55.84±3.9	54.62±2.3
ADF	44.01±4.8	42.96±2.3
Nitrogen balance		
N intake (g/d)	78.56[a]±1.22	83.80[b]±1.19
Faecal N (g/d)	30.90[a]±1.02	35.48[b]±1.21
Absorbed N (% of intake)	60.66[a]±1.43	57.66[b]±1.13
Urinary N (g/d)	28.70[a]±1.25	31.42[b]±1.24
Total N loss (g/d)	59.60[a]±2.27	66.90[b]±2.45
N balance (g/d)	18.96[a]±1.43	16.90[b]±1.26
% of intake N	24.13[a]±3.24	20.16[b]±2.29
% of absorbed N	31.81[a]±3.99	25.26[b]±2.98

[a,b]Means bearing different superscripts in the same row differ significantly (P < 0.05).

Table 4. Plane of nutrition of the animals in low and high RFI groups during metabolic trial

Item	Group	
	Low RFI	High RFI
Initial BW (kg)	148.26±7.8	138.32±8.4
Final BW (kg)	151.58±7.9	141.27±8.4
Average BW (kg)	149.92[a]±7.9	139.80[b]±8.4
DMI (kg/d)	3.53±0.15	4.10±0.17
NRC req. of DMI (kg/d)	4.08[a]±0.16	3.87[b]±0.16
Difference in actual intake and req.	–0.55[a]±0.06	0.23[b]±0.02
DMI (kg/100 kg BW)	2.39[a]±0.05	2.63[b]±0.05
CPI (kg/d)	0.491[a]±0.0058	0.525[b]±0.0047
NRC req. of CPI (kg/day)	0.531±0.010	0.518±0.010
Difference in actual intake and req.	–0.04±0.01	0.007±0.01
CPI (kg/100 kg BW)	0.327[a]±0.20	0.375[b]±0.02
DCP intake (kg/day)	0.350[a]±0.34	0.377[b]±0.36
DCP intake (kg/100 kg BW)	0.240[a]±0.35	0.252[b]±0.37
TDNI (kg/day)	2.19[a]±0.07	2.46[b]±0.04
NRC req. of TDN (kg/day)	2.46[a]±0.09	2.35[b]±0.10
Difference in actual intake and req.	–0.27[a]±0.05	0.11[b]±0.11
TDNI (kg/100 kg BW)	1.49[a]±0.05	1.83[b]±0.11
Total water intake (L/d)	24.88±1.30	24.60±0.94
Total water intake (L/kg DMI)	7.37±0.49	7.82±0.52

[a,b]Means bearing different superscripts in the same row differ significantly (P<0.05).

Sharma *et al*. 2018). There was high correlation among RFI and DMI, as most efficient animals consumed 16% less feed than the less efficient ones for the same performance (Lancaster *et al*. 2009, Chander *et al*. 2017). Arthur *et al.* (1999) and Richardson *et al.* (1998) reported that cattle with lower RFI at weaning required less feed intake as cows with same level of performance. Therefore, RFI could be used to improve feed efficiency without influencing growth and mature size of beef cattle. Herd *et al.* (2002) found that Angus cattle divergently selected for RFI attained the same growth rates but differ by approximately 15% in their voluntary feed intake. The low RFI steers consumed 17–19.1% less DM than high RFI steers (Gomez *et al.* 2007, Ribeiro *et al*. 2007). Golden *et al*. (2008) reported that low RFI steers ate fewer times and consumed less feed than high RFI steers. Cattle of low RFI consumed 0.335 and 0.705 kg/lesser DM/d than medium and high RFI animals, respectively (Basarab *et al*. 2003). Carstens *et al*. (2002) and Basarab *et al*. (2003) found differences in DMI between animals of low (21%) and high (12%) RFI. Also, Richardson *et al.* (2004) reported that the difference of the intake between two groups of animals (less and more efficient) was lower in magnitude (6%) which could be due to high metabolizability of consumed feed and the accompanying decreased need to energy intake required for growth and maintenance (Bose *et al.* 2014).

Intake of CP was also significantly higher (P<0.05) in high RFI Group compared to low RFI Group (Table 4) and it was observed that low RFI group consumed 7.53% less and high RFI group consumed 1.35% more CP than expected requirements (NRC 2001). Similar was the case with TDN intake, i.e. low RFI group consumed less than expected while high RFI groups consumed more than expected intake. Total water intake (L/d) was also observed during the trial and it was found 24.88 and 24.60 in low and high RFI groups, respectively.

Performance and efficiency measures: The digestibility values for DM, OM, CP, total CHO, EE, NDF and ADF were 59.68 and 59.14, 61.38 and 60.61, 63.78 and 63.28, 55.95 and 55.69, 64.43 and 63.18, 55.84 and 54.62 and 44.01 and 42.46% in low and high RFI group, respectively (Table 3) and they were similar in both the groups. The digestibility of DM between high and low RFI was similar (Cruz *et al*. 2010). Nkrumah *et al*. (2006) showed that RFI tended to be negatively associated (P<0.10) with apparent digestibility of DM (r=–0.33) and CP (r=–0.34). Animal variation in RFI is associated with variation in apparent nutrient digestibility. Heifers with low RFI consumed 23% less DMI and had 20% lower feed: gain ratios than heifers with high RFI. Nkrumah *et al*. (2006) reported that apparent digestibility in low and high RFI group was 70.87 and 75.33% for DM, 69.76 and 74.70% for CP, 17.29, 31.49% for NDF and 3.26 and 14.67% for ADF. The low-RFI Brangus heifers fed a roughage based diet had 3% higher apparent digestibility than Brangus heifers with high RFI (Krueger *et al*. 2009). The low RFI Angus heifers and bulls tended to show a higher DM digestibility compared to high RFI Angus bulls and heifers (Richardson *et al*. 1996) and RFI was negatively correlated with DM, NDF, ADF and CP digestibility. Heifers with low RFI had higher DM, NDF, ADF and CP digestibility.

The data on intake, absorption, excretion and retention of N in low and high RFI groups have been presented in Table 3. The intake of N, N voided in faeces and urine and total N loss was lower (P<0.05) in low RFI group but N retention (% of N intake and N absorbed) was higher (P<0.05) in low RFI group than the high RFI group. Negative RFI cows would have greater apparent digestibility of N than the positive RFI animals. Intakes of N did not differ between negative RFI and positive RFI cows (Richardson *et al.* 1996). Negative RFI cows had a greater apparent N digestibility (77.2 vs. 75.5%) and a tendency toward greater DM and OM digestibility. The negative RFI cows had a lower faecal N output (126 vs. 138 g/d) and a lower partition of feed N to faecal N (23.1 vs. 24.7%) compared with positive RFI animals (Richardson *et al*. 1996). Urinary N as well as daily urine production was similar in low and high RFI animals (Nkrumah *et al.* 2006, Bose *et al*. 2014).

The ADG was 0.539 and 0.498 kg in low and high RFI groups, respectively which was similar in both the groups. Basarab *et al.* (2003) found that low RFI steers consumed 10.4% less and had a 9.4% lower FCR with no differences

in BW or ADG. Almeida *et al*. (2004) reported that animals such as Nellore heifers of 26 months of age of high RFI consumed 26% more than the most efficient cattle but the ADG was similar (1.3 kg/d). Basarab *et al*. (2003) reported that there was no significant relationship between RFI and ADG indicating that variation in RFI reflected animal's maintenance requirements rather than growth, size and appetite. Kelly *et al*. (2010) also showed that was no significant difference in ADG for high RFI (1.52 kg) and low-RFI (1.54 kg) groups of animals. The relationship between RFI and FCR indicated that low RFI animals consumed less feed for each kg gain in BW than the high RFI group (Fig. 2). Hegarty *et al*. (2007) observed no difference in ADG between low and high RFI steers although low RFI steers ate 41% less DM each day and expressed improved feed conversion efficiency relative to high RFI steers. Homm *et al*. (2007) reported that ADG and body weight during the test period was not correlated to RFI in crossbred steers. Nkrumah *et al.* (2006) observed that ADG for high RFI, medium RFI, and low-RFI groups were 1.46±0.20, 1.51±0.16 and 1.48±0.16, respectively, which was similar among all the groups. It was observed that FCR was higher for high RFI group as compared to low RFI group. The data (Table 2) clearly indicated that feed conversion efficiency of high RFI group is lower than low RFI group, i.e. high RFI group animals are less efficient as compared to low RFI group. Negesse *et al*. (2016) also reported lower FCR for low RFI group compared to high RFI group. Kelly *et al*. (2010) reported that there was significant difference (P<0.05) in FCR between high RFI (4.86) and low-RFI (4.04) groups. Nkrumah *et al.* (2006) also showed significant difference (P<0.05) in FCR for high and low-RFI group of animals. Arthur *et al*. (2001) concluded that RFI intake was genetically and phenotypically correlated with feed intake and FCR but not with ADG.

Blood metabolites: The means of all blood variables (Table 5) studied were within the normal range reported for cattle by Kaneko *et al.* (1997) and Dias *et al.* (2006). Blood glucose values similar (P<0.05) in both the groups. Sharma *et al*. (2014) also reported similar values of blood glucose level in low (60.48 mg/dL) and high (59.52 mg/dL) RFI growing male Sahiwal calves while Kolath *et al.* (2006) observed that high RFI steers had greater

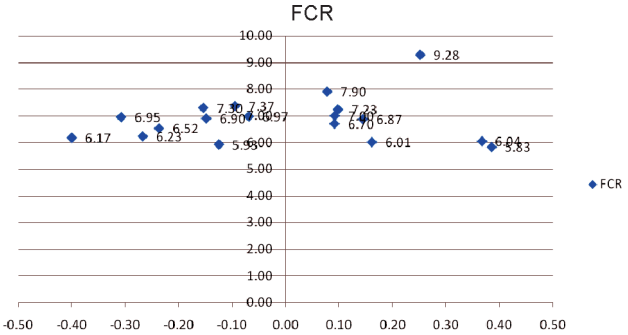

Fig. 2. Feed conversion ratio in low and high RFI groups of Sahiwal calves

Table 5. Blood biochemical and physiological parameters in low and high RFI groups

Parameter	Group	
	Low RFI	High RFI
Insulin (ng/mL)	1.37±0.27	1.47±0.36
IGF-I (ng/mL)	1.08±0.007	1.11±0.003
GH (ng/mL)	4.53±0.12	4.24±0.12
ALT (IU/L)	25.85[a]±1.21	35.72[b]±1.18
AST (IU/L)	80.33[a]±2.91	100.57[b]±1.63
Blood metabolites		
Glucose (mg/dL)	60.48±0.99	59.52±1.07
Creatinine (mg/dL)	1.27[a]±0.01	1.78[b]±0.01
Total protein (g/dL)	7.34[a]±0.20	8.24[b]±0.23
BUN (mg/dL)	15.45[a]±1.23	22.22[b]±1.21

[a,b]Means bearing different superscripts in the same row differ significantly (P < 0.05).

concentrations of glucose in their blood. Richardson *et al.* (2004) found that at the beginning of the RFI test period, plasma glucose concentrations were positively correlated with RFI in Angus steers. Kelly *et al.* (2010) observed that circulating glucose was not associated with RFI. The concentration of creatinine (mg/dL) was 1.27 and 1.78 and for BUN (mg/dL) were 15.45 and 22.22 mg/dL, respectively in low and high RFI groups and these were higher (P<0.05) in high RFI group compared to low RFI group. The concentration of total protein in blood plasma averaged 7.34 and 8.24 g/dL in low and high RFI groups, respectively and these values being higher (P<0.05) in high RFI group. Richardson *et al.* (1996) also demonstrated a significant increase in total plasma protein in high RFI steers compared to low RFI steers (70.05 vs. 65.20 g/L). Richardson *et al.* (2004) found greater blood concentrations of urea in less efficient genotypes. This may be due to greater protein intake in high-RFI animals, a greater rate of body protein degradation, or deviation in the supply of AA due in part to variation in the efficiency of microbial protein production in the rumen (Lush *et al.* 1991, Kahn *et al*. 2000). Harvey *et al*. (1993) observed that inefficient steers (high RFI) had greater concentrations of serum urea nitrogen compared to efficient steers (low RFI) during the finishing phase. Carstens *et al.* (2002) also found a higher concentration of BUN in high RFI steers.

The values for ALT activity were 25.85 and 35.72 IU/L in low and high groups with corresponding values of 80.33 and 100.57 IU/L for AST. The levels of these enzymes were higher (P<0.05) in high RFI group compared to low RFI group of Sahiwal calves. The plasma insulin level was 1.37 and 1.47 ng/dL in low and high RFI group, respectively with corresponding values of 1.08 and 1.11 ng/mL for IGF-I. The values of IGF-1 were higher (P<0.05) in calves of low RFI groups (Dudi and Chander Datt 2015). Brown *et al.* (2004) found a positive correlation between IGF-1 and RFI in which low RFI steers and bulls had 29 and 25% lower concentrations of serum IGF-I compared to high RFI

(> 0.5 SD) steers and bulls. However, Richardson *et al*. (1996) found no significant differences in concentrations of IGF-I between high and low RFI cattle. Results in beef cattle showed that circulating levels of IGF-1 are genetically associated with growth and finishing performance of beef cattle and may prove useful as a genetic predictor of carcass and feed efficiency traits (Johnston *et al.* 2001, 2002; Herd *et al*. 2002). A genetic and economic evaluation of the use of IGF-1 as an indirect selection criterion in beef cattle showed that it can increase the profitability of selection decisions and would best used as a screening test to identify animals to be placed into RFI tests in a two-stage selection program (Wood *et al.* 2002). The GH concentration was 4.53 and 4.24 ng/mL in the respective groups. Walker *et al.* (2010) documented there were no significant main effects of glucose, insulin for the low, medium, and high RFI group of cattle.

Calves of low RFI group consumed less feed than high RFI group whereas no differences existed for the average daily gain. Therefore, selection of low RFI animals would be expected to result in reduced feed inputs without altering growth rate and daily weight gain. However, a significant association was found between some plasma biochemical parameters and RFI. Thus, it is likely that measurement of these metabolic indicators (alanine amino transferase, aspartate amino transferase, total protein, blood urea nitrogen and creatinine) will be useful in the early identification of efficient animals. Therefore, selection of animals based on RFI would be an effective tool in livestock production system.

ACKNOWLEDGEMENT

The authors are thankful to the Director, ICAR-National Dairy Research Institute, Karnal, Haryana, India for providing necessary facilities to carry out this research work.

REFERENCES

Almeida R, Lanna D P D and Leme P R. 2004. Residual feed intake: a new trait to evaluate beef cattle efficiency. *Proceedings of the 41th Annual Meeting of the Brazilian Society of Animal Science.* Campo Grande, Brazil **41**: 3–14.

AOAC. 2005. *Official Methods of Analysis*. Association of Official Analytical Chemists. 18th edn. Arlington, Washington, DC, USA.

Archer J A, Arthur P F, Herd R M, Parnell P F and Pitchford W S. 1997. Optimum post-weaning test for measurement of growth rate, feed intake and feed efficiency in British breed cattle. *Journal of Animal Science* **75**: 2024–32.

Archer J A, Richardson E C, Herd R M and Arthur P F. 1999. Potential for selection to improve efficiency of feed use in beef cattle: a review. *Australian Journal of Agricultural Research* **50**: 147–61.

Arthur P F, Archer J A, Herd R M, Richardson E C, Exton S C, Oswin C, Dibley K C P and Burton D A. 1999. Relationship between post-weaning growth, net feed intake and cow performance. *Proceedings of 13th Animal Breeding Genetics. Symposium*, Mandurah, WA, Australia. pp. 484–87.

Arthur P F, Archer J A, Johnston D J, Herd R M, Richardson E C and Parnell P F. 2001. Genetic and phenotypic variance and covariance components for feed intake, feed efficiency and other post weaning traits in Angus cattle. *Journal of Animal Science* **79**: 2805–11.

Basarab J A, Price M A, Aalhus J L, Okine E K, Snelling W M and Lyle K L. 2003. Residual feed intake and body composition in young growing cattle. *Canadian Journal of Animal Sciences* **83**: 189–204.

Bose B K S, Kundu S S, Tho N T B, Sharma V K and Sontakke U B. 2014. Residual feed intake as a feed efficiency selection tool and its relationship with feed intake, performance and nutrient utilization in Murrah buffalo calves. *Tropical Animal Health and Production* **46**: 615–21.

Brown E G, Carstens G E, Fox J T, White M B, Curley K O, Bryan T M, Slay L J, Welsh T H, Randel R D, Holloway J W and Keisler D H. 2004. Physiological indicators of performance and feed efficiency traits in growing steers and bulls. *Beef Cattle Res Tex.* 163–66.

Carstens G E, Theis C M, White M B, Welsh T H, Warrington B G, Randel R D, Forbes T D A, Lippke H, Greene L W and Lunt D K. 2002. Residual feed intake in beef steers: I. Correlation with performance traits and ultrasound measures of body composition. *Proceedings of West American Society of Animal Science* **53**: 552–55.

Chander Datt, Sharma V K, Dudi K, Nana B B, Sharma Ph S, Negesse T, Kundu S S, Datta M M, Gupta R and Singh D. 2017. Residual feed intake as a tool for selecting more efficient animals: A Review. *Indian Journal Animal Nutrition* **34**: 238–55.

Cruz G D, Rodríguez-Sánchez J A, Oltjen J W and Sainz R D. 2010. Angus-Hereford steers housed in individual or group pens performance, residual feed intake, digestibility, carcass traits and profitability. *Journal of Animal Science* **88**: 324–29.

Dias R F, Bracarense A P F R L, Marcal W S, Rocha M A and Dias R C F. 2006. Reference values and age effect on the erythrogram of bovine females of the Aquitania breed. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia* **58**: 311–15.

Dudi K and Chander Datt. 2015. Relationship of residual feed intake with blood metabolites and hormones in Sahiwal female calves. *Forage Research* **41**: 40–45.

Gaines A M, Peterson B A and Mendoza O F. 2012. Herd management factors that influence whole herd feed efficiency. *Feed Efficiency in Swine.* (Ed.) Patience J F. Wageningen Academic Press, Wageningen. pp. 15–39.

Golden J W, Kerley M S and Kolath W H. 2008. The relationship of feeding behavior to residual feed intake in crossbreed Angus steers fed traditional and no roughage diets. *Journal of Animal Science* **86**: 180–86.

Gomez R R, Bourg B M, Paddock Z D, Carstens G E, Lancaster P A, Miller R K, Tedeschi L O, Lunt D K, Moore S A and Delaney D S. 2007. Evaluation of feed efficiency in Santa Gertrudis steers and relationship with temperament and feeding behavior. *Journal of Animal Science* **85**: 454–55.

Harvey R W, Armstrong J D, Heimer E P and Campbell R M. 1993. Feedlot performance, carcass characteristics, hormones, and metabolites in steers actively immunized against growth hormone releasing factor. *Journal of Animal Science* **71**: 2853–59.

Hegarty R S, Goopy J P, Herd R M and Mc-Corkell B. 2007. Cattle selected for lower residual feed intake have reduced daily methane production. *Journal of Animal Science* **85**: 1479–86.

Herd R M, Arthur P F, Archer J A and Johnston D J. 2002. IGF-I is associated with genetic variation in key production traits in young Angus cattle. *Animal Production Australia* **24**: 313.

Homm J W, Berger L L and Rodriguez-Zas S L. 2007. Factors affecting residual feed intake in feedlot steers. *Journal of Animal Science* **85**: 454.

ICAR. 2013. *Nutrient Requirements of Cattle and Buffalo*. 1st edn. Indian Council of Agricultural Research, New Delhi, India.

Johnston D J, Herd R M, Kadel M J, Graser H U, Arthur P F and Archer J A. 2002. Evidence of IGF-I as a genetic predictor of feed efficiency traits in beef cattle. *Proceedings of 7th World Congress Genetics Applied Livestock Production,* Montepellier, France.

Johnston D J, Herd R M, Reverter A and Oddy V H. 2001. Heritability of IGF-I in beef cattle and its association with growth and carcase traits. *Proceedings of Association of Advancement of Animal Breeding and Genetics, New Zealand* **14**: 163–66.

Kahn L P, Leng R A and Piper L R. 2000. Rumen microbial yield from sheep genetically different for fleece weight. *Asian Australasian. Journal of Animal Science* **13**: 137.

Kaneko J J, Harvey J W and Bruss M L. 1997. *Clinical Biochemistry of Domestic Animals*. San Diego Academy Press, USA. p. 606.

Kelly A K, Mc-Gee M, Crews Jr D H, Sweeney T, Boland T M and Kenny D A. 2010. Repeatability of feed efficiency, carcass ultrasound, feeding behavior and blood metabolic variables in finishing heifers divergently selected for residual feed intake. *Journal of Animal Science* **88**: 3214–25.

Koch R M, Swiger L A, Chambers D and Gregory K E. 1963. Efficiency of feed use in beef cattle. *Journal of Animal Science* **22**: 486–94.

Kolath W H, Kerley M S, Golden J W and Keisler D H. 2006. The relationship between mitochondrial function and residual feed intake in Angus steers. *Journal of Animal Science* **84**: 861–65.

Krueger W K, Carstens G E, Lancaster P A, Slay L J, Miller J C and Forbes T D A. 2009. Relationships between residual feed intake and apparent nutrient digestibility in growing calves. *Journal of Animal Science* **86**: 758–63.

Lancaster P A, Carstens G E, Riberio F R B, Tedeschi L O and Crews DH Jr. 2009. Characterization of feed efficiency traits and relationships with feeding behavior and ultrasound carcass traits in growing bulls. *Journal of Animal Science* **87**: 1528–39.

Lush J M, Gooden J M and Annison E F. 1991. The uptake of nitrogenous compounds from the gut of sheep genetically different in wool production. *Proceedings of Nutrition Society of Australia* **16**: 144.

Negesse T, Chander Datt and Kundu S S. 2016. Variability in residual feed intake and nutrient utilization in Murrah buffalo heifers. *Tropical Animal Health and Production* **48**: 1577–84.

Nkrumah J D, Basarab J A, Wang Z, Li C, Price M A, Okine E K, Crews Jr D H and Moore S S. 2007. Genetic and phenotypic relationships of feed intake and different measures of feed efficiency with growth and carcass merit of beef cattle. *Journal of Animal Science* **85**: 2711–20.

Nkrumah J D, Okine E K, Mathison G W, Schmid K, Li C, Basarab J A, Price M A, Wang Z and Moore S S. 2006. Relationships of feedlot feed efficiency, performance, and feeding behaviour with metabolic rate, methane production and energy partitioning in beef cattle. *Journal of Animal Science* **84**: 145–53.

NRC. 2001. *Nutrient Requirements of Dairy Cattle*. 7th rev. edn. National Research Council, National Academy Press, Washington, DC, USA.

Reitman S and Frankel S. 1957. A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic transaminases. *American Journal of Clinical Pathology* **28**: 56–63.

Ribeiro F R B, Carstens G E, Lancaster P A, Tedeschi L O and Davis M E. 2007. Relationship of feed efficiency with carcass and non-carcass tissue composition in Angus bulls and heifers. *Journal of Animal Science* **85**: 455–87.

Richardson E C and Herd R M. 2004. Biological basis for variation in residual feed intake in beef cattle. 2. Synthesis of results following divergent selection. *Australian Journal of Experimental Agriculture* **44**: 431–40.

Richardson E C, Herd R M, Archer J A, Woodgate R T and Arthur P F. 1998. Steers breed for improved net feed efficiency eat less for the same feedlot performance. *Proceedings of Australian Society of Animal Production* **22**: 213–16.

Richardson E C, Herd R M, Arthur P F, Wright J, Dibley G, Xu and Oddy V H. 1996. Possible physiological indicators for net feed conversion efficiency in beef cattle. *Proceedings of Australian Society of Animal Production* **21**: 103–06.

Richardson E C, Herd R M, Oddy V H, Thompson J M, Archer J A and Arthur P F. 2001. Body composition and implications for heat production of Angus steer progeny of parents selected for and against residual feed intake. *Australian Journal of Experimental Agriculture* **41**: 1065–72.

Sharma V C, Mahesh M S, Mohini M, Chander Datt and Nampoothiri V M. 2014. Nutrient utilization and methane emissions in Sahiwal calves differing in residual feed intake. *Archieves of Animal Nutrition* **68**: 345–57.

Sharma V K, Kundu S S, Chander Datt, Prusty S, Kumar M and Sontakke U B. 2018. Buffalo heifers selected for lower residual feed intake have lower feed intake, better dietary nitrogen utilisation and reduced enteric methane production. *Journal of Animal Physiology and Animal Nutrition* **102**: 607–14. https://doi.org/10.1111/jpn.12802

Sharma V K, Kundu S S, Prusty S, Chander Datt and Kumar M. 2016. Nutrient utilisation, growth performance and blood metabolites in Murrah buffalo calves (*Bubalus bubalis*) divergently selected for residual feed intake. *Archieves of Animal Nutrition* **70**: 455–69.

SPSS. 2010. *Statistical Package for Social Sciences*. version 16.0., Chicago, IL, USA.

Van Soest P J, Robertson J B and Lewis B A. 1991. Methods for dietary fibre, neutral detergent fibre and non starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science* **74**: 3583–97.

Walker D K, Titgemeyer E C, Baxa T J, Chung K Y, Johnson D E, Laudert S B and Johnson B J. 2010. Effects of ractopamine and sex on serum metabolites and skeletal muscle gene expression in finishing steers and heifers. *Journal of Animal Science* **88**: 1349–57.

Wood B J, Archer J A and Van der Werf J H J. 2002. Genetic and economic evaluation of the use of IGF-1 as an indirect selection criterion in beef cattle. *Proceedings of 7th World Congress of Genetics and. Applied Livestock Production*. Montpellier, France. Communication No. 02–26.

Yambayamba E S K, Price M A and Foxcroft G R. 1996. Hormonal status, metabolic changes, resting metabolic rate in beef heifers undergoing compensatory growth. *Archieves of Animal Nutrition* **74**: 57–60.

Yelich J V, Wettemann R P, Marston T T and Spicer L J. 1996. Luteinizing hormones, growth hormone, insulin-like growth factor-I, insulin and metabolites before puberty in heifers fed to rates of gain. *Domestic Animal Endocrinology* **13**: 325–38.