Association between Residual Feed Intake and Some Biochemical Metabolites of Growing Hamari Lambs

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Abstract

Background

Recently the use of residual feed intake (RFI) trait for the identification of animal that are more efficient in feed utilization has received much attention from scientist. Since basal metabolic processes are responsible for a large proportion of energy requirements; blood metabolites that reflect the workload placed on them may give indication of differences in animal efficiency. The objectives of this study were to estimate the differences in growth performance, some blood metabolites indices in growing Hammari lambs selected for high, medium and low residual feed intake (RFI). Moreover, correlation between RFI, feed conversion ratio (FCR), gross feed efficiency (GFE) and some blood indices was carried out.

Results

The results indicated there were no significant differences among RFI classes for initial BW ($P = 0.69$) final BW ($P = 0.84$) and ADG ($P = 0.51$). Significant differences among RFI classes were observed for DM intake, RFI ($P = 0.001$), FCR ratio ($P = 0.01$), and GFE ($P = 0.03$). Low RFI animals consumed, on average, 0.62 kg/d DM less than high RFI animals. Low and med RFI animals had lower serum total protein ($P=0.01$), globulin ($P=0.01$), urea ($P=0.02$), and aspartate aminotransferase (AST) ($P=0.01$) levels than high RFI. A comparison of serum creatinine among RFI groups showed that the med and the low RFI groups had higher concentration than high RFI group. There were associations between RFI and the serum metabolites for total protein ($rRFI = 0.44$), globulin ($rRFI = 0.31$), urea ($rRFI = 0.40$), AST ($rRFI = 0.76$) and HDL ($rRFI = 0.50$). Also, associations between FCR and serum globulin ($rFCR = 0.31$) and AST ($rFCR = 0.41$) were detected. Results for serum mineral concentrations showed no significant ($P>0.05$) differences among RFI classes. The same trend was observed to results of correlation between mineral metabolites and RFI, except for phosphorus, which was positively correlated with RFI ($rRFI = 0.32$).

Conclusion

The study concluded that the low RFI animals had less concentration of serum total protein, globulin, urea, AST and HDL. All these measures showed that low RFI animals were more efficient in feed utilization, than high RFI animals.

Background

Sheep in Sudan constitute about 37% of total livestock numbers [1]. They are bred mainly for meat production, having a role in food security, highly demanded in local market and abroad. Sudanese sheep classified into four distinct ecotypes according to locality, one of these ecotypes Sudan desert sheep, which constitute 65% of sheep population in the country [2]. There are many sub types of Sudanese desert sheep in Kordofan state, and the major sub types Kabbashi and Hamari considered as a prototype of export [3].

The trend for rising costs associated with raising sheep have been decreasing profit margins in sheep industry, preventing expansion [4]. Decreasing inputs would increase the profitability of sheep production through the minimization of input costs since feed provision is one of the greatest costs of production [5]. Small improvements in feed efficiency can reduce the cost of gain considerably since the price of feed comprises 70 to 80% of the total gain cost [6]. Feed efficiency is an economically important trait for the animal feeder. It has been determined that a 5% improvement in feed efficiency is equivalent to any one of the following, reducing ration costs on a dry matter basis by \$8 per ton, reducing purchase costs of the feeder animal by \$1.75 cwt or increasing daily gain by 0.6 lbs per day [6].

The feed efficiency animals have an important influence on production and promote industry competitiveness that provides the potential to identify and select animals with high ability to convert feed into animal products [7]. The concept of residual feed intake (RFI) is one of tools that use to calculate the feed efficiency of growing animals. RFI is difference between observed feed intake and expected feed intake based on estimated maintenance and production requirements [8].

Animals classified as more efficient would be represented by a low RFI since they eat less than expected for the same growth while high RFI would be considered inefficient since they have intakes that are greater than expected. This feed efficiency trait represents variations in the requirements for basic metabolic processes rather than variations due to differences in level of production [9, 10, 11]. These requirements for background metabolic processes represent 60 to 70% of total energy expenditures [12] with a large proportion of individual variation due to differences in visceral organ metabolism [10, 13]. There is no phenotype link between RFI and characteristics used to calculate expected feed intake, which allows for comparison of animals that function at differing production numbers. This has led some authors to believe that RFI is representative of individual differences in metabolic processes of the animals [14]. Searching for physiological parameters such as blood becomes useful in better understanding the possible physiological variation in efficiency of diet use among individuals. Globally for sheep, there are few studies on feed efficiency from RFI [15, 16, 17].

Sudan has no previous studies on animal feed efficiency from RFI for different kind of animals. Therefore, the study was designed to evaluate the potential differences in feedlot performance, some blood metabolites of Hamari lambs classified into feed efficiency groups according to the RFI. Moreover, correlation studies between feed efficiency represented by RFI, FCR, GFE, and some blood parameters of Hamari lambs were calculated.

Results

Performance traits and Residual feed intake:

The results from present study indicated that all animals consumed a mean of 1.21 kg of ration (DM) per day during the study period; these values were close to range that reported by NRC [18].

During the residual feed intake (RFI) determination period, lambs in the low RFI group (16 animals) consumed on average, 0.62 kg/d DM less feed than lambs in the high RFI group (10 animals), showing there is 14.28% variation in consumption between high and low RFI classes. No significant differences among RFI classes were observed for body weight (BW) at the beginning ($P = 0.69$) and at the end ($P = 0.84$), or ADG ($P = 0.51$) during the tested period (Table 1). With respect to the other efficiency measures studied, significant differences among RFI classes were observed for RFI ($P = 0.001$), FCR ($P = 0.01$), and GFE ($P = 0.032$). All these measures showed that low RFI animals were more efficient in feed utilization than medium (13 animals) and high RFI animals.

Table 1
Means and SEM of performance traits and feed efficiency of Hamari lambs of different residual feed intake (RFI) classes

Parameters	RFI classes						P-Value	Sig.
	High(n=10)	SEM	Med(n=13)	SEM	Low(n=16)	SEM		
Initial BW(Kg)	26.77	1.17	26.00	0.93	27.18	0.93	0.69	NS
DMI _{obs} (Kg/day)	1.28 ^a	0.004	1.24 ^b	0.003	1.12 ^c	0.002	0.001	**
ADG (Kg/day)	0.19	0.01	0.20	0.01	0.21	0.01	0.51	NS
RFI (Kg/day)	0.34 ^a	0.05	0.09 ^b	0.04	-0.28 ^c	0.04	0.001	**
Final BW(Kg)	44.50	1.49	44.15	1.30	45.16	1.18	0.84	NS
GFE	0.16 ^c	0.01	0.17 ^{ab}	0.01	0.18 ^a	0.01	0.03	*
FCR	6.87 ^a	0.35	6.35 ^a	0.31	5.47 ^b	0.28	0.01	*
BW: body weight, DMI _{obs} : observed dry matter intake, ADG: average daily gain, RFI: residual feed intake, GFE: Gross feed efficiency and FCR: Feed conversion ratio. ^{a-c} Means with different superscripts within a row are significantly different based on LSD comparison test ($P \leq 0.05$). NS: Non-Significant difference ($P > 0.05$). *: Statically significant ($P \leq 0.05$). SEM: standard error of means. P: probability, Sig.: significance.								

Residual feed intake and blood metabolite parameters:

The high RFI lambs significantly had a greater concentration of total serum protein ($P=0.01$), globulin ($P=0.01$), urea ($P=0.02$) and aspartate aminotransferase (AST) ($P=0.01$) than the lambs with a low RFI (Table 2). A comparison of serum creatinine concentrations among RFI groups showed that the med and the low RFI groups had higher concentration than high RFI group. While, no significant ($P>0.05$) differences were found among RFI classes for serum creatine kinase enzyme (Table 2).

Table 2
Means and SEM of serum protein metabolites and some enzymes for Hamari lambs of different residual feed intake (RFI) classes

Parameters	RFI classes						P-Value	Sig
	High(n=10)	SEM	Med(n=13)	SEM	Low(n=15)	SEM		
Total protein (mg/dl)	5.79 ^a	0.08	5.37 ^b	0.07	5.37 ^b	0.07	0.01	*
Albumin (mg/dl)	3.18 ^a	0.04	3.10 ^{ab}	0.04	3.03 ^b	0.04	0.05	*
Globulin (mg/dl)	2.64 ^a	0.11	2.22 ^b	0.09	2.22 ^b	0.09	0.01	*
Urea (mg/dl)	62.70 ^a	2.48	55.85 ^b	2.72	52.93 ^b	2.02	0.02	*
Creatinine (mg/dl)	0.64 ^b	0.06	0.79 ^a	0.05	0.92 ^a	0.01	0.002	**
AST (U/L)	162.90 ^a	10.29	120.35 ^b	9.02	124.07 ^b	8.41	0.01	*
CK (U/L)	116.60	10.04	105.46	8.81	100.20	8.20	0.45	NS
AST: Aspartate transaminase, CK: creatine kinase. ^{a-b} Means with different superscripts within a row are significantly different based on LSD comparison test ($P \leq 0.05$). NS: Non-Significant difference ($P > 0.05$). *: Statically significant ($P \leq 0.05$). SEM: standard error of means. P: probability, Sig.: significance.								

RFI was positively correlated with the concentrations of total serum protein, urea ($P=0.01$) and globulin ($P=0.05$), but negatively with creatinine level ($P=0.02$). Although, FCR was positively correlated with total serum protein ($P=0.05$) and AST ($P=0.001$), the GFE was negatively correlated with AST ($P=0.03$) (Table 3).

Table 3
Person correlation coefficients (n=38) of blood biochemical components with residual feed intake (r_{RFI}), feed conversion ratio (r_{FCR}) and gross feed efficiency (r_{GFE}).

Parameters	r_{RFI}	P	r_{FCR}	P	r_{GFE}	P
Total protein	0.44*	0.01	0.32*	0.05	-0.30	0.06
Albumin	0.17	0.30	-0.004	0.98	-0.001	0.90
Globulin	0.31*	0.05	0.12	0.47	-0.18	0.28
Urea	0.40*	0.01	0.17	0.30	-0.24	0.15
Creatinine	-0.37*	0.02	-0.08	0.62	0.14	0.40
AST	0.25	0.13	0.52**	0.001	-0.35*	0.03
CK	0.14	0.42	0.28	0.09	-0.08	0.65
AST: Aspartate transaminase, CK: Creatinine Kinase. *: Statically significant ($P \leq 0.05$). **: Statically significant ($P \leq 0.001$).						

Residual feed intake and lipids profile:

Table 4 shows the influence of RFI status on serum lipids profile. The results showed that there were no significant ($P > 0.05$) differences on all lipid parameters among RFI classes, with the exception to total lipids ($P = 0.05$) and HDL ($P = 0.04$) which were significantly different between high RFI and low RFI. A positive correlation was found between RFI and HDL ($P = 0.002$) and the most efficient (LRF) animal showed the lowest concentration (Table 5).

Table 4
Means and SEM of lipid metabolites for Hamari lambs of different residual feed intake (RFI) classes

Parameters	RFI classes						P-Value	Sig
	High(n=10)	SEM	Med(n=13)	SEM	Low(n=15)	SEM		
Total lipids (mg/dl)	23.57 ^a	1.56	21.85 ^{ab}	1.36	18.67 ^b	1.27	0.05	*
HDL (mg/dl)	28.80 ^a	1.33	27.40 ^{ab}	1.17	24.47 ^b	1.10	0.04	*
LDL (mg/dl)	19.55	0.72	19.92	0.63	19.53	0.59	0.89	NS
Cholesterol (mg/dl)	52.20	2.30	47.92	2.02	46.71	1.88	0.18	NS
Triglycerides (mg/dl)	29.60	1.31	27.39	1.16	27.00	1.08	0.29	NS
HDL: High Density Lipoprotein. LDL: Low Density Lipoprotein. ^{a-b} Means with different superscripts within a row are significantly different based on LSD comparison test ($P \leq 0.05$). NS: Non-Significant difference ($P > 0.05$). *: Statically significant ($P \leq 0.05$). SEM: standard error of means.								

Table 5
Person correlation coefficients (n=38) of lipid biochemical components with residual feed intake (r_{RFI}) and feed conversion ratio (r_{FCR}) and gross feed efficiency (r_{GFE}).

Items	r_{RFI}	P	r_{FCR}	P	r_{GFE}	P
Total lipids	0.30	0.07	0.04	0.81	-0.09	0.61
HDL	0.52**	0.001	0.18	0.27	-0.32*	0.05
LDL	0.08	0.65	0.21	0.21	-0.23	0.16
Cholesterol	0.22	0.19	0.12	0.46	-0.12	0.46
Triglycerides	0.23	0.17	-0.11	0.51	0.08	0.65
HDL: High Density Lipoprotein, LDL: Low Density Lipoprotein.						
*: Statically significant ($P \leq 0.05$).						

Residual feed intake and serum minerals profile:

Results for serum mineral concentrations were presented in Table 6, there was no significant ($P > 0.05$) differences among RFI classes. Moreover, the same trend was observed to results of correlation between mineral metabolites and efficiency traits, with exception for phosphorus ($P = 0.05$) which was correlated positively with RFI (Table 7).

Table 6
Means and SEM of macro-minerals profile for Hamari lambs of different residual feed intake (RFI) classes

Items	RFI classes						P	Sig
	High(n=10)	SEM	Med(n=13)	SEM	Low(n=15)	SEM		
Ca (mg/dl)	9.10	0.35	8.54	0.31	9.20	0.29	0.26	Ns
Cl (mmol/L)	109.20	1.20	109.00	1.05	108.33	0.98	0.83	Ns
K(mmol/L)	4.40 ^a	0.22	4.53 ^a	0.19	4.31 ^a	0.18	0.71	Ns
Mg (mg/dl)	1.71	0.08	1.73	0.07	1.56	0.06	0.15	Ns
Na(mg/dl)	147.80	1.02	149.62	0.89	149.20	0.83	0.39	Ns
P(mg/dl)	5.13	0.13	4.94	0.11	5.17	0.11	0.31	Ns
Ca: Calcium, Cl: Chloride, K: Potassium, Mg: Magnesium, Na: Sodium, P: Phosphorus.								
SEM: standard error of means. NS: Non-Significant difference ($P > 0.05$).								

Table 7
Person correlation coefficients (n=39) of mineral biochemical components with residual feed intake (r_{RFI}) and feed conversion ratio (r_{FCR}) and gross feed efficiency (r_{GFE})

Items	r_{RFI}	P	r_{FCR}	P	r_{GFE}	P
Ca ⁺⁺	0.09	0.59	0.22	0.19	-0.12	0.49
Cl ⁻	0.10	0.54	-0.14	0.41	-0.04	0.81
K ⁺	0.23	0.17	0.18	0.28	-0.06	0.71
Mg	0.08	0.65	0.08	0.64	-0.20	0.23
Na ⁺	-0.11	0.52	0.01	0.94	0.11	0.50
P	0.31*	0.05	0.26	0.12	-0.12	0.46
Ca ⁺⁺ : Calcium, Cl ⁻ : Chloride, K ⁺ : Potassium, Mg: Magnesium, Na ⁺ : Sodium, P: Phosphorus.						

Discussion

The objectives of this study were, to evaluate potential differences in feedlot performance, blood variables of lambs classified according to RFI, and to estimate correlation between feed efficiency represented by RFI, FCR, GF, and some metabolites blood parameters. The main findings of this study were; firstly, the low RFI animals had a greater GFE, and lower DMI and FCR values, with approximately a similar ADG and final body weight. Secondly; the RFI trait had a positive correlation with total protein, globulin, urea, HDL, phosphorus, and negative correlation with creatinine. FCR had a positive correlation with total protein and AST.

Consistent with our results, many previous studies have found variation in feed efficiency using the RFI approach between lambs, with the most efficient animals having lower dry matter intake [7, 17].

The mean values of RFI of the most efficient and least efficient group was -0.28 Kg DM/day and 0.34 Kg DM/day, respectively, making a total difference of 0.62 Kg DM/day between the two groups. This difference was larger than the results found by Edson et al. [7] in their evaluation of Ile de France lambs, in which RFI values between efficiency groups ranged from -0.42 to 0.14 Kg DM/day. The results obtained for DMI, indicated that low RFI animals had 10.71% lower daily DMI than the med RFI animals and 14.28% than high RFI animals. This difference was slightly higher than the values of Low-RFI Ile de France lambs, that had a 12.92% lower DMI than high-RFI lambs.

In the current study, the overall mean for ADG was 0.21 and 0.19 kg/day in low and high RFI groups, respectively. Basarab et al. [19] reported that the relationship between RFI and ADG was zero suggesting that RFI could be used as an indicator of the animal's maintenance requirements rather than growth, size and/or appetite. Therefore, RFI could become an important tool to increase profitability in the meat production industry. François et al. [20] and Snowden and VanVleck [21] reported a moderate heritability for RFI in sheep of 0.30 and 0.26, respectively, which indicates the possibility of response to individual selection. However, it is essential to know the effects of using RFI as a genetic selection criterion in sheep.

A higher level of total protein, globulin, aspartate amino transferase and urea (the markers of liver function for higher protein catabolism) provide evidence for greater protein turnover in high RFI lambs than low RFI. The same results were demonstrated in previous studies in cattle, the high RFI animals had greatest total plasma protein levels [14]. The increasing level of blood protein may reflect the increasing rate of protein turnover in less efficient animals [22].

The higher globulin concentration in inefficient lambs may be associated with a greater stress response in these animals include an increase in metabolic rate and energy consumption coupled with increase in catabolic processes such as increased lipolysis and protein degradation [16]. Ricon-Delgado et al. [17], suggesting that less efficient sheep is on average more excitable or easily stressed than more efficient sheep.

The mean values of blood urea nitrogen (BUN) differed significantly ($P=0.02$) between high and low RFI groups. A significant correlation ($r_{FCR} = 0.40$) was observed between RFI value and BUN concentration. Previous reports in cattle by Richardson et al. [14] have found greater blood concentrations of urea in less efficient genotypes. This may be due to a greater protein intake in high RFI animals, a greater rate of body protein degradation, or deviation in the supply of amino acids due in part to variation in the efficiency of microbial protein production in the rumen [23, 24]. Blood urea concentration has been reported as negatively correlated with high lean growth and positively correlated with backfat depth in sheep [25].

Creatinine is a metabolite product of creatine phosphate, an energy storage compound in the muscle, that has a positive association with muscle mass in sheep [25], cattle [26] and negatively with fat depth in sheep [25]. A negative correlation ($r = -0.38$) between RFI and creatinine was shown in this study ($P = 0.02$), a similar negative correlation ($r = -0.45$) between serum creatinine and RFI for beef steers was observed by Richardson et al. [14]. Moreover, Richardson et al. [14] reported that animal selected for RFI may result in higher concentrations of blood creatinine and lead to changes in composition of the body with lower fat content in the carcass and a higher proportion of muscle mass in the carcass.

The mean values of AST activity were found to be 124.07 and 162.90 (U/L) in low and high RFI groups, respectively. AST is a key enzyme in amino acid metabolism and it acts as a marker of liver function and indicates higher levels of protein catabolism in the liver of less efficient steers [14]. Richardson and

Herd [27] reported that the high level of AST was found in the cattle with high RFI. Therefore, metabolites may give indicator of differences in animal metabolism which may reflect genetics differences in feed efficiency.

The positive correlation between RFI and HDL ($r_{FIr}=0.49$), was in the same line with result obtained by Rauw et al. [28] who found that RFI tended to correlate positively with HDL.

Ions transport contributes 20% of the variation in basal energy expenditure between animals [29]. No strong correlation was observed between RFI and mineral concentrations except for phosphorus ($r_{FIr}=0.32$), which is essential for cellular biology and energy metabolism with implications for protein synthesis [30]. Higher concentrations of phosphorus in young cattle have been directly related to growth hormone activity, which promotes intestinal phosphate absorption and renal phosphate re-absorption [31]. Phosphorus also contributes to the production of the muscle storage molecules, kreatine phosphate and ATP [32].

Conclusion

The present study concluded that, although, all lambs of the different classes of RFI had similar average daily gain and final weight, the lambs with low RFI consumed less feed than the other groups. Moreover, RFI was positively correlated with urea, globulin, HDL, AST, phosphorus and negatively with creatinine. There are associations between RFI and feed utilization as reflected mainly by total protein, globulin, urea, creatinine, HDL and phosphorus.

Methods

Study area

The study was carried out at Faculty of Animal Production (Small Ruminant Research Unit), and laboratory of Department of Physiology, Faculty of Veterinary Medicine, University of Khartoum, during the period from July 2018 to October 2018.

Experimental Animals

Thirty-nine Hamari desert lambs were collected from Elnehoud locality, to ensure homogeneity within selected lambs following criteria were adopted: health, breed, body weight (26.65 ± 0.6 kg) and age (180 ± 15 days).

Housing, feeding management

On arrival to the experimental site, each lamb was identified by an ear-tag then after they were treated against internal and external parasites. The animals were individually housed in elevated pens with a concrete sloped floor (approximately $1.5\text{ m} \times 1.5\text{ m} \times 2\text{ m}$) equipped with manual feeders and water sources. Ration was formulated to meet the nutrient requirement for growing lambs [18] (Table 8). Sheep were released after experiment.

Table 8
Ingredient and chemical composition
of total mixed diet given to lambs

Ingredient	Inclusion
Sorghum	
Groundnut cake	26%
Groundnut hall	20%
Molasses	23%
Nacl	30%
Lime stone	0.5%
Chemical composition	0.5%
Crude protein	
ME(MJ/Kg)	
	14%
	10
ME: Metabolisable energy	

Residual feed intake determination

After 15 days of adaptation to diet and management, the animals were kept confined for 90 days, the individual refusal feed was taken each morning allowing formation of weekly composite samples for the determination of DM and later to obtain observed dry matter intake (DMI_{obs}), which was calculated as difference between the amount of feed offered and the feed refused.

During the experimental period, lambs were weekly weighed and the average daily gain (ADG) was determined as the difference between final BW and initial BW divided by the experimental period. The RFI was measured as difference between the observed dry matter intake (DMI_{obs}) and the estimated dry matter intake (DMI_{est}) [33]. The DMI_{est} was calculated by regressing the daily DMI_{obs} as function of metabolic BW ($LWI + LWM + LWF/3$)^{0.75}; measured on days (0, 45, 90) during the experimental period, and ADG, using R Development core Team statistical software (2010), following the model:

$$DMI_{est} = \beta_0 + \beta_1 ADG + \beta_2 MBW$$

β_0 : regression intercept.

β_1 : partial regression coefficient of DMI_{est} on ADG.

β_2 : partial regression coefficient of DMI_{est} on MBW.

After calculating the RFI coefficient for each animal, the lambs were classified into highest positive (least efficient; > 0.5 SD above the mean $n = 10$) and (medium efficient; between ± 0.5 SD from the mean $n = 13$) and lowest negative (most efficient; < 0.5 SD below the mean $n = 17$), efficiency classes based on RFI.

Feed conversion was calculated as the ratio between DMI and ADG, whereas gross feed efficiency is its inverse, that is, the ratio between ADG and DMI.

Blood sampling and processing

At the last weighing, blood samples were collected from 39 animals (after that one sample was waved due to hemolysis) via jugular vein puncture using plastic disposal syringes. The blood samples were allowed to stay for 1-2 hours at room temperature and then centrifuged at 3000 rpm for 15 minutes to separate serum and stored at -20°C until being analyzed.

Blood analysis

The serum total protein and albumin levels were estimated according to the methods of Grant et al. [34] and Doumas et al. [35], respectively. The serum globulin was calculated by subtracting the albumin from the obtained total protein [36]. The serum activities of aspartate aminotransferase (AST) and creatin kinas (CK) were determined according to the method of Reitman and Frankel [37]. The serum urea and creatinine level were measured according to the methods of Patton and Crouch [38] and Henry [39], respectively.

Serum total lipid, triglyceride, low density lipoprotein and high density lipoprotein were determined using analytical methods [40, 41, 42, 43], respectively. Cholesterol (enzymatic colorimetric method of cholesterol oxidase-peroxidase-4-aminophenazone).

Serum calcium concentration was determined by colorimetric method [44]. Phosphorus concentration (mg/dl) in serum was determined by methods described by Farrell [45]. Serum sodium, potassium and chloride were determined by colorimetric method described by Kim et al. [46].

Experimental design and Statistical analysis

The experimental protocol was approved by the research board of the Faculty of Animal Production, University of Khartoum, Sudan (RB 2016/126) and was in accordance with institutional and national guidelines for the care and use of animals.

Data from different efficiency groups were subjected to analysis of variance (ANOVA) for a completely randomize design to verify the difference by F test at 5% significance, and the least significant difference (LSD) was used to mean separation. The Residual feed intake correlations with the mean values of blood variables were estimated by person's simple correlation analysis using the Cor-test analytical procedure of the R Development core Team (2010) statistical program to separate between means.

Abbreviations

Alanine aminotransferase	AST
Average daily gain	ADG
Body weight	BW
Creatinine Kinase	CK
Dry matter intake	DM
Estimated dry matter intake	DM _{est.}
Feed conventional ratio	FCR
Gross feed efficiency	GFE
High density lipoprotein	HDL
Low density lipoprotein	LDL
Ministry of Animal Resources and Fisheries	MARF
Metabolic body weight	MBW
energy	ME
Observed dry matter intake	DM _{obs.}
Residual feed intake	RFI

Declarations

Ethics approval and consent to participate

The experimental protocol was approved by the research board of the Faculty of Animal Production, University of Khartoum, Sudan (RB 2016/126) and was in accordance with institutional and national guidelines for the care and use of animals. The Animal Production Research Board approved this study without ethics approval, this is because the study depends only on feeding and collecting blood samples from the sheep. The animals were released after experiment. Animals were owned by Department of Animal Nutrition- faculty of Animal Production, UofK. Written informed consent to use the animals in the study was obtained from the owner of the animals.

Consent for publication

Not Applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

All other authors declare no competing interests.

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Authors' contributions

BA and TA contributed to the study design and execution, sample collection, sample analysis and was responsible for interpretation of analyzed data, and preparation of the manuscript. All authors read and approved the final manuscript.

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