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Original Research Article

Effects of physical form of diet on nutrient digestibility, rumen fermentation, rumination, growth performance and protozoa population of finishing lambs

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This study was conducted to compare effects of 3 physical forms of feed including mash (diet 1), pellet (diet 2) and complete feed block (CFB; diet 3) on digestion, fermentation and performance of lambs. Twenty-one lambs with an initial average body weight of 26 ± 2.5 kg and 6 ± 1.5 months of age were assigned through a completely randomized design to 3 treatments and 7 replicates. The experimental treatments had the same formulation. The results of present experiment showed that CFB significantly increased feed intake and nutrient digestibility ($P < 0.05$). There was no significant difference among the diets for rumen fluid pH, blood glucose, concentration of volatile fatty acids ($P > 0.05$), except acetic acid ($P < 0.05$). The rumen ammonia nitrogen (NH_3–N), mixed rumen protozoa population (RPP), *Entodiniums* spp., *Epidiniums* spp., blood urea nitrogen (BUN) concentration, rumination time adjusted for dry matter (DM), neutral detergent fiber (NDF), acid detergent fiber (ADF) intake, and total body weight gain of lambs in CFB diet were the highest among all diets ($P < 0.05$). Feed conversion ratio at days 31 to 45 and whole experimental period were better in CFB than in other diets ($P < 0.05$). Overall, according to the findings of the present study, among 3 physical forms of the diets, CFB had the best efficiency due to improvement of nutrient digestibility, rumen fermentation and performance of lambs. Therefore, the CFB diet offers the best result in lambs compared with mash and pellet diets.

1. Introduction

Livestock production in developing countries largely depends on fibrous feeds — mainly crop residues and low quality pasture that are deficient in nitrogen, minerals and vitamins (Makkar, 2007). Protein supplements are only available at a very high price in developing countries, and this has led to the use of non-protein-nitrogen sources, such as urea, to compensate for the nitrogen deficiency in fibrous feeds, thus enhancing their digestibility, intake and nutrient availability through optimization of rumen fermentation (Makkar, 2007).

Complete feed block (CFB) is comprised of forage, concentrate and other supplementary nutrients in desired proportion capable to fulfill nutrient requirements of animals. The feeding of CFB stabilizes rumen fermentation, minimizes fermentation loss, and ensures better ammonia utilization (Prasad et al., 2001). Advantages of CFB are using local feed raw materials which are cheaper and easier in the distribution because the distance between the processing place and the farm is closer; besides, it has a competitive advantage compared with commercial feed manufactured in large industrial scale because it is more efficient in production, lower in transportation costs, and easier in storage, and it can reduce operating costs, especially labor (Sunarso et al., 2011). Also, with CFB we can include less or non-palatable feed in animal diets; for instance, Aswandi et al. (2012) used the CFB for inclusion banana weevil pea in the diet of goat. The banana weevil can be used as a source of energy for ruminants, but raw banana weevil is less palatable and nutrient utilization is low, to overcome this, it is done

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through a process of practical and simple technology, and improvement of palatability is approached through processing feed into a CFB by technology. The CFB is an extensive system, which provides abundant and constant availability of forages year round. This will in turn increase possibilities of meeting animal requirements, facilitating management, allowing full mechanization and more flexibility for inclusion of a wide range of alternative feeds (Cavani et al., 1991).

A CFB diet, used in cattle and buffalo (Verma et al., 1996; Singh et al., 2001) feeding, can be explored for small ruminants. Wanapat and Khampa (2006) reported that supplementation of CFB could increase feed intake, nutrient digestibility, and rumen volatile fatty acids (VFA). Moreover, supplementation of CFB in lactating dairy cow indicates that rumen ecology was significantly improved (Koakhunthod et al., 2001). Furthermore, supplementation of leguminous feeds or tree fodder has been shown to improve rumen ecology and ruminant performance (Devendra, 1989). The CFB containing urea, molasses, by-pass protein and other essential ingredients has been used as a supplement for ruminants. Supplementation with high-quality feed block (Wanapat et al., 1999) or a urea-molasses block (Srinivas et al., 1997) has resulted in improvements in terms of intake of rice straw, digestibility, growth, and milk yield and composition.

Briefly, CFB was used as a method for inclusion the less or non-palatable feed in animal diets. On the other hand, most studies were about mineral or urea-molasses block, or when CFB and complete feed mash were compared, their chemical composition were not exactly same (Aswandi et al., 2012; Samanta et al., 2003; Koakhunthod et al., 2001). But, there are not any literature that compare the 3 physical forms of feed constitution — CFB, pellet and mash with same chemical composition on performance, rumen fermentation, apparent nutrients digestibility, and protozoa population. Therefore, the aim of this study was to investigate the effect of CFB compared with mash and pelleted diets on digestibility, microbial fermentation, rumination activity, blood metabolites, some growth parameters, and rumen protozoa population (RPP) of Arabi lambs.

2. Materials and methods

2.1. Diets, animals and experimental design

The rations were prepared in animal feed mill of Shoeybiyeh (Shoshtar, Khuzestan, Iran). The first step in making CFB is grinding of concentrate ingredients, followed by their mixing and addition of the feed additives, then mixing of these ingredients and forage along with addition of molasses in a specifically designed total mixed ration mixer.

Experimental dietary physical forms included: 1) mash diet, 2) pelleted diet, and 3) CFB diet. All diets were identical in chemical composition and differ only in physical form. Lambs were fed 60 days, which included 15 days of adaptation to diets and conditions and a 45-day growth study. The diets were formulated according to the weight of animals in NRC (2007) tables of requirements (Table 1).

In this experiment, 21 Arabi male lambs (mean age = 6 ± 1.5 months; initial average body weight = 26 ± 2.5 kg) were selected from the University farm. Animals were randomly divided into 3 treatment groups with 7 replicates. The lambs freely access to the feed and fresh water.

2.2. Feed intake and digestibility

Animals were fed the experimental diets for 45 days in individual metabolic cages, and daily feed intake was recorded. A digestion trial for 7 days (sample collection) was conducted at the end of experimental feeding, and daily feed intake and faeces excretion were recorded. Samples (about 10%) of feed, orts and faeces were collected every morning and stored in a freezer at −20 °C. Faeces was collected using a total collection method over 24 h. The feed, faeces and orts samples for 7-day collection were pooled, oven dried (60 °C, 48 h), ground to pass through a 1-mm screen and preserved for chemical analysis. All samples were analyzed for DM (method 930.15), ash (method 924.05), acid detergent fiber (ADF) (method 973.18) and N (method 984.13) of AOAC (1990) expressed inclusive of residual ash. Neutral detergent fiber (NDF) was determined without the use of sodium sulphite or α-amylase according to Van Soest et al. (1991).

Table 1
Ingredients and nutrient chemical composition of experimental diets (DM basis).

Item	Experimental diets (different physical forms)		
	Complete feed mash	Complete feed pellet	Complete feed block
Ingredients, %			
Corn	19.0	19.0	19.0
Barley	20.0	20.0	20.0
Wheat bran	16.0	16.0	16.0
Soybean meal	4.0	4.0	4.0
Sugarcane molasses	5.0	5.0	5.0
Bagasse pith	34.5	34.5	34.5
Urea	0.5	0.5	0.5
$CaCO_3$	0.025	0.025	0.025
NaCl	0.025	0.025	0.025
Premix[1]	0.5	0.5	0.5
Chemical composition[2], %			
DM	94.0	94.0	94.0
CP	11.0	11.0	11.0
OM	89.3	89.3	89.3
NDF	46.3	46.3	46.3
ADF	26.25	26.25	26.25
ME, Mcal/kg	2.50	2.50	2.50
Ash	10.7	10.7	10.7
Ca	0.4	0.4	0.4
P	0.3	0.3	0.3

DM = dry matter; CP = crude protein; OM = organic matter; NDF = neutral detergent fiber; ADF = acid detergent fiber; ME = metabolizable energy.
[1] Premix provided the following per kilogram diet: 99.2 mg Mn, 50.0 mg Fe, 84.7 mg Zn, 1.0 mg Cu, 1.0 mg I, 0.2 mg Se, 9,000 IU vitamin A, 2,000 IU vitamin D, and 18.0 IU vitamin E (Roshd Daneh Co., Iran).
[2] Calculated values.

2.3. Rumen fluid parameters and protozoa population

During the middle part of the experiment, rumen fluid samples were taken from each animal at 3 h post feeding. About 100 mL of representative rumen liquor was collected from the rumen with a stomach tube using light suction. Rumen liquor pH was recorded immediately after collection using a digital pH meter (Metrohm model 691, Switzerland). The rumen liquor was then strained through 4 layers of muslin cloth. The strained samples were preserved after acidifying with 0.2 mol/L HCl solution and kept in labeled polypropylene bottles at −20 °C till further analysis: NH_3−N concentration was determined for rumen fluid samples according to Broderick and Kang (1980), and VFA were analyzed according to Erwin et al. (1961). Rumen fluid was used to direct count of protozoa using the methods of Dehority (2003) by a Neobar lam (Boeco, Singapore).

2.4. Chewing activity

During the sampling period, the chewing activities of each animal were recorded through a visual observation method for a period of 24 h continuously (08:00 to 08:00 the next day) at 5-min intervals. The total number of minutes of eating, ruminating, and

Table 2
Effect of physical forms of ration on nutrient intakes and apparent digestibility in lambs.

Item	Experimental diets (different physical forms)			SEM	*P*-value
	Complete feed mash	Complete feed pellet	Complete feed block		
Intake, g/day					
DM	1,240.0[c]	1,285.5[b]	1,325.0[a]	15.60	0.002
OM	1,220.71[c]	1,258.55[b]	1,299.05[a]	10.80	0.001
CP	135.50[b]	140.40[b]	146.80[a]	2.70	0.010
NDF	621.75[b]	628.40[b]	677.10[a]	11.30	0.010
ADF	172.00[c]	188.50[b]	212.30[a]	3.60	0.010
Ash	25.29	24.95	25.95	1.70	0.070
Digestibility, %					
DM	64.05[b]	66.89[a]	68.76[a]	1.20	0.030
OM	47.50	47.20	48.40	0.40	0.900
CP	62.03[b]	62.12[b]	65.21[a]	1.13	0.001
NDF	64.05[b]	65.34[b]	70.28[a]	1.08	0.020
ADF	32.01[c]	36.75[b]	41.72[a]	2.09	0.020

SEM = standard error of means; DM = dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber.
[a,b,c] Means with different superscripts in the same row differ significantly ($P < 0.05$).

resting activity were then estimated by the sum of each observation and multiplied by a factor of 5 (Kononoff et al., 2002). The chewing activities were adjusted for DM, NDF and ADF intake (Beauchemin, 1991).

2.5. Blood samples

Blood samples from jugular vein were collected in serum tubes containing anticoagulant agent approximately 4 h after morning feeding (Coverdale et al., 2004) from all animals at the final days of the experiment. Collected samples were centrifuged for 3,000× *g* at 4 °C for 15 min (Hermel, Germany), and separated plasma was stored in −20 °C until further analysis, Glucose (QC.M.87.23.3) and blood urea nitrogen (BUN) (TS.M.91.47.5) were measured using a quantity detection kit (Parsazmun company, Iran) and a spectrophotometer (model S Bio-Rad Libra, England), respectively.

2.6. Performance

To evaluate the growth performance i.e., body weight (BW) changes and feed conversion ratio (FCR), the animals were weighed at the beginning of the experiment (with starvation of 8 h before the start of the experiment) and then at 1.5 h before the morning feeding every 15 days. The BW changes were calculated by difference of final and initial weights. Due to the need to calculate feed intake and FCR (kg DMI/kg live mass gain) during the 45-day trial, feed intake and orts were recorded daily, and DM Intake was calculated by determination of the ration dry matter (60 °C, 48 h).

2.7. Statistical analysis

Data were analyzed as a completely randomized design with 3 treatments and 7 replicates of treatments using the GLM procedure of SAS (version 9.1). A comparison of means by Duncan's multiple range tests was carried out at the probability of 5% level.

3. Results

3.1. Nutrient intake and digestibility

The feed intake (in terms of g/day) was significantly affected by treatments ($P < 0.05$). The organic matter (OM), crude protein (CP), NDF, and ADF intake were the higher in lambs receiving CFB than in lambs of other diets ($P < 0.05$), and the pellet was in the second place (Table 2).

The digestibility of DM, NDF, ADF and CP was greater in sheep fed CFB than in sheep fed other diets ($P < 0.05$). The physical form of diet did not affect OM digestibility (Table 2).

3.2. Rumen fermentation characteristics

Rumen fluid pH, total volatile fatty acids (TVFA), propionate, butyrate, valerate and isovalerate concentrations and acetate-to-propionate ratio were not altered by changes in physical form of diets. The effect of diets on rumen NH_3—N and acetate concentrations was significant ($P < 0.05$), and these parameters were the highest in CFB (Table 3).

3.3. Rumen protozoa population

The RPP are presented in Table 4. The whole RPP, *Entodiniums* spp., and *Epidinium* spp. populations were significantly different among diets ($P < 0.05$) and more in the CFB diet than in other diets ($P < 0.05$); but they had no difference between mash and pellet. The physical form of diets had no significant effect on *Holotricha* spp. and *Diplodinium* spp. population, and the value was numerically more in CFB than in other diets.

3.4. Blood metabolites

The physical form of diet significantly influenced the concentration of BUN, although did not affect the concentration of blood glucose (Table 5).

3.5. Rumination activity

The eating, rumination and chewing activity individually or adjusted for nutrients intake (DM, NDF and ADF) are shown in Table 6. The duration of eating, rumination and chewing alone and per gram of DM, ADF intake were affected by physical form of diets, and were higher in CFB diet ($P < 0.05$).

3.6. Performance recording

The dry matter intake (DMI), initial and final live weights, BW changes and FCR are presented in Table 7. The experimental diets had significant effect on DMI, total weight gain, and FCR. For the all mentioned variables, the highest or best values were achieved by CFB diet.

4. Discussion

Dry matter intake and nutrients digestibility observed in this study were similar to the results of Raghuvansi et al. (2007). In their experiment, the lambs received *ad libitum* CFB or were allowed grazing on a pasture and supplemented with mash concentrate. The intakes of DM, CP and OM were higher in animals fed the CFB than the mash diet. Digestibility of OM and CP were greater in animals fed the CFB versus other diets. The results of present study for nutrients digestibility except DM were incompatible with Verma et al. (1996). However, the results of nutrients intake and DM digestibility agreed with theirs. They assigned 12 buffaloes to 3 diets with different physical forms with similar ingredient composition. The physical form of the diet had no significant influence on nutrient utilization as well as on the digestibility of various nutrients except DM. However, feeding of CFB resulted in a significantly higher intake of DM, digestible DM, and all other nutrients compared with the feeding of diets in other 2 ways.

Table 3
Effect of physical forms of ration on various rumen fermentation parameters in lambs.

Rumen parameters	Experimental diets (different physical forms)			SEM	*P*-value
	Complete feed mash	Complete feed pellet	Complete feed block		
pH	6.62	6.33	6.58	0.19	0.05
Ammonia N, mg/dL	14.44[b]	14.68[b]	15.32[a]	0.17	0.02
TVFA, mmol/L	101.2	100.1	102.4	1.2	0.2
Acetate, mol/100 mol	61.05[ab]	60.00[b]	61.70[a]	0.32	0.02
Propionate, mol/100 mol	28.25	28.15	28.50	0.22	0.30
Butyrate, mol/100 mol	8.85	8.95	8.95	0.11	0.50
Isovalerate, mol/100 mol	1.50	1.45	1.60	0.10	0.50
Valerate, mol/100 mol	1.55	1.55	1.65	0.15	0.70
Acetate: propionate	2.16	2.13	2.12	0.03	0.40

SEM = standard error of means; TVFA = total volatile fatty acid.
[a,b] Means with different superscripts in the same row differ significantly ($P < 0.05$).

Table 4
Effect of physical forms of ration on rumen protozoa populations (10^4/mL) in lambs.

Item	Experimental diets (different physical forms)			SEM	*P*-value
	Complete feed mash	Complete feed pellet	Complete feed block		
Holotricha	5.0	3.3	7.5	2.1	0.3
Entodinium	15.83[b]	22.50[b]	34.16[a]	4.20	0.01
Diplodinium	15.00	21.66	25.00	4.90	0.20
Epdiniumi	0.00[b]	1.66[b]	14.16[a]	2.10	0.0005
Ophryoscolex	11.66	10.38	10.00	2.03	0.90
Total protozoa	47.50[b]	60.00[b]	90.00[a]	8.07	0.002

SEM = standard error of means.
[a,b] Means with different superscripts in the same row differ significantly ($P < 0.05$).

Table 5
Effect of physical form of ration on blood metabolites in lambs.

Item	Experimental diets (different physical forms)			SEM	*P*-value
	Complete feed mash	Complete feed pellet	Complete feed block		
Glucose, mg/dL	72.30	71.83	73.25	2.60	0.90
Blood urea nitrogen, mg/dL	7.58[b]	8.12[b]	11.29[a]	0.86	0.01

SEM = standard error of means.
[a,b] Means with different superscripts in the same row differ significantly ($P < 0.05$).

Similarly, Bashtani et al. (2011) using CFB, complete feed mash or pellet diet in heifers observed non changes in intake of DM and CP; digestibility coefficient of DM, OM, CP, NDF, ADF also showed no significant difference among diets (Samanta et al., 2003). When the feed is compressed by blocking, its volume is reduced, and the density is increased, in this case, the voluntary intake of feed increases (Raghuvansi et al., 2007; Verma et al., 1996).

The reason for increasing the digestibility of nutrients in the CFB compared with other diets in the present experiment may be attributed to differences in RPP of them (Table 4); the whole RPP, *Entodiniums* spp., *Diplodinium* spp. and *Epidinium* spp. in the CFB were significantly greater than in other diets. About 16% to 30% of total rumen microbial fiber digestion was done with protozoa (Lee et al., 2000; Jabari et al., 2014). The researches indicated that the ability of *Entodiniums* spp. (Jabari et al., 2014), *Epidinium* spp. (Coleman, 1985; Jabari et al., 2014), and *Diplodinium* spp. (Bonhomme, 1990; Jabari et al., 2014) to degrade cellulose, hemicellulose or NDF was high.

The rumen liquor pH was within the range considered optimal for microbial digestion activity. The fiber-digesting bacteria thriving best at pH 6.0 to 6.8 and starch-digesting bacteria at 5.5 to 6.0, the best balance of fiber and starch digestion occurs at a rumen pH of around 6.0. A ruminal pH 5.6 to 5.8 suggests a marginal or developing problem of ruminal acidosis, and a pH greater than 5.9 is considered normal (Olson, 1997). The optimal ruminal pH is from 5.8 to 6.0 for fiber digestion (Kolver and De Veth, 2002).

As main source of rumen NH_3–N arises from the degradation of dietary protein nitrogen, so do the deamination of amino acids, lysing bacteria by protozoa, and conversion endogenous non protein nitrogen compounds (Makkar, 2003). Therefore, the higher rumen NH_3–N concentrations in CFB diet is probably related to the more consumption of protein or higher RPP in CFB diet because the protein intake and RPP of the CFB diet were 8.34% and 89.5% higher, respectively (Table 2). The rumen protozoa proteolytic and deamination activity cause production of NH_3–N (Williams and Coleman, 1991). The ciliate protozoa engulf rumen bacteria and excrete amino acids and NH_3–N (Coleman, 1975). The rumen ammonium levels are as twice as high in faunated sheep than in protozoa free sheep (Eadie and Gill, 1971). Rumen NH_3–N concentration in this study agreed with the report of Wanapat and Pimpa (1999) for NH_3–N, which it ranged from 13.6 to 17.6 mg/dL. The optimal concentrations of rumen NH_3–N required to maximize microbial protein synthesis are controversial (8.5 to over 30 mg/dL), but 5 mg/dL of NH_3–N maximized microbial protein synthesis *in vitro* (Satter and Slyter, 1974; McDonald et al., 2010). Thus in present experiment, the rumen NH_3–N was sufficient to ensure optimum microbial growth and nutrient utilization.

In support of this observation, Raghuvansi et al. (2007) reported that the pH of the rumen content and the concentration of TVFA in the rumen liquor of the lambs received CFB were similar to those of lambs allowed grazing on a pasture and supplemented with mash concentrate; however, the concentrations of NH_3–N were higher in CFB animals. Similarly, Samanta et al. (2003) using CFB or complete feed mash diet in sheep, observed non changes in rumen pH and TVFA. However, in agreement with the result of the present experiment, concentration of NH_3–N was lower in CFB diet than that of complete feed mash.

The RPP observed in the present study was contrasting to the results of Samanta et al. (2003) and Molina-Alcaide et al. (2010); the RPP was similar in CFB or complete feed mash diet in sheep and goat, respectively. The authors did not find any experiment in literature about the effects of CFB in comparison with mash, which reported the increase of RPP by CFB feeding, and all sources have reported no difference between the mash and CFB rations.

Blood urea nitrogen reflects the dietary CP intake, the ratio of dietary CP to rumen fermentable OM, and also serves as an indicator of ruminal protein supply (Martin et al., 2005; Hammond, 1997). Increasing dietary protein increases BUN concentration (Martin et al., 2005; Hammond, 1997). Thus, probably higher BUN in CFB diet are related to more CP intake from this diet (Table 2); the similar BUN and CP intake in mash and pellet diets confirm this reason. On the other hand, BUN is highly correlated with ruminal ammonia (Javaid et al., 2008; Burgos et al., 2007; Hammond, 1997), so probably greater BUN concentration in CFB diet was due to higher NH_3–N concentration of it versus other diets (Table 3). Samanta et al. (2003) reported no changes in blood glucose and BUN between CFB and complete feed mash diet in sheep.

The increasing chewing activity in CFB than in mash and pellet diets probably is attributed to more NDF intake from CFB (Table 2), as Beauchemin (1991) reported eating, ruminating and total chewing individually or adjusted for nutrients intake increased linearly as NDF intake increased. Bashtani et al. (2011) reported lower chewing and rumination in CFB than in complete feed mash

Table 6
The effects of physical forms of ration on the chewing activity (min/day) in lambs.

Item	Experimental diets (different physical forms)			SEM	*P*-value
	Complete feed mash	Complete feed pellet	Complete feed block		
Chewing	524.25^{ab}	402.00^{b}	622.00^{a}	49.22	0.01
Eating	282.25^{ab}	215.00^{b}	318.25^{a}	25.49	0.04
Ruminating	242.00^{b}	187.00^{b}	303.75^{a}	24.38	0.01
Chewing per kilogram DMI	422.78^{a}	312.72^{b}	469.43^{a}	23.49	0.02
Eating per kilogram DMI	227.62^{b}	167.25^{b}	240.19^{a}	10.72	0.03
Ruminating per kilogram DMI	195.16^{a}	145.47^{b}	229.24^{a}	11.57	0.03
Chewing per kilogram NDFI	843.18	639.72	918.62	78.28	0.20
Eating per kilogram NDFI	453.96	342.14	470.01	40.15	0.20
Ruminating per kilogram NDFI	389.22	297.58	448.60	45.62	0.08
Chewing per kilogram ADFI	3,043.96^{a}	2,132.62^{b}	2,929.82^{ab}	282.33	0.04
Eating per kilogram ADFI	1,639.53^{a}	1,140.58^{b}	1,499.06^{ab}	148.91	0.04
Ruminating per kilogram ADFI	1,406.98^{a}	992.04^{b}	1,430.76^{a}	117.62	0.03

SEM = standard error of means; DMI = dry matter intake; NDFI = neutral detergent fiber intake; ADFI = acid detergent fiber intake.
^{a,b} Means with different superscripts in the same row differ significantly ($P < 0.05$).

Table 7
The effects of physical forms of ration on performance in lambs.

Item	Experimental diets (different physical forms)			SEM	*P*-value
	Complete feed mash	Complete feed pellet	Complete feed block		
DMI, g/d					
0 to 15 d	1,024.17^{b}	1,112.50^{ab}	1,152.50^{a}	28.10	0.02
16 to 30 d	1,133.7^{b}	1,230.0^{a}	1,242.5^{a}	24.7	0.02
31 to 45 d	1,255.0^{b}	1,305.0^{b}	1,383.7^{a}	19.05	0.003
0 to 45 d	1,137.64^{b}	1,216^{a}	1,259.56^{a}	38.2	0.0003
BW, kg					
Initial	26.62	28.25	25.87	1.20	0.30
15 d	28.12	29.87	27.54	1.10	0.30
30 d	30.12	31.87	29.62	1.20	0.40
45 d	32.12	33.75	32.50	1.20	0.60
BWG, kg					
0 to 15 d	1.5	1.6	1.6	0.06	0.20
16 to 30 d	2.00^{b}	2.00^{b}	2.08^{a}	0.01	0.02
31 to 45 d	2.0^{ab}	1.8^{b}	2.8^{a}	0.06	0.04
0 to 45 d	5.5^{b}	5.5^{b}	6.6^{a}	0.4	0.01
FCR					
0 to 15 d	10.24^{b}	10.30^{b}	10.52^{a}	0.40	0.02
16 to 30 d	9.71	10.19	9.94	0.30	0.20
31 to 45 d	9.30^{a}	9.29^{a}	7.54^{b}	0.20	0.01
0 to 45 d	9.75^{b}	9.92^{a}	9.33^{c}	0.30	0.02
ADG					
0 to 15 d	0.100	0.107	0.107	0.0040	0.2
16 to 30 d	0.134^{b}	0.134^{b}	0.139^{a}	0.0007	0.02
31 to 45 d	0.134^{ab}	0.120^{b}	0.187^{a}	0.004	0.04
0 to 45 d	0.122^{b}	0.122^{b}	0.141^{a}	0.01	0.02

SEM = standard error of means; DMI = dry matter intake; NDFI = neutral detergent fiber intake; ADFI = acid detergent fiber intake; BW = body weight; BWG = body weight gain; FCR = feed conversion ratio; ADG = average daily gain.
^{a,b} Means with different superscripts in the same row differ significantly ($P < 0.05$).

and pelleted diets was observed in Brown Swiss dairy cows, those was due to the increased density of forage particle and decreased bulk density by compacting the diet in CFB process.

Dry matter intake and average daily gain in CFB animals in the present study were consistent with those of the Raghuvansi et al. (2007). In their experiment, the lambs received *ad libitum* CFB had significantly higher average daily gain than animals allowed grazing on a pasture and supplemented with mash concentrate. Better performance in lambs fed CFB than mash and pellet diets probably was due to its higher nutrients digestibility (Table 2) because the nutrient digestibility has positive relationship with growth performance in all species (Wang et al., 2016), and increasing dietary inclusion of ADF content of diets linearly reduced apparent total tract digestibility coefficient and average daily gain of pigs fed sugar beet pulp.

5. Conclusion

In conclusion, the feeding of the CFB increased the nutrients intake and digestibility, rumen NH_3–N, acetate, chewing activity (eating and ruminating), BW gain, and improved FCR compared with the mash and pellet diets. The CFB sustained higher RPP in the rumen compared with mash and pellet. Therefore, CFB would be a proper diet for ruminants.

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