IJAS Iranian Journal of Applied Animal Science

Effects of Ensiling Total Mixed Ration Based on Fresh Alfalfa with or without Wheat Straw on Feed Intake, Digestion, Growth Performances and Carcass Characteristics in Fattening Male Lambs

Research Article

F. Badouei[1], O. Dayani[1,2*], A.R. Aghashahi[3*], M.M. Sharifi Hosseini[1] and M.A. Tajaddini[1]

[1] Department of Animal Science, College of Agriculture, Shahid Bahonar University of Kerman, Kerman, Iran
[2] Afzalipour Research Institute, Shahid Bahonar University of Kerman, Kerman, Iran
[3] Department of Animal and Poultry Nutrition and Physiology, Animal Science Research Institute of Iran (ASRI), Agricultural Research, Education and Extension Organization (AREEO), Karaj, Iran

Received on: 22 Aug 2025
Revised on: 1 Nov 2025
Accepted on: 14 Nov 2025
Online Published on: Dec 2025

*Correspondence E-mail: odayani@uk.ac.ir; aghashahimobin@gmail.com

Online version is available on: www.ijas.ir
https://doi.org/10.71798/ijas.2025.1228581

ABSTRACT

The effects of fermented total mixed ration (FTMR) silage using fresh-cut alfalfa and the addition of wheat straw on growth performances and carcass characteristics in fattening male lambs was evaluated. Thirty Kermani male lambs (20.5±0.4 kg initial body weight (BW); 6 months of age) were assigned to three treatments in a completely randomized design experiment for 80 days. Treatments were based on the conservation method of TMR (fresh *vs.* fermented TMR) including: 1) CON, fresh TMR with alfalfa hay; 2) FTMR1, fermented TMR with fresh-cut alfalfa similar to CON formulation; and 3) FTMR2, fermented TMR with fresh-cut alfalfa and wheat straw. Feeding FTMR2 increased dry matter and organic matter intake in lambs (P<0.05). Feeding the FTMR2 diet compared to CON and FTMR1 increased organic matter digestibility (P<0.05). Final weight, daily gain, warm and cold carcass weights were higher in the FTMR2 than in CON (P<0.05). Furthermore, feeding lambs with FTMR1 decreased carcass cooler shrink and increased cold dressing percentage (P=0.01) in comparison to CON and FTMR2, respectively. Weights of carcass prime cuts were similar among treatments except for brisket cut which was higher in the FTMR2 group (P<0.05), as were the weights of head and testis (P<0.05). Feeding FTMR2 increased lean meat and decreased back fat thickness (P≤0.02) in FTMR2 lambs. Overall, the results of this study indicated that FTMR with fresh-cut alfalfa and wheat straw was a suitable option to adjust the dry matter content of silage, could improve the feed intake, growth performance, and carcass traits of fattening lambs and can be considered as a cost-effective and feasible conservation method for TMR.

KEY WORDS ensiling, fattening lambs, feed intake, fresh alfalfa, total mixed ration, wheat straw.

INTRODUCTION

The practice of using ensiled total mixed ration (TMR) instead of fresh TMR in ruminant feeding is growing worldwide. Indeed, ensiling TMR seems an ideal strategy to conserve totally mixed diets at targeted dry matter (DM) content that not only makes it possible to balance the moisture content of prepared diet by using moist crops, but also improves palatability by preserving by alteration in odor of feedstuffs (Bueno *et al.* 2020; Li *et al.* 2021a). In this process, high-moisture feedstuffs and by-products such as apple pomace, bamboo shoot shells, cactus cladodes, and alfalfa fresh forage are mixed with dry ingredients such as cereal grains, wheat bran, rice straw, and oat hay (Fang *et al.* 2019; Santos *et al*. 2020; Gao *et al*. 2021; Zhao *et al.* 2021). Ensiled TMR has several advantages, including the supply of homogeneous feed over time, the ability to incorporate wet by-products in formulation, improved aerobic stability, avoiding self-selection of feedstuff by animals, and labor savings during the preparation compared to fresh TMR (Nishino et *al*. 2004; Xu *et al*. 2022). Fermented total mixed rations (FTMR) have longer storage life and contribute to stabilizing rumen function, also improving the protein utilization by animals (Bueno *et al*. 2020). Compared to fresh TMR, FTMR is reported to improve nutrient digestibility and reduce ruminal methanogenesis, thus theoretically would result in greater efficiency of dietary energy utilization (Cao *et al*. 2010). Therefore, FTMR can be used as an environmentally cleaner technology in animal farming (Miyaji and Nonaka, 2018; Li *et al.* 2021b). Lambs fed with the FTMR diet showed better meat quality traits compared to lambs fed with a fresh TMR diet (Liu *et al.* 2023).

Alfalfa is a productive, high-quality, long-lasting legume widely grown as a forage legume for hay, pasture, and silage for livestock. Using mixed silages of sweet sorghum and alfalfa (40% to 60%) in TMR has been reported to improve production performance and meat quality in sheep (Wang *et al*. 2020). However, compared to other forages, reaching a good quality alfalfa silage is frequently difficult due to the low water-soluble carbohydrate (WSC) content, high buffering capacity, and susceptibility to undesirable secondary clostridial fermentation (Li *et al*. 2019; Wang *et al*. 2020). Therefore, mixing fresh alfalfa (high moisture content) with dry feedstuffs (wheat straw, beet pulp, etc.) to prepare TMR silage could improve the quality of FTMR and the feeding level of ruminants. Compared to TMR preparation using ensiled-alfalfa, preparation of FTMR using fresh-cut alfalfa takes less time, subsequently shortening the feeding duration and saving time, which can also economize labor and resources.

Further research is needed to investigate the effects of feeding an FTMR diet containing fresh-cut alfalfa on growth performance and carcass composition of fattening lambs. Therefore, the present study aimed to investigate the effects of ensiling TMR and the use of wheat straw (to adjust for a higher dry matter (DM) content of silage) on dry matter intake (DMI), nutrient digestibility, growth performance, and carcass composition of fattening male lambs.

MATERIALS AND METHODS

This study was performed at the small ruminants' research unit of the Animal Science Department, Shahid Bahonar University of Kerman, Kerman, Iran (located at E 57◦010 longitude and N 30◦150 latitude), where all animal husbandry procedures were complied according to the Animal Care and Use Committee of Shahid Bahonar University of Kerman based on EU standards (Approval No. 1284120).

Animals and experimental treatments

The current study was conducted using 30 *Kermani* male lambs (20.5±0.4 kg initial BW; 6 months of age) randomly divided into straw-bedded individual pens (1.5×1 m) on a completely randomized design of 10 lambs per treatment. Three experimental diets (Table 1) were all formulated to be isoenergetic and isonitrogenous to meet the nutrient requirements of fattening male lambs (NRC, 2007). Treatments were based on the ensiling of TMR (fresh, made just before feeding vs. fermented TMR) including 1) CON, the typical fresh TMR with alfalfa hay and forage: concentrate (F:C) ratio of 45:55; 2) FTMR1, fermented TMR using fresh-cut alfalfa similar to CON formulation; 3) FTMR2) fermented TMR using fresh-cut alfalfa and wheat straw with F:C ratio of 40:60. The CON TMR were prepared fresh by mixing the feed ingredient every morning. The fermented TMR was prepared by totally mixing chopped fresh-cut alfalfa and concentrate, and ensiling the diets into nylon bags (60 L) for at least 45 days before the start of the animal trial in anaerobic conditions and stored outdoors at approximately 10 to 25 °C. The lambs were offered the diets for *ad libitum* intake (allowing approximately 5-10% refusals) twice daily (0900 and 1900 h) with free access to fresh water.

Growth trial, nutrients intake and digestibility, slaughter and carcass traits

Animals were fed a control diet for 10 days for adaptation to diets following an 80-day experimental period. The amount of feed offered daily was adjusted based on the intake of the previous day. Samples of feed offered and refused were collected weekly during the fattening period, and fecal samples were collected from all lambs (replicates) / treatment directly from the rectum each 4 h (in order to obtain representative fecal samples of 24 h) during 2 periods of 5 consecutive days (d 40 to 44 and d 75 to 79) and stored individually by animals and treatments at - 20 ◦C for further analysis.

Subsequently, the samples of diet, refusals and feces were dried for 72 h at 60 ˚C (55 L, Shimaz co.), then ground with Wiley mill (standard model 4; Arthur H. Thomas Co., Philadelphia, PA) and chemically analyzed for dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), and acid detergent fiber (ADF) according to standard procedures (AOAC, 1990). Neutral detergent fiber (NDF) was determined without heat-stable α-amylase (Van Soest *et al*. 1991).

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

Ingredients	Experimental diets[1]		
	CON	FTMR1	FTMR2
Alfalfa hay	45.0	-	-
Alfalfa forage	-	45.0	35.0
Wheat straw	-	-	5.00
Beet pulp	6.00	6.00	7.00
Corn grain, ground	8.00	8.00	6.00
Barley grain, ground	30.0	30.0	30.0
Wheat bran	8.50	8.50	13.4
Soybean meal	1.00	1.00	2.00
Urea	0.50	0.50	0.60
Sulfur	0.10	0.10	0.10
Mineral-vitamin premix[2]	0.60	0.60	0.60
Salt	0.30	0.30	0.30
Chemical composition			
Metabolizable energy (ME, Mcal/kg)	2.53	2.53	2.51
Crude protein (CP, %)	14.41	14.52	14.47
Dry matter (DM, %)	91.40	35.57	40.81
Ether extracts (EE, %)	4.41	4.45	5.30
Organic matter (OM, %)	90.51	90.56	91.20
Neutral detergent fiber (NDF, %)	41.21	41.14	36.40
Acid detergent fiber (ADF, %)	26.78	26.28	23.13
Non-fiber carbohydrates (NFC, %)	30.41	30.52	37.13

[1] CON: typical fresh TMR with alfalfa hay and F:C ratio of 45:55; FTMR1: fermented TMR using fresh-cut alfalfa similar to CON formulation and FTMR2: fermented TMR using fresh-cut alfalfa and wheat straw with F:C ratio of 40:60.
[2] Composition of premix per kg: vitamin A: 700000 IU; vitamin D_3: 100000 IU; vitamin E: 5000 IU; Ca: 120 g; P: 60 g; Na: 40 g; S: 15 g; Mg: 10000 mg; Cu: 500 mg; Co: 45 mg; I: 45 mg; Mn: 2000 mg; Se: 15 mg; Zn: 3000 mg and Fe: 200 mg.
[3] NFC= 100 - (NDF+CP+EE+ash).

Apparent total tract digestibility of nutrients was evaluated using acid-insoluble ash as an internal marker according to the method of Van Keulen and Young (1977). The lambs were weighed at 14-day intervals before the morning feeding to monitor body weight gain, average daily gain (ADG), and feed conversion ratio (FCR). At the end of the feeding trial, the final body weight was recorded. Lambs were slaughtered after an overnight fasting period, then skinned, and the head, feet, warm carcass and internal organs (liver, kidneys, lungs, heart, spleen, gallbladder, testis, internal fats, and parts of gastrointestinal tract) were weighed. Carcasses were hung and chilled for 24 h at 4 ˚C to measure cold carcass weight and cooler shrink. The carcasses were sagittal split, and the right sides were divided into six prime cuts including neck, brisket, loin, legs, shoulder, and fat-tail (Kashan *et al.* 2005), and the carcass cute were separately weighed. Each cut was then dissected into lean and bone. Half sides were cut across the 12th rib (over the midpoint of longissimus thoracis) to measure backfat thickness; eye muscle areas were also recorded using a caliper. The dressing percent was calculated as the ratio between hot/cold carcass weight and final BW.

Statistical analysis

The data were analyzed according to a completely randomized design using the MIXED procedure of SAS (2005) using the model:

$$Y_{ij} = \mu + T_i + \beta (X_{ij} - X) + e_{ij}$$

Where:
Y_{ij}: dependent variable.
μ: overall mean.
T_i: treatment effect i.
$\beta (X_{ij}-X)$: effect of initial body weight as a covariate.
e_{ij}: residual error.

The diet was fitted as fixed factor while the animal was considered as random effect in the model. The initial live body weight was used as the co-variate for final BW, and the carcass weight was used as a covariate for analysis of carcass components. Daily measures for parameters such as DMI, nutrient intake and digestibility were averaged into weekly data for analysis. The mean of recorded measurements in each experimental unit was considered in the statistical analysis. The significance was declared at $P < 0.05$ using the Tukey's test to separate the means.

RESULTS AND DISCUSSION

Results of the present study indicated that ensiling the TMR diet increased DM and OM intake (Table 2) in lambs fed with FTMR1 and FTMR2 ($P<0.05$). However, daily intakes of crude protein, NDF, and ADF were not affected by dietary treatments.

Table 2 Dry matter and nutrients intake, and digestibility of fattening lambs fed fermented total mixed ration (FTMR) with or without wheat straw

Items	Experimental diets[1]			SEM	P-value
	CON	FTMR1	FTMR2		
Intake (kg/day)					
Dry matter	1.36[c]	1.40[b]	1.43[a]	0.03	0.01
Organic matter	1.23[c]	1.26[b]	1.33[a]	0.03	0.03
Crude protein	0.21	0.22	0.26	0.04	0.10
Neutral detergent fiber (NDF)	0.74	0.77	0.66	0.04	0.07
Acid detergent fiber (ADF)	0.34	0.39	0.36	0.05	0.31
Digestibility (%)					
Dry matter	82.38	81.78	84.18	1.61	0.30
Organic matter	69.21[b]	67.55[b]	73.18[a]	1.19	0.03
Crude protein	73.05	71.81	75.15	1.25	0.20
Neutral detergent fiber (NDF)	69.71	71.01	73.21	1.95	0.13
Acid detergent fiber (ADF)	44.83	46.48	48.55	2.10	0.15
Ether extracts (EE)	61.88	63.60	66.19	2.16	0.11

[1] CON: typical fresh TMR with alfalfa hay and F:C ratio of 45:55; FTMR1: fermented TMR using fresh-cut alfalfa similar to CON formulation and FTMR2: fermented TMR using fresh-cut alfalfa and wheat straw with F:C ratio of 40:60.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Likewise, the digestibility of most nutrients (Table 2); however, OM digestibility was increased by feeding the FTMR2 diet compared to CON and FTMR1.

Final weight, daily gain, warm and cold carcass weights were increased and FCR was improved with FTMR2 compared to CON (P<0.05). In addition, feeding ensiled TMR decreased carcass cooler shrink and increased cold dressing percentage (P=0.01) in comparison to CON and FTMR2, respectively (Table 3).

Weights of carcass prime cuts did not differ among treatments (Table 4) except for the brisket cut which increased in response to feeding lambs with the FTMR2 diet (P<0.05). Also, the head and testis weights were higher for FTMR2 lambs (Table 5) compared to the other two experimental groups (P<0.05); while no treatment effects were found for the other non-carcass components. Feeding TMR with wheat straw increased lean meat and decreased backfat thickness (P≤0.02) in FTMR2 lambs (Table 6). However, as a proportion of carcass weight, lean meat percentage was lower for the FTMR1 lambs compared to other treatments. Although, bone weight and percentage, eye muscle area, lean/bone ratio, full and empty weights of gastrointestinal tract parts, and different (perirenal, intestinal, and heart) visceral fat parts were not impacted among experimental groups.

In the present study, the FTMR1 diet was prepared similarly to the CON diet formulation, however, the FTMR2 diet was formulated containing wheat straw with a slightly lower forage: concentrate ratio (45:55 in the FTMR1 *vs.* 40:60 in the FTMR2).

This led to an increase in NFC and a decrease in NDF and ADF content with the FTMR2 diet compared to CON and FTMR1. With increasing dietary NDF, a decrease in DMI is reported that is caused by rumen fill which limits DM and OM intake (Allen, 1996).

In addition, slow clearance from the rumen with poorly digestible feeds might result in limited DMI (NRC, 2001). Thus, higher DMI in FTMR2 lambs might be due to lower diet NDF and ADF, added to the positive effect of ensiling on the FTMR1 and FTMR2 palatability and thus higher feed consumption. In addition, the apparent total tract digestibility of OM was also increased by feeding FTMR2 ensiled diet to the lambs.

Although the whole-tract digestibility of starch was not measured in the present study, we speculate that the ensiling storage period of the diet might impact ruminal starch degradability of TMR, according to Miyaji *et al.* (2016). These authors suggested that the ruminal DM and starch degradability of TMR increased during ensiling, and this could be explained by the proteolysis of protein matrix that stimulates the solubilization of starch granules (Peyrat *et al.* 2014) or by the swelling of the starch granules (during the ensiling process) which makes the granules more accessible for α-amylase through the small intestine (Sholly *et al.* 2011). Thus, the promotion of the swelling and/or the solubilization of starch granules due to ensiling could increase the ruminal degradation and the whole-tract digestibility of starch and consequently the OM, while other studies did not observe any effects of TMR ensiling on the OM digestibility (Cao *et al.* 2010; Shakeri *et al.* 2021).

Feeding lambs with the FTMR2 diet resulted in higher final live weight, daily weight gain, warm and cold carcass weights, and increased FCR. These observed results on growth performance of the lambs might be mainly attributed to higher OM intake and digestibility due to higher starch digestibility in this group. It was reported that feeding ensiled TMR did increase total ruminal volatile fatty acids (VFA) especially propionic acid, decrease butyric acid and enhance milk production in dairy cows (Miyaji and Nonaka, 2018; Bueno *et al.* 2020).

Table 3 Growth performance and carcass traits of fattening lambs fed fermented total mixed ration (FTMR) with or without wheat straw

Items	Experimental diets[1]			SEM	P-value
	CON	FTMR1	FTMR2		
Initial weight (kg)	20.3	20.5	20.9	0.87	0.43
Final weight (kg)	37.2[b]	38.1[ab]	39.4[a]	0.63	0.02
Live daily gain (kg)	0.21[c]	0.22[bc]	0.23[a]	0.002	0.03
Feed conversion ratio (kg DMI/ kg gain)	6.36[a]	6.37[a]	6.15[b]	0.13	0.02
Warm carcass weight (kg)	17.10[b]	17.85[ab]	18.21[a]	0.77	0.04
Cold carcass weight (kg)	16.77[b]	17.63[ab]	17.88[a]	0.72	0.03
Warm dressing percentage	45.97	46.85	46.10	0.65	0.07
Cold dressing percentage	45.08[b]	46.27[a]	45.26[b]	0.21	0.01
Cooler shrink (% of warm carcass)	1.92[a]	1.23[b]	1.81[a]	0.12	0.01

[1] CON: typical fresh TMR with alfalfa hay and F:C ratio of 45:55; FTMR1: fermented TMR using fresh-cut alfalfa similar to CON formulation and FTMR2: fermented TMR using fresh-cut alfalfa and wheat straw with F:C ratio of 40:60.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 4 Weight of carcass prime cuts of fattening lambs fed fermented total mixed ration (FTMR) with or without wheat straw

Items	Experimental diets[1]			SEM	P-value
	CON	FTMR1	FTMR2		
Neck (kg)	1.20	1.25	1.32	0.11	0.24
Neck (% of carcass)	7.16	7.30	7.37	0.32	0.61
Shoulder (kg)	2.51	2.58	2.66	0.27	0.65
Shoulder (% of carcass)	14.95	14.70	14.87	0.29	0.47
Brisket (kg)	2.98[b]	3.16[b]	3.76[a]	0.22	0.03
Brisket (% of carcass)	17.75[b]	18.02[b]	21.02[a]	0.96	0.02
Loin (kg)	3.49	3.88	3.55	0.48	0.11
Loin (% of carcass)	20.81	22.11	19.83	0.94	0.17
Leg (kg)	4.85	4.89	4.90	0.92	0.26
Leg (% of carcass)	28.91	27.86	27.43	1.09	0.38
Fat-Tail (kg)	1.69	1.77	1.68	0.14	0.71
Fat-Tail (% of carcass)	10.05	10.06	9.41	0.33	0.41

[1] CON: typical fresh TMR with alfalfa hay and F:C ratio of 45:55; FTMR1: fermented TMR using fresh-cut alfalfa similar to CON formulation and FTMR2: fermented TMR using fresh-cut alfalfa and wheat straw with F:C ratio of 40:60.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Table 5 Weight of non-carcass components of fattening lambs fed fermented total mixed ration (FTMR) with or without wheat straw

Items (kg)	Experimental diets[1]			SEM	P-value
	CON	FTMR1	FTMR2		
Feet	0.79	0.74	0.81	0.06	0.13
Pelt	3.76	3.48	3.81	0.49	0.47
Heart	0.11	0.14	0.12	0.02	0.11
Liver	0.51	0.54	0.59	0.07	0.23
Kidneys	0.07	0.09	0.08	0.03	0.33
Lung	0.29	0.31	0.30	0.03	0.78
Spleen	0.79	0.74	0.81	0.08	0.38
Gallbladder	0.02	0.03	0.03	0.004	0.29
Head	2.22[b]	2.03[b]	2.65[a]	0.22	0.01
Testis	0.21[b]	0.23[b]	0.32[a]	0.07	0.04

[1] CON: typical fresh TMR with alfalfa hay and F:C ratio of 45:55; FTMR1: fermented TMR using fresh-cut alfalfa similar to CON formulation and FTMR2: fermented TMR using fresh-cut alfalfa and wheat straw with F:C ratio of 40:60.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

In addition, Cao *et al.* (2010) reported that feeding fermented TMR versus fresh TMR increased nutrient digestibility, total VFA and propionate, also it caused a noticeable decrease in ruminal methane emission. Generally, lactic acid in the silage is fermented to propionate by microorganisms in the rumen, that is a hydrogen consuming reaction (Russell and Wallace, 1997; Moss *et al.* 2000).

Thus, the hydrogen in the rumen will decrease, which in turn can reduce methanogenesis and consequently lowers the loss of energy through methane formation and improves efficiency of dietary energy utilization (Cao *et al.* 2010). Altogether, these alterations could impact the growth performance of FTMR2 lambs through higher energy utilization efficiency.

Table 6 Carcass composition and gastrointestinal tract parts of fattening lambs fed fermented total mixed ration (FTMR) with or without wheat straw

Items	Experimental diets[1]			SEM	P-value
	CON	FTMR1	FTMR2		
Lean meat (kg)	12.69[b]	13.01[b]	13.60[a]	0.29	0.02
Lean meat (% of carcass weight)	75.67[a]	73.79[b]	76.06[a]	0.60	0.04
Bone (kg)	2.39	2.85	2.60	0.20	0.11
Bone (% of carcass weight)	14.25	16.15	14.53	0.83	0.21
Lean/bone ratio	5.42	5.29	5.50	0.63	0.84
Back fat thickness (mm)	4.18[a]	4.35[a]	3.78[b]	0.30	0.01
Eye muscle area (cm^2)	15.55	16.39	17.23	0.69	0.07
Perirenal fat (kg)	0.12	0.14	0.12	0.01	0.13
Intestinal fat (kg)	0.41	0.45	0.43	0.13	0.87
Heart fat (kg)	0.09	0.07	0.06	0.04	0.51
Full forestomach + abomasum	6.30	7.01	6.58	0.85	0.63
Empty forestomach (kg)	2.10	2.13	2.06	0.31	0.93
Full rumen (kg)	3.83	3.87	3.90	0.66	0.98
Empty rumen (kg)	0.79	0.81	0.78	0.11	0.78
Empty abomasum (kg)	0.13	0.14	0.13	0.02	0.43
Small intestine (kg)	0.61	0.57	0.58	0.11	0.78
Large intestine (kg)	0.19	0.20	0.21	0.04	0.69
Cecum (kg)	0.1	0.11	0.1	0.005	0.25

[1] CON: typical fresh TMR with alfalfa hay and F:C ratio of 45:55; FTMR1: fermented TMR using fresh-cut alfalfa similar to CON formulation and FTMR2: fermented TMR using fresh-cut alfalfa and wheat straw with F:C ratio of 40:60.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Lambs fed with the FTMR1 diet exhibited lower cooler shrink and higher cold dressing percentage of the carcass compared to CON and FTMR2. This also indicates greater water-holding capacity of meat, thus lesser weight loss as one of the major economic losses during the rigor mortis process (Zhang *et al.* 2019). The cost of lost weight was calculated as 17 times that of the energy used by small industrial users in the UK (Brown *et al.* 2009). Cooler shrink (also named chilling loss) highly differs among various breeds, according to More-O'Ferrall *et al.* (1989); and higher cooler shrink results in lower meat water-holding capacity, which has high importance in packaging trades. However, the reduced cooler shrink observed in FTMR1 lambs might be attributed to marbling fat deposits that affect water losses during the chilling process, although results of the relationship between the intermuscular fat and water-holding capacity of meat are not consistent among studies (Watanabe *et al.* 2018).

To the best of our knowledge, no study has evaluated the effect of feeding ensiled TMR on carcass traits such as carcass prime cuts, composition and/or non-carcass organs. The weight of the carcass brisket cut was higher for FTMR2 lambs which might be attributed to higher final BW in this group, as was the case of head and testis components. However, the weights of breast, shoulder, leg, loin and ribs carcass cuts of fattening lambs were not affected by the forage: concentrate ratio in the diet (Archimède *et al.* 2008).

Reducing the forage: concentrate ratio of the diet resulted in higher carcass lean meat and lower backfat thickness in the FTMR2 group. Rumen microorganisms generally transform the dietary glycogenic organic components into utilizable energy precursors such as VFA through the fermentation process for the host animal. Furthermore, the body fat deposition rate is also primarily controlled by the production of the ruminal VFA, specifically acetate and butyrate, which are the main precursors for *de novo* fatty acid biosynthesis in ruminants (Ladeira *et al.* 2016; Kotupan and Sommart, 2021). Thus, an increase in the NFC and a decrease in the NDF content in the FTMR2 diet might have demoted the production of major lipogenic VFA (acetate and butyrate) in the diet which, in turn, might have impacted the *de novo* synthesis of fatty acids and reduced backfat thickness in FTMR2 lambs. In addition, the previously mentioned alterations in FTMR2 compared to CON and/or FTMR1 diets might have stimulated the microbial protein synthesis in the rumen, which is a suitable source of metabolizable protein promoting muscle tissue growth and formation during the growth phase in this group of lambs. These results are in contradiction with the findings of Kim *et al.* (2018) who reported no effects on carcass backfat thickness of Hanwoo steers when feeding fermented TMR compared to fresh TMR. Also, Kim *et al.* (2021) who found no responses on carcass backfat thickness when supplementing Hanwoo steers with fermented feed. However, Kotupan and Sommart (2021) reported higher carcass backfat thickness and marbling score in fattened beef cattle with increasing levels of broken rice in fermented TMRs.

CONCLUSION

To the best of our knowledge, this study was the first to investigate the effect of incorporating alfalfa forage in FTMR on the growth performance and carcass characteristics of fattening fat-tailed lambs. According to the findings, FTMR not only enhanced feed intake, growth performance but also improved the carcass composition traits of fattening male lambs compared to the conventional fresh TMR feeding strategy using alfalfa hay. Under the conditions of this study, wherein the alfalfa forage and wheat straw are used to prepare FTMR diets, the use of fresh alfalfa forage and a slight increase in concentrate proportion of diet and wheat straw as a proper tool to adjust for the desired DM content of silage would be recommended as a cost-effective and feasible TMR conservation method. Furthermore, dietary substitution of the agricultural byproducts for common feedstuffs; also, dietary supplementation with ruminal fermentation modifiers are addressed as some recommendations to be evaluated in future TMR silage fed fattening trials.

ACKNOWLEDGEMENT

The authors thank the staff of the small ruminant research unit of the animal science department of the faculty of agriculture (Shahid Bahonar University of Kerman) for kind helping through animal trial and sample collection procedures.

REFERENCES

Allen M.S. (1996). Physical constraints on voluntary intake of forages by ruminants. *J. Anim. Sci.* **74,** 3063-3075.

AOAC. (1990). Official Methods of Analysis. Vol. I. 15th Ed. Association of Official Analytical Chemists, Arlington, VA, USA.

Archimède H., Pellonde P., Despois P., Etienne T. and Alexandre G. (2008). Growth performances and carcass traits of Ovin Martinik lambs fed various ratios of tropical forage to concentrate under intensive conditions. *Small Rumin. Res.* **75,** 162-170.

Brown T., Richardson R.I., Wilkin C.A. and Evans J.A. (2009). Vascular perfusion chilling of red meat carcasses – A feasibility study. *Meat Sci.* **83,** 666-671.

Bueno A.V.I., Lazzari G., Jobim C.C. and Daniel J.L.P. (2020). Ensiling Total Mixed Ration for Ruminants: A Review. *Agronomy*. **10,** 879-887.

Cao Y., Takahashi T., Horiguchi K., Yoshida N. and Cai Y. (2010). Methane emissions from sheep fed fermented or non-fermented total mixed ration containing whole-crop rice and rice bran. *Anim. Feed Sci. Technol.* **157,** 72-78.

Fang J., Xia G. and Cao Y. (2019). Effects of replacing commercial material with apple pomace on the fermentation quality of total mixed ration silage and its digestibility, nitrogen balance and rumen fermentation in wethers. *Grassl. Sci.* **66,** 124-131.

Gao R., Luo Y., Xu S., Wang M., Sun Z., Wang L. and Yu Z. (2021). Effects of replacing ensiled-alfalfa with fresh-alfalfa on dynamic fermentation characteristics, chemical compositions, and protein fractions in fermented total mixed ration with different additives. *Animals*. **11,** 572-581.

Kashan N.E.J., Manafi Azar G.H., Afzalzadeh A. and Salehi A. (2005). Growth performance and carcass quality of fattening lambs from fat-tailed and tailed sheep breeds. *Small Rumin. Res.* **60,** 267-271.

Kim D., Jung J.S. and Choi K.C. (2021). A preliminary study on effects of fermented feed supplementation on growth performance, carcass characteristics, and meat quality of Hanwoo steers during the early and late fattening period. *Appl. Sci.* **11,** 5202-5210.

Kim T.I., Mayakrishnan V., Lim D.H., Yeon J.H. and Baek K.S. (2018). Effect of fermented total mixed rations on the growth performance, carcass and meat quality characteristics of Hanwoo steers. *J. Anim. Sci.* **89,** 606-615.

Kotupan S. and Sommart K. (2021). Broken rice in a fermented total mixed ration improves carcass and marbling quality in fattened beef cattle. *Anim. Biosci.* **34,** 1331-1341.

Ladeira M.M., Schoonmaker J.P., Gionbelli M.P., Dias J.C.O., Gionbelli T.R.S., Carvalho J.R.R. and Teixeira P.D. (2016). Nutrigenomics and beef quality: A review about lipogenesis. *Int. J. Mol. Sci.* **17,** 918-924.

Li P., Zhang Y., Gou W., Cheng Q., Bai S. and Cai Y. (2019). Silage fermentation and bacterial community of bur clover, annual ryegrass and their mixtures prepared with microbial inoculant and chemical additive. *Anim. Feed Sci. Technol.* **247,** 285-293.

Li R., Zheng M., Jiang D., Tian P., Zheng M. and Xu C. (2021). Replacing alfalfa with paper Mulberry in total mixed ration silages: Effects on ensiling characteristics, protein degradation, and *in vitro* digestibility. *Animals*. **11**, 1273-1281.

Li Y., Lv J., Wang J., Zhou S., Zhang G., Wei B., Sun Y., Lan Y., Dou X. and Zhang Y. (2021). Changes in carbohydrate composition in fermented total mixed ration and its effects on *in vitro* methane production and microbiome. *Front. Microbiol.* **12,** 1-9.

Liu M.J., Wang Y., Li Y.Y., Si Q., Bao J., Ge G.T., Wang Z.J., Jia Y.S. and Du S. (2023). Effects of alfalfa and oat supplementation in fermented total mixed rations on growth performances, carcass characteristics, and meat quality in lambs. *Small Rumin. Res.* **218,** 106877-106887.

Miyaji M., Matsuyama H. and Nonaka K. (2016). Effect of ensiling process of total mixed ration on fermentation profile, nutrient loss and *in situ* ruminal degradation characteristics of diet. *J. Anim. Sci.* **88,** 134-139.

Miyaji M. and Nonaka K. (2018). Effects of altering total mixed ration conservation method when feeding dry-rolled versus steam-flaked hulled rice on lactation and digestion in dairy cows. *J. Dairy Sci.* **101,** 5092-5101.

More-O'ferrall G.J., Joseph R.L., Tarrant P.V. and McGloughlin P. (1989). Phenotypic and genetic parameters of carcass and meat-quality traits in cattle. *Livest. Prod. Sci.* **21,** 35-47.

Moss A.R., Jouany J.P. and Newbold J. (2000). Methane production by ruminants: its contribution to global warming. *Ann. Zootech*. **49,** 231-253.

Nishino N., Wada H., Yoshida M. and Shiota H. (2004). Microbial counts, fermentation products, and aerobic stability of whole crop corn and a total mixed ration ensiled with and without inoculation of *Lactobacillus casei* or *Lactobacillus buchneri*. *J. Dairy Sci.* **87,** 2563-2570.

NRC. (2001). Nutrient Requirements of Dairy Cattle. 7th Ed. National Academy Press, Washington, DC., USA.

NRC. (2007). Nutrient Requirements: Sheep, Goats, Cervids, and New World Camelids. National Academy Press, Washington, DC, USA.

Peyrat J., Noziere P., Le Morvan A., Ferard A., Protin P.V. and Baumont R. (2014). Effects of ensiling maize and sample conditioning on *in situ* rumen degradation of dry matter, starch and fibre. *Anim. Feed Sci. Technol.* **196,** 12-21.

Russell J.B. and Wallace R.J. (1997). Energy-yielding and energy-consuming reactions. Pp. 246-282 in The Rumen Microbial Ecosystem. P.N. Hobson and C.S. Stewart, Eds., Blackie Academic and Professional, London, United Kingdom.

Santos F.N.S., Santos E.M., Oliveira J.S., Medeiros G.R., Zanine A.M., Araújo G.G.L., Perazzo A.F., Lemos M.L.P., Pereira D.M., Cruz G.F.L., Paulino R.S. and Oliveira C.J.B. (2020). Fermentation profile, microbial populations, taxonomic diversity and aerobic stability of total mixed ration silages based on Cactus and Gliricidia. *J. Agric. Sci.* **158,** 396-405.

SAS Institute. (2005). SAS®/STAT Software, Release 9.4. SAS Institute, Inc., Cary, NC. USA.

Shakeri P., Fazeli H., Aghashahi A.R. and Shakeri A.A. (2021). Effects of using ensiled total mixed ration based on fodder beet on performance, digestibility, and blood parameters in fattening Zell lambs. *J. Rumin. Res.* **9,** 97-108.

Sholly D.M., Jørgensen H., Sutton A.L., Richert B.T. and Bach Knudsen K.E. (2011). Effect of fermentation of cereals on the degradation of polysaccharides and other macronutrients in the gastrointestinal tract of growing pigs. *J. Anim. Sci.* **89,** 2096-105.

Van Keulen J. and Young B. (1977). Evaluation of acid-insoluble ash as a natural marker in ruminant digestibility studies. *J. Anim. Sci.* **44,** 282-287.

Van Soest P.J., Robertson J.B. and Lewis B.A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci*. **74,** 3583-3597.

Wang M., Franco M., Cai Y. and Yu Z. (2020). Dynamics of fermentation profile and bacterial community of silage prepared with alfalfa, whole-plant corn and their mixture. *Anim. Feed. Sci. Technol.* **270**, 114702-114702.

Watanabe G., Motoyama M., Nakajima I. and Sasaki K. (2018). Relationship between water-holding capacity and intramuscular fat content in Japanese commercial pork loin. *Asian-Australas. J. Anim. Sci*. **31,** 914-918.

Xu G., Han Z., Wang S., Dai T., Dong D., Zong C., Yin X., Jia Y. and Shao T. (2022). Soy sauce residue in total mixed ration silage: fermentation characteristics, chemical composition, *in vitro* digestibility and gas production. *Italian J. Anim. Sci.* **21,** 1058-1066.

Zhang Y., Mao Y., Li K., Luo X. and Hopkins D.L. (2019). Effect of carcass chilling on the palatability traits and safety of fresh red meat. *Compr. Rev. Food Sci. Food Saf.* **18,** 1676-1704.

Zhao J., Wang S., Dong Z., Chen L. and Shao T. (2021). Partial substitution of whole-crop corn with bamboo shoot shell improves aerobic stability of total mixed ration silage without affecting *in vitro* digestibility. *J. Anim. Physiol. Anim. Nutr.* **105,** 431-441.