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Effect of alfalfa hay on growth performance, carcass characteristics, and meat quality of growing lambs with *ad libitum* access to total mixed rations

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ABSTRACT - Forty male Naemi lambs were used to evaluate the effect of total mixed rations (TMR) alone or in combination with supplementation of alfalfa hay offered at different schedules on growth, carcass characteristics, and meat quality. Lambs at the age of three months, with an average weight of 28.85±1.09 kg, were randomly selected and distributed into four different feeding systems, 10 lambs each, as follows: TMR diet (control); TMR plus 100 g alfalfa hay; TMR plus 200 g alfalfa hay every two days; and TMR plus 300 g alfalfa hay every three days. The TMR and fresh drinking water were offered *ad libitum*. Lambs in the treated groups (with alfalfa hay) had significantly higher body weight, body weight change, dry matter intake, and feed conversion ratio compared with the control. Similarly, slaughter weight, carcass weight (hot and cold), and internal organs weight significantly increased in the treated groups, except for dressing weight percentage, which improved only in the treatment with TMR plus 300 g alfalfa hay. By contrast, mesentery fat, back fat, and body wall fat decreased in treated groups. Meat quality characteristics indicated that cooking loss and pH values did not differ between the control and treated groups; however, meat colour (lightness, yellowness, and redness) and pH (1 and 24 h) improved in post-slaughter treated groups. Furthermore, no difference was found in texture profile analysis (hardness, springiness, cohesiveness, and chewiness), although the shear force decreased significantly in treated groups. Addition of alfalfa hay offered at the present plan may not only improve the growth and carcass characteristics, but also enhance the meat quality of Naemi lambs. From the labour and economic point of view, TMR plus 300 g alfalfa hay every three days may be adopted while taking into account the management decision.

Key Words: body weight, fat depots, feeding management, slaughter characteristics, supplementation

Introduction

In the past decades, researchers and producers focused on satisfying consumer demand and the perception of the healthiness of red meat, thereby increasing acceptability and profitability. Recently, due to the increasing demand for local lamb meat, the production of lambs in Saudi Arabia has been shifted from a traditional feeding system to a new intensive fattening system in which the animals have *ad libitum* access to a high-concentrate diet to ensure fast growth (Alhidary et al., 2016). The post-weaning stage is a critical period during which young lambs are exposed to high-energy diets and can lead to serious complications such as rumen acidosis and abnormal structural and functional development of the rumen wall (Cavini et al., 2015). In addition, raising lambs on high starch increases the incidence of accumulating fat depots inside the body, which reduces their acceptability at consumer level due to increased awareness of diseases associated with consumption of fats (Resconi et al., 2009; Jacques et al., 2011).

The type of diet influences carcass composition and meat quality in food animals (Lee et al., 2008). To achieve the desired target of weight in lambs, different systems are practised, in which the most important are based on pasture, silage, concentrate, and forage (Bodas et al., 2014). Total mixed rations (TMR) consisting of a balanced amount of all feed ingredients have provided a practical solution to achieve the desired goal in fattening animals (Nissanka et al., 2010; Shekarchian, 2012). A diet based only on forage may produce desirable body weight; however, such a dietary plan is linked to higher feed intake and poor feed efficiency (Casasús et al., 2012). A combination of a certain level of TMR and roughages has produced better rumen conditions (Tufarelli et al., 2011; Tufarelli et al., 2012; Alvarez-Rodríguez et al., 2012; Bodas et al., 2014; Alhidary et al., 2016). However, feeding roughages only to growing

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animals does not support the optimal growth of the rumen (Papi et al., 2011; Alvarez-Rodríguez et al., 2012; Steele et al., 2012). Feeding a highly concentrate diet or a diet plan based on only forages are not beneficial for the rumen health. Therefore, it is essential to formalize a dietary plan that can maintain the rumen health with no negative effects on the performance of the animal and acceptability of its meat.

Evaluation of growth and carcass is necessary to assess the relative efficiency of the animals in converting feed to animal tissue (Resconi et al., 2009; Majdoub-Mathlouthi et al., 2013). Such evaluation system is rarely practiced in Saudi Arabia. In the literature, most of the studies compared the meat traits in lambs raised on concentrate versus forage-based diets at different ratios. In the current study, alfalfa hay was supplemented assuming that the additional neutral detergent fibre provided in the form of alfalfa in the diet of growing Naemi lambs with free access to TMR may positively affect their growth performance, carcass characteristics, and meat quality. Therefore, the purpose of this study was to evaluate the effect of graded levels of alfalfa hay (100 g/day, 200 g/2 days, 300 g/3 days) with *ad libitum* TMR, on the growth, carcass characteristics, and meat quality of growing Naemi lambs. Furthermore, the labour of supplementation is a major practical and economical factor to consider when making management decisions. Therefore, the second objective was to choose the best option from the labour and economic point of view.

Material and Methods

Growing male Naemi lambs (n = 40), 3 months old, average weight 28.85±1.09 kg, were used in this experiment. Healthy lambs were housed in individual pens. The lambs were randomly divided after 15 days of the adaptation period into four dietary feeding systems (10 lambs/treatment). The dietary systems were: control (TMR); TMR + 100 g alfalfa hay/day; TMR + 200 g alfalfa hay/2 days; and TMR + 300 g alfalfa hay/3 days. The TMR consisted of barley, wheat, palm kernel meal, soybean hulls, wheat bran, alfalfa, salt, limestone, and molasses (Table 1). The TMR was offered at 8.00 h in automatic feeders *ad libitum*; the offered amount was increased daily by 20%, and refusals were weighed and discarded. The treatment of alfalfa was continued for three months.

Feed samples were collected weekly for nutritional analysis (AOAC, 1990). Feed intake was recorded weekly until the end of the trial. Body weights were recorded at the beginning of the experiment and every two weeks until the end of the experiment.

At the end of the experiment, lambs (six months old) were fasted for 16 h with free access to water prior to slaughter. Pre-slaughter weights were determined and the animals were slaughtered in the abattoir by the Halal method. After slaughter, the heads were removed at the atlanto-occipital joint and the fore and hind feet were removed at the carpal and tarsal joints, respectively. The animals were partially skinned lying on their back on the floor of the abattoir and then suspended by the hind leg (Achilles tendon) for further skinning. Carcass and non-carcass components were separated and weighed immediately. After skinning and evisceration, stomach, intestines, heart, liver, spleen, and kidneys were removed and weighed (as a % of the slaughter weight) on an electronic balance after removing the fat. Omental and mesentery fats were removed and weighed. Stomach and intestines were freed of digesta, washed, and then weighed. After determining hot carcass weight, each carcass was chilled to 4 °C within 45 min *post-mortem* similarly to the commercial practice. The slaughter procedure and measurements for all the groups were similar. After slaughtering, hot and cold carcass weights were taken and recorded to determine dressing percentage.

pH (1 h and after 24 h) was measured at the fourth vertebral region with a pH meter (Model pH 211, Hanna Instruments, Woonsocket, RI, USA) equipped with a Crison 507 penetrating electrode (Crison Instruments S.A., Barcelona, Spain). Similarly, meat colour (*rectus abdominis*) was measured after 1 and subsequently 24 h *post-mortem* by using a chroma meter (Konica Minolta, CR-400- Japan)

Table 1 - Chemical composition of total mixed rations and alfalfa (%, dry matter basis) (mean ± standard deviation)

Ingredient (dry matter basis, %)	Total mixed ration	Alfalfa
Barley	18.00	-
Wheat	29.92	-
Palm kernel meal	20.00	-
Soybean hulls	12.03	-
Wheat bran	3.00	-
Alfalfa	6.00	-
Salt	0.47	-
Limestone	2.58	-
Molasses	7.85	-
Commercial premix[1]	0.15	-
Composition (%)		
Dry matter	91.04±1.1	18.1±0.03
Crude protein	12.4±0.3	18.5±0.8
Crude fibre	11.98±0.12	28.2±1.2
Ether extract	2.61±0.17	1.9±0.03
Neutral detergent fibre	41.95±2.11	43.5±2.13
Acid detergent fibre	26.10±3.42	21.6±0.8
Ash	9.09±0.4	10.95±0.1

[1] Contained per kg: 10,000 IU vitamin A; 1,000 IU vitamin D; 20 IU vitamin E; 300 mg Mg; 24 mg Cu; 0.6 mg Co; 1.2 mg I; 60 mg Mn; 0.3 mg Se; 60 mg Zn.

and the CIELAB System (1976) for the colour values (L* for lightness, a* for redness, and b* for yellowness). Each colour value was recorded at three locations randomly selected, avoiding blood blots, discolorations, and less covered areas. Back and body wall fat was recorded using an AUSMEAT procedure for lambs as described by Pannier et al. (2014). A muscle sample (150 g) from the *longissimus dorsi* was collected, placed in polyethylene bags, and stored at −20 °C for measurement of tenderness using a Warner-Bratzler shearing test instrument as described by Ponnampalam et al. (2014). Cooking loss was determined according to the method described by Lee et al. (2008). The difference in weight of samples before and after cooking was expressed as a percentage cooking loss.

Data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS, version 9.1) according to the following model:

$$y_{i,j} = \mu + \tau_j + \varepsilon_{i,j},$$

in which i = 1,..., I is an index over experimental units (animals); j = 1,..., J is an index over treated groups (diet treatments); $y_{i,j}$ are observations; μ is the grand mean of the observations; τ_j is the j-th treatment effect, a deviation from the grand mean; and $\varepsilon_{i,j}$ are normally distributed zero-mean random errors.

Results

There were no significant differences between all dietary groups in terms of initial live body weight, but significant (P<0.05) differences were detected in body weight on a monthly basis or final body weight, with higher values in lambs fed alfalfa compared with control (Table 2). Furthermore, significantly (P<0.05) higher total body gain, total dry matter intake, and total feed conversion ratio (TFCR) were found in lambs fed TMR with different alfalfa hay feeding protocols compared with TMR alone (Table 3).

The different feeding regimens caused significant (P<0.05) differences in slaughter weight, hot carcass, cold carcass, heart, empty stomach, empty body, liver, spleen, kidneys, empty intestine, and dressing percentages (Table 4). Lambs fed alfalfa with different protocols showed significantly (P<0.05) higher values for slaughter weight, cold carcass weight, spleen weight, kidney weight, and chill shrink percentage compared with control. No significant difference was found in omental fat between control and treated groups; however, mesentery fat, back fat, and body wall fat decreased significantly (P<0.05) in treated groups (Table 5).

There was no significant difference in cooking losses and pH (1 and 24 h) between control and treated groups (Table 6). Water-holding capacity decreased significantly (P<0.05) in treated groups. Lightness (L*) and redness (a*) were significantly low (P<0.05) in treated groups, while yellowness (b*) was significantly (P<0.05) high in treated groups when measured 1 and 24 h after slaughter.

The highest shear value (the least tender meat) was attained by lambs from control group (4.16 kg). Shear force decreased significantly (P<0.05) in treated groups (Table 7). The different feeding systems did not cause any significant effect on the measurements of the texture profile analysis.

Discussion

An adequate amount of roughages is necessary in TMR for proper structural and functional development of the rumen (van Ackeren et al., 2009). In this research work, weaning weight was similar in the four groups; however, the inclusion level of alfalfa hay in addition to TMR increased feed intake and improved weight gain in the lambs. Previously, in line with our research, it was reported that manipulation of TMR with certain types of roughages may improve feed intake and weight gain in fattening animals (Tufarelli et al., 2012; Bodas et al., 2014). Alfalfa provides higher energy content compared with other grasses

Table 2 - Effects of TMR alone or with different supplementary protocols of alfalfa hay on body weight of growing Naemi lambs

	Body weight, kg			
	Initial	1st month	2nd month	Final
TMR	27.78	34.03a	40.96a	46.26a
TMR + 100 g alfalfa hay/day	29.81	38.02b	45.00b	51.95b
TMR + 200 g alfalfa hay/2 days	29.78	37.36b	45.79b	52.25b
TMR + 300 g alfalfa hay/3 days	28.04	36.47b	44.44b	51.93b
Standard error	0.97	0.95	1.12	1.16

Means within a row followed by different letters differ significantly (P<0.05).
TMR - total mixed ration.

Table 3 - Effects of TMR alone or with different protocols of alfalfa hay supplement on body weight (BW) change, total DMI, and TFCR of growing Naemi lambs

	BW change, kg	DMI, kg	TFCR
TMR	18.48a	118.41a	6.51a
TMR + 100 g alfalfa hay/day	22.14b	152.26b	6.96b
TMR + 200 g alfalfa hay/2 days	22.47b	152.38b	6.82b
TMR + 300 g alfalfa hay/3 days	23.89b	152.06b	6.75b
Standard error	0.83	0.51	0.22

Means within a row followed by different letters differ significantly (P<0.05).
TMR - total mixed ration; DMI - dry matter intake; TFCR - total feed conversion ratio.

Table 4 - Effects of TMR alone or with different protocols of alfalfa hay supplement on the weight of body components of growing Naemi lambs

	Control	TMR + 100 g alfalfa hay/day	TMR + 200 g alfalfa hay/2 days	TMR + 300 g alfalfa hay/3 days	SE
Slaughter weight, kg	52.9a	54.69b	54.68b	54.57b	1.42
Hot carcass weight, kg	25.6a	29.57b	27.65b	28.08b	0.84
Cold carcass weight, kg	25.5a	30.92b	27.07b	28.45b	0.83
Heart weight, kg	0.15a	0.21b	0.24b	0.23b	0.06
Liver weight, kg	0.70a	0.83b	0.86b	0.95b	0.02
Spleen weight, kg	0.06a	0.08b	0.08b	0.09b	0.03
Kidneys weight, kg	0.10a	0.13b	0.13b	0.14b	0.03
Empty stomach weight, kg	1.29a	1.38b	1.35b	1.68c	0.09
Empty intestines weight , kg	1.30a	1.52b	1.83b	1.97b	0.11
Hot carcass dressing, %	50.70a	50.56a	50.78a	49.74b	0.01
Cold carcass dressing, %	50.53a	50.43a	50.70a	48.86b	0.01

Means within a row followed by different letters differ significantly (P<0.05).
TMR - total mixed ration; SE - standard error.

Table 5 - Effects of TMR alone or with different protocols of alfalfa hay supplement on carcass fat depots of growing Naemi lambs

Characteristic	Control	TMR + 100 g alfalfa hay/day	TMR + 200 g alfalfa hay/2 days	TMR + 300 g alfalfa hay/3 days	SE
Omental fat, kg	0.91a	0.95a	1.00a	0.96a	0.21
Mesentery fat, kg	0.36a	0.21b	0.18b	0.22b	0.02
Back fat, mm	10.06a	8.40b	8.90b	8.10b	0.03
Body wall fat, mm	6.69a	4.48b	4.67b	5.12b	0.39

Means within a row followed by different letters differ significantly (P<0.05).
TMR - total mixed ration; SE - standard error.

Table 6 - Effects of TMR alone or with different protocols of alfalfa hay supplement on meat quality of growing Naemi lambs

Characteristic	Control	TMR + 100 g alfalfa hay/day	TMR + 200 g alfalfa hay/2 days	TMR + 300 g alfalfa hay/3 days	SE
Cooking loss, %	30.70	32.00	29.98	32.16	0.12
pH (1 h PM)	6.16	6.07	6.17	6.23	0.09
pH (24 h PM)	5.89	5.80	5.87	5.83	0.02
Meat color (1 h PM)					
L*	38.10a	27.81b	25.27b	28.38b	2.54
a*	16.30a	20.55b	19.38b	18.58b	0.47
b*	3.06a	4.33b	4.10b	4.39b	0.30
Meat color (24 h PM)					
L*	39.20a	45.35b	43.22b	46.48b	0.78
a*	17.90a	23.85b	24.55b	23.99b	0.97
b*	7.07a	11.40b	9.20b	10.87b	0.66

Means within a row followed by different letters differ significantly (P<0.05).
TMR - total mixed ration; SE - standard error; PM - *post mortem*.

Table 7 - Effects of TMR alone or with different protocols of alfalfa hay supplement on shear force, hardness, springiness, cohesiveness, and chewing quality of meat of growing Naemi lambs

Characteristic	Control	TMR + 100 g alfalfa hay/day	TMR + 200 g alfalfa hay/2 days	TMR + 300 g alfalfa hay/3 days	SE
Shear force, kg	2.16a	1.65b	1.78b	1.62b	0.16
Texture profile analysis					
Hardness, kg	0.41	0.34	0.39	0.43	0.02
Springiness	0.64	0.65	0.66	0.69	0.02
Cohesiveness	0.52	0.50	0.51	0.49	0.01
Chewiness	0.16	0.21	0.16	0.15	0.03

Means within a row followed by different letters differ significantly (P<0.05)
TMR - total mixed ration; SE - standard error.

or grazing, which can result in a low growth rate (Alhidary et al., 2016). From the results of the present study, it could be inferred that free access of lambs to a certain amount of long alfalfa straw may have a beneficial impact on feed intake compared with TMR group and thus increased weight gain and feed efficiency in the respective groups. These results could have positive implications for better ruminal conditions. In line with the previous reports, consumption of roughages supports rumen motility, increases the size and muscular development, and promotes rumination (van Ackeren et al., 2009; Alvarez-Rodríguez et al., 2012). It is generally accepted that more fibre intake results in physical fill of the rumen and thus regulates intake (Jacques et al., 2011). Papi et al. (2011) documented that dry matter and energy intakes as well as body weight decreased when the level of concentrate was increased in the diet of lambs receiving different ratios of alfalfa hay, and concluded that this may be related to rumen acidosis and stasis. Therefore, it is inferred that feeding alfalfa hay in addition to TMR enhanced the feed intake and consequently weight gain of lambs. In the current study, the worst FCR was recorded in the group of lambs fed TMR alone. According to Karim et al. (2007), a higher fat depot (which was observed in this study) reduces FCR and increases the cost of feed per kg gain in live weight; thus, it is not cost-effective.

This study indicated that carcass weight and organ weight increased when alfalfa hay was supplemented in the lamb diet. In line with our study, Papi et al. (2011) reported that the increasing concentrate level had no beneficial effect on most of the carcass weight. In our experiment, we found that dressing percentage decreased significantly in the treatment with TMR plus 300 g alfalfa hay every three days. Dressing percentage is an important trait that is affected by age, breed, and nutrition (Karim et al., 2007). The only plausible reason for the reduction of dressing percentage in control group may be the corresponding increase in the fat depots and relatively higher slaughter weight compared with the other treated groups. The dressing percentage of 6-month-olds varies from 48 to 50% (Karim et al., 2007) which agrees with our findings. The weights of the digestive tract and gastric components are logically related to the type of diet consumed by the ruminants (Archimede et al., 2008). Thus, the carcass dressing was better in treated groups because of better body development.

The result of weight of the internal organs is heavier in the treated groups compared with the control group. In the present study, empty stomach was significantly higher in treated groups, particularly in the treatment with TMR plus 300 g alfalfa hay compared with the control group. Similar results were reported by Jacques et al. (2011). Our results do not agree with Joy et al. (2008), who reported heavier reticulum in lambs fed a concentrated diet. The heavier empty stomach weight may also partially be due to the corresponding heavier body weight in the treatment with TMR plus 300 g alfalfa hay. Similarly, the dressing percentage decreased ($P>0.05$) in this treatment compared with concentrate-fed lambs. The reduced dressing percentage may probably be due to the removal of heavier internal contents, which correspondingly reduced dressing percentage.

The results showed that omental fat, mesentery fat, back fat, and body wall fat decreased in lambs fed alfalfa hay. These results are in agreement with other researchers who found that lambs on high forage tended to deposit less subcutaneous and intestinal fats (Karim et al., 2007; Papi et al., 2011). Lambs fed a concentrate diet display significantly greater fatness than lambs raised on forage-based diets (Jacques et al., 2011). The reduced carcass fat may also be attributed to lower energy intake (Karim et al., 2007). In addition, high starch consumption in full-concentrate diets produces higher amounts of propionate, which ultimately increases insulin secretion and stimulates fat synthesis (Jacques et al., 2011).

Just after weaning, young animals fed hay and concentrate may show a different performance and thereby have their meat composition and quality affected (Lee et al., 2008). Dietary feeding systems did not have any influence on the cooking loss of lamb meat in the present study. Lee et al. (2008) reported that dietary feeding did not influence cooking loss in pork and chevon. Meat juiciness is influenced by its water content, which is a major contributor to the sensation of juiciness during eating (Lee et al., 2008). In the present study, the fat colour of the meat (L^*, a^*, and b^*) did not differ between control and treated groups. A relationship exists between concentrate intake and meat colour (Archimede et al., 2008). Undoubtedly, the lambs were slaughtered under similar conditions; lambs supplemented with alfalfa hay showed better meat colour than those fed TMR only, although the final pH was similar. Similarly, no difference was noted in these parameters between the treated groups. Partially similar results were reported by Carrasco et al. (2009) and Jacques et al. (2011) in the fat tissue of animals raised on pasture. Fat deposition in the animal body is affected by feeding system (Jacques et al., 2011). The colour variations in meat may be the consequence of the amount of green carotenoids stored in the meat (Carrasco et al., 2009). The results of the present study are important from the point of view of consumers satisfaction, as they are more interested in purchasing lean meat. Similar observations were recorded by Lee et al. (2008), who found that the brightness and yellowness of meat were higher when the goats were fed a diet consisting of concentrate and hay compared with the concentrate diet alone.

Hardness and springiness increased slightly in the treatment with TMR plus 300 g alfalfa hay every three days, although cohesiveness and chewiness decreased correspondingly in the same group. The increased hardness and springiness may be due to the lower fat content in the meat of this group. In the current study, shear force decreased significantly in the treated groups compared with control, although it was within the acceptable limit for lambs of about 3 kg (Webb et al., 2005). Shear force depends upon several factors, including treatment of the animals prior to slaughter, *post-mortem* technique, type of muscle, and its preparation (Lee et al., 2008).

Conclusions

A dietary plan based on *ad libitum* total mixed ration with addition of alfalfa at the rate of 300 g every three days not only enhances the growth performance but also improves carcass characteristics and meat quality of Naemi lambs. In addition, this treatment is more economical from the management point of view.

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