Pakistan J. Zool., vol. 50(6), pp 2129-2134, 2018. DOI: http://dx.doi.org/10.17582/journal.pjz/2018.50.6.2129.2134

Impact of Feeding Different Levels of Neutral Detergent Fiber as Total Mixed Rations on Sensory Attributes, Carcass Characteristics and Meat Quality of Growing Lambs

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Article Information
Received 11 November 2017
Revised 19 March 2018
Accepted 08 May 2018
Available online 06 September 2018

Authors' Contribution
MA and IAA performed experimental work. RSA did field work and statistical analysis. RSA, MA and IAA wrote the manuscript. GMS processed the data and did lab work. AHA ad MYA processed samples and presented and justified the data and results. FAA and MMA did field work and collected samples

Key words
Total mixed rations, Growing lambs, Performance, Carcass characteristics, Meat quality.

ABSTRACT

A feeding trial was conducted to study the effect of feeding Total Mixed Ration (TMR) with different levels of neutral detergent fibre (NDF), compared with the traditional feeding, on growth rate, carcass and meat quality measurements of growing lambs. Twenty growing lambs, 3 month old, were selected and randomly distributed to four different treatments as a complete randomized design as follow: Barley grain and alfalfa hay (BA); TMR1 (25.67% NDF; low level); TMR2 (30.88% NDF; medium level-recommended); TMR3 (55.93% NDF; high level). A significantly higher ($P<0.05$) average daily gain and lower value for the feed conversion ratio of lambs fed TMR2 compared with other dietary groups. There were no significant differences ($P>0.05$) between lambs fed TMRs with different levels of NDF for slaughter and body components parameters, except empty stomach (TMR2) and chill shrink (TMR1). Furthermore, the meat color (L*, a* and b*) values of lambs fed TMR2 were numerically higher compared with other groups with variable significant differences. A significantly lower values for the omental and mesentery fat were reported for lambs fed BA (0.55 and 0.67 kg, respectively), while the kidney knob and channel fat (KKCF) was significantly lower for lambs fed TMR2. In conclusion, feeding growing lambs a total mixed ration (TMR) with around 30% NDF improve the general performance and most of the required meat quality measurement.

INTRODUCTION

Total mixed ration (TMR) can be defined as mixture of roughage and concentrate in a form that avoid animal selection of concentrate which can prevent many metabolic disorders such as acidosis (Tufarelli *et al*., 2012a, b; Alhidary *et al*., 2016a; Abdelrahman *et al*., 2017a). In the last few years, a great shift is noticed from traditional extensive and semi intensive production systems to be an intensive system, using TMRs dietary regimes, in the most of the semi-arid countries, in order to increase and maximize animals' productivity by covering their nutrient requirements under different physiological conditions (Alhidary *et al*., 2016b; Abdelrahman *et al*., 2017b). Nissanka *et al*. (2010) reported an improvement in body weight, growth rate and muscle composition of growing heifers when fed TMR compare with separate feeding. Feeding system affect carcass confirmation, carcass fatness and distribution with the animal body (Carrasco *et al*., 2009) and meat and fat color (Joy *et al*., 2008). Meat color is the most important criteria that considered by the consumers to take a decision for purchasing the meat.

However, there have been inadequate and very limited information regarding growth performance; carcass and meat quality of growing lambs fed TMRs with different nutritional contents, especially dietary fiber. Fiber is considered to be an important ingredient in ruminant animal diet since it is efficiently utilized by ruminal bacteria to a useful product. Total mixed ration with high fiber content produces more acetic acid whereas high concentrate proportion leads to produce more propionic acid at the expense of the acetic acid (France and Dijkstra,

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0030-9923/2018/0006-2129 $ 9.00/0

2005). Neutral detergent fibre (NDF) is a combination of cellulose, hemicellulose and lignin accurately measure the dietary fiber level, which affect the feed intake, passage rate and consequently the nutrient digestibility (Grabber *et al*., 2009). It is very crucial to identify the proper dietary NDF level in the TMR to growing lambs with special consideration to the environmental factors in the semiarid areas. Recently, Alhidary *et al*. (2017) reported that feeding growing lambs TMR contents around 30% NDF leads to achieve a proper rumen and reticulum chemical characteristics, microbial efficiency and general performance in term of growth rate and feed efficiency. This finding agreed with Kozloski *et al*. (2006) which found feeding growing lambs TMR with 30% NDF significantly improve their productivity. Unfortunately, insufficient data has been reported regarding feeding TMRs with different levels of NDF to growing lambs on carcass composition and meat quality. The objective of this trial was to evaluate the effect of feeding different TMR, contain different NDF levels, compared to the traditional feeding system on the general performance of growing Naemi lambs, carcass characteristics and meat quality.

Table I.- The analytical nutritive values of the experimental diets (dry matter basis).

Nutrients	AH and BA*	TMR1	TMR2	TMR3
Dry matter (%)	18.10	90.04	88.34	91.21
Crude protein (%)	17.95	13.50	14.00	13.98
Crude fiber (%)	27.00	12.00	11.65	12.03
Ether extract (%)	1.80	2.45	2.50	2.54
NDF (%)	42.12	25.67	30.88	55.93
ADF (%)	20.98	25.76	25.11	25.42
Ash (%)	11.23	8.96	8.69	8.54

*AH and BA, Alfalfa hay and Barley grain was 50:50.

MATERIALS AND METHODS

Growing Naemi male lambs (n= 20), 3 month old, were used in this experiment. Lambs were housed in an individual pens at King Saud University (KSU) research station and injected sub-cutanously with 2 ml enterotoxaemia vaccine and Ivomic for internal and external parasites. The lambs were randomly divided, after one month adaptations period, into 4 dietary treatments (5 lambs/treatment). The dietary treatments were: 1. Alfalfa hay and barley grain (AB); 2. TMR1 (25.67% NDF; low level); 3. TMR2 (30.88% NDF; medium level-recommended); 4. TMR3 (55.93% NDF; high level). The TMRs were iso-caloric (GE= 4333.0±39.13 Kcal/kg DM basis) and iso-nitrogenous (CP= 13.70±0.44% DM basis; AOAC, 1990). Lambs were fed these diets as *ad libitum* for three months. The nutritive values of these assigned diets are presented in Table I. The main source of dietary NDF in the different TMRs was the alfalfa hay and wheat bran. All lambs were treated according to King Saud University welfare regulation and approval obtained to perform the trial.

The weights of offered feed and feed refusals were measured weekly and then feed intake was calculated on a dry matter (DM) basis. Lambs were weighed, using an electronic small animal scale for lambs, before morning feeding at 0730 h on day 1 of the study and every two weeks thereafter until the end of each study. Gain to feed ratio for each animal was calculated and expressed as bodyweight gain per kg of dry matter intake (DMI).

Three lambs from each group were slaughtered after 16 h fasting according to Islamic legislations by severing the jugular vein and the carotid artery. Hot and cold carcass characteristics were weighed to calculate dressing percentage. After slaughtering, hot and cold carcass weights were taken and recorded to determine dressing percentage. Liver, kidney, heart and spleen were collected and weighed. The rib eye area, kidney fat, omental fat, back fat thickness were measured. Furthermore, the meat color was measured using a Chroma meter (Konica Minolta, CR-400- Japan) and CIELAB Color System (1976) for the color values (L* for Lightness; a* for Redness and b* for Yellowness). The initial and ultimate meat pH was measured using a microprocessor pH-meter (Model pH 211, Hanna Instruments). Two readings were taken for each carcass and the average value was calculated. Moreover, taste panel was performed using 8-points hedonic scale. Cooking loss were measured by placing weighted meat samples in a plastic bag and cooked in a water path at 75°C for one hour and cooking loss calculations were performed for each treatment group. Furthermore, the shearing force was measured using Intron machine with a cutting speed of 200 mm/min and the average shear force value were calculated for each group.

Statistical analysis

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:

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

Where, i = 1,..., I is an index over experimental units(Lambs); j = 1,..., J is an index over treated groups (diet treatments); $y_{i,j}$= are different 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 AND DISCUSSION

A great limitation are reported for the proper NDF dietary requirement for growing lambs fed a complete feed as a TMR to maintain a proper rumen and reticulum chemical and physical characteristics for a suitable microbial fermentation to cover their energy requirements for growth without negative effect on feed intake. By identifying the proper dietary NDF and digestibility values, TMR can be very beneficial to maximize a nutrient utilization and digestibility and consequently improve growing lambs' growth and feed efficiency. In recent study conducted by Alhidary *et al.* (2017) concluded that feeding growing lambs with TMRs containing 30.88% NDF leads to obtain a safer and suitable rumen characteristics, microbial fermentation and growth performance and FCR. Previously, many researchers reported that manipulation of TMR with certain types of roughages, as a general trend, and consequently NDF levels may improve the performance of fattening ruminant animals in term of body weight gain and feed efficiency (Amaral *et al.*, 2015; Alhidary *et al.*, 2016). Nowadays, consumers develop a great health concern of meat quality in term of fat content and other nutrient contents. So, it is very crucial to investigate the effect of feeding different levels of NDF complete feed to growing lambs on the carcass characteristics and meat quality.

Growth rate, DMI and FCR

The effects of feeding different commercial TMR diets containing different levels of dietary NDF compared with the traditional diets (alfalfa hay plus barley grain) on the average daily gain and feed conversion of the growing lambs are presented in Figures 1 and 2. There was a significant effect ($P<0.05$) of dietary treatment on the average body gain between the dietary groups. Lambs fed TMR2 with medium- recommended NDF levels showed a significantly ($P<0.05$) higher average daily gain, followed by lambs fed TMR1 and TMR3. Benton *et al.* (2007) reported an increase in average daily gain (ADG) as a result of increasing NDF which is coincided with results obtained in this study especially for treatment groups TMR1 and TMR2, but not TMR3. The decrease in ADG for this group may be attributed to the extended increase in NDF level in this group, which in turn limited feed intake as a result of fill capacity (Tjardes *et al.*, 2002; Mertens, 2009). Morazán *et al.* (2015) concluded that increasing levels of NDF has hampered lean tissue gain. The lowest values were reported for lambs fed traditional dietary regimes. Moreover, a significant lower FCR ($P<0.01$) reported for lambs from TMR2 group when compared with those of lambs in the other groups (Fig. 2). While, feeding lambs on the TMR diet containing NDF at level 30.88% resulted in a decrease ($P<0.02$) in DMI when compared with lambs in the other treatments.

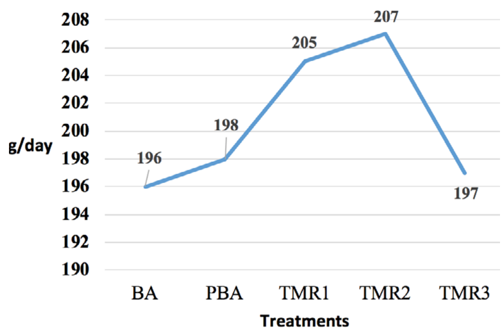

Fig. 1. Average daily gain (ADG: g/day) of growing lambs fed diets containing different levels of NDF. For abbreviations and statistical details, see Table II.

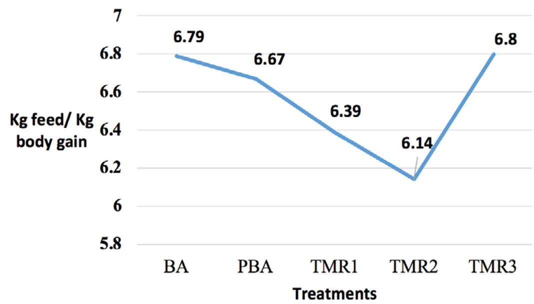

Fig. 2. Feed conversion ratio (FCR: Kg feed/Kg body gain) of growing lambs fed diets containing different levels of NDF. For abbreviations and statistical details, see Table II.

Slaughter and body components data

Data representing slaughter and body components are shown in Table II. The treatments were significantly ($P<0.05$) different in all parameters except for heart, liver, spleen, kidneys and empty intestines. It is observed that animals on group TMR1 recorded the highest weight values (44.91, 41.54, 22.66, 22.52, 0.70 and 2.76 kg) of slaughter, empty body, hot carcass, cold carcass, liver and tail, respectively. On the other hand, lambs fed traditional feeding (BA) gained the lowest weight values (40.59, 36.53, 19.83, 19.79, 0.14, 0.63, 0.09, 1.11, 2.36, 53.20 and 0.51 kg) of slaughter, empty body, hot carcass, cold carcass, heart, liver, kidneys, empty intestine, tail, dressing percentage and chill shrink, respectively. In addition, there were no significant differences ($P>0.05$) between lambs fed TMRs with different levels of NDF for slaughter and body components parameters, except lowest value reported for the empty stomach (TMR2) and chill shrink (TMR1). Contrary, Iraira *et al.* (2015) found no significant differences in average slaughter weight and hot carcass weight of beef heifers given concentrate and straw as total mixed ration.

Table II.- Effect of different dietary treatments on slaughter and body components data.

Data	Experimental group				SEM
	BA	TMR1	TMR2	TMR3	
Slaughter wt. (kg)	40.59^b	44.91^a	43.88^a	44.58^a	0.97
Empty body wt. (kg)	36.23^b	41.54^a	40.20^a	40.20^a	0.90
Hot carcass wt. (kg)	19.88^b	22.66^a	21.70^a	22.13^a	0.50
Cold carcass wt.(kg)	19.79^b	22.52^a	21.46^a	21.87^a	0.50
Heart wt.(kg)	0.14	0.15	0.15	0.15	0.01
Liver wt.(kg)	0.63	0.70	0.67	0.68	0.02
Spleen wt. (kg)	0.06	0.06	0.07	0.06	0.01
Kidneys wt. (kg)	0.09	0.10	0.10	0.10	0.01
Empty stomach wt. (kg)	1.39^a	1.29^b	1.14^c	1.22^b	0.04
Empty intestine wt. (kg)	1.11	1.30	1.36	1.34	0.06
Tail wt. (kg)	2.36^a	2.76^b	2.40^a	2.54^a	0.12
*Dressing (%)	53.20^b	54.71^a	54.11^a	55.42^a	0.48
Chill shrink (%)	0.51^c	0.67^b	1.11^a	1.19^a	0.09

BA, Control (Alfalfa and barley) –Traditional; TMR, total mixed ration; TMR1, total mixed ration contain 25.67% NDF as DM basis; TMR2, total mixed ration contain 30.88% NDF as DM basis; TMR3, total mixed ration contain 55.93% NDF as DM basis; SEM, standard error of means. *Dressing percentage on empty body weight base. $^{a, b, c, d}$ Means in the same row bearing same superscripts are significantly different at (P < 0.05).

Table III.- The effect of different dietary treatments on meat quality and carcass characteristics.

Data	Experimental groups				SEM
	BA	TMR1	TMR2	TMR3	
Cooking loss (%)	20^c	30.69^b	33.29^b	35.20^a	0.81
WHC	0.38	0.39	0.41	0.41	0.01
Rib-eye area (cm^2)	44.77	35.16	39.08	40.57	1.54
pH_1 (1 h PM)	6.23^b	6.16^b	6.41^a	6.20^b	0.04
pH_{24} (24 h PM)	5.92^{ab}	5.89^b	5.98^a	5.96^a	0.02
Temp. (°C)	26.41	26.65	26.44	27.10	0.16
Color$_1$					
L*	41.12	41.12	41.38	41.07	0.50
a*	14.97	14.97	15.20	15.59	0.33
b*	3.00	3.00	3.69	3.33	0.14
Color$_{24}$					
L*	43.51^{ab}	43.51^{ab}	46.28^a	43.34^{ab}	0.57
a*	17.47^b	17.47^b	19.72^a	18.18^{ab}	0.30
b*	7.07^b	7.07^b	8.64^a	6.78^b	0.35

For abbreviations and statistical details, see Table II. WHC, water-holding capacity (ratio); PM, post-mortem. $^{a, b, c,}$ Means in the same row bearing same superscripts are significantly different at (P < 0.05).

Meat quality and carcass characteristics

Meat quality and carcass characteristics results are presented in Table III. The treatments were statistically (P<0.05) different in cooking loss, initial and final *pH*, and color values after 24 h postmortem. On the other side, they didn't show any significant (P>0.05) differences in water-holding capacity (WHC), rib-eye area (REA), initial temperature, and initial color values. These results contrasted to those obtained by Iraira *et al.* (2015). The cooking loss was significantly lower for lambs' meat from BA group (20%) and significantly higher value (35.20%) for lambs from TMR3 that fed high NDF. A significantly variation (P<0.05) were reported in term of meat initial pH_1 and final pH_{24}, and color$_{24}$ for lambs fed TMR2. The lightness (L*), redness (a*) and yellowness (b*) values of meat color$_{24}$ for lambs fed TMR2 were numerically higher (P<0.05) compared with the other treatment groups.

Shear force, texture profile analysis and subjective evaluation

Results for shear force, texture profile and subjective evaluation are presented in Table IV. The treatment groups were significantly (P<0.05) different in shear force and three of the texture profile values except springiness. The most tender meat samples were of group TMR2 followed by TMR1< BA < TMR3. It was observed that BA group attained the highest (P< 0.05) values for hardness, cohesiveness, chewiness and the highest but not significant (P>0.05) value for springiness. A numerically lower value for the meat springiness reported for lambs fed TMR2 compared with the other treatments. Once again, the result of shear force reported here is different from that obtained by Iraira *et al.* (2015). The treatment groups of this study showed lower shear force value compared to the control group.

Subjective evaluation results were also projected in Table IV. There were no significant differences (P>0.05) reported for the flavor, tenderness and juiciness. The treated groups were differ significantly (P<0.05) in overall acceptability with the lowest value scored by lambs fed TMR3 followed by TMR1and TMR2 and finally BA.

Carcass fat depots

Carcass fat depots are showed in Table V. All fat depots were significantly (P<0.02) different between the treatment groups except for pericardial and body wall fat. The treatment TMR1 attained the highest (P<0.05) fat values 0.91, 0.76 and 0.41kg for omental, mesentery and kidney-knob and channel, respectively. While the treatment groups TMR2 and TMR3 scored the highest (P<0.05) backfat 11.17 kg and body wall fat 9.29 kg, respectively. A significantly lower values (P<0.05) for the omental and mesentery fat were reported for lambs fed BA (0.55 and 0.67 kg, respectively), while the Kidney Knob and Channel Fat (KKCF) was significantly lower for lambs fed TMR2 compared to the other groups. Generally, the treatment groups tended to deposit more external carcass fats than the control group (BA). The backfat also followed the same previously mentioned trend except that of TMR3 where showed a non-significant change compared with the control (BA). Morazán et al. (2015) also reported an increase in backfat thickness as a consequence of increasing NDF level.

Table IV.- The effect of different dietary treatments on carcass meat shear force, texture profile analysis and subjective evaluation.

Characteristics	Experimental groups				SEM
	BA	TMR1	TMR2	TMR3	
Shear force (kg)	4.25c	4.16c	3.85b	4.53a	0.17
TPA					
Hardness (kg)	0.86[a]	0.41[b]	0.46[b]	0.36[c]	0.03
Springiness	0.67	0.64	0.61	0.62	0.01
Cohesiveness	0.58[a]	0.52[b]	0.50[b]	0.44[c]	0.01
Chewiness	0.32[a]	0.16[b]	0.14[bc]	0.11[c]	0.01
Subjective evaluation					
Flavor	4.50	4.33	3.83	4.67	0.16
Tenderness	4.83	4.67	4.33	4.33	0.16
Juiciness	4.17	4.33	4.33	4.00	0.19
Acceptability	4.83[ab]	4.33[b]	4.33[b]	4.17[c]	0.14

For abbreviations and statistical details, see Table II.

Table V.- The effect of different dietary treatments on the carcass fat depots.

Depot	Experimental groups				SEM
	BA	TMR1	TMR2	TMR3	
Omental fat (kg)	0.55[b]	0.91[c]	0.68[a]	0.64[a]	0.05
Mesentry fat (kg)	0.67[b]	0.76[a]	0.75[a]	0.72[a]	0.04
KKCF (kg)	0.35[b]	0.41[a]	0.31[c]	0.40[a]	0.02
Pericardial fat (kg)	0.09	0.09	0.09	0.09	0.01
Backfat (mm)	8.22[c]	10.06[b]	11.17[a]	8.11[c]	0.03
Body wall fat (mm)	7.49	8.69	8.61	9.29	0.30

For abbreviations and statistical details, see Table II. KKCF, Kidney knob and Channel fat.

CONCLUSION

Feeding growing lambs a total mixed ration (TMR) with around 30% NDF improve the average daily gain, feed conversion ratio and most of the required meat quality measurement when compared with lower or higher dietary NDF. As a general trend, growing lambs fed different TMRs tend to lay more internal and external fat depots than the traditional feeding. On the other hand, further investigation is needed to specify the effect of different NDF sources, considering the NDF digestibility, and the proper levels of physical effective NDF to be used without affecting the feed intake and the rumen microbial fermentation process.

ACKNOWLEDGMENT

This project was funded by King Saud University, Deanship of Scientific Research, College of Food and Agricultural Sciences, Research Center. A great appreciation for this funding is extended by the authors.

Statement of conflict of interest

Authors have declared no conflict of interest.

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