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Growth rate, carcass characteristics and meat quality of growing lambs fed buckwheat or maize silage

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Objective: This study evaluated inclusion of buckwheat silage to the diet of growing lambs in terms of meat quality as compared to maize silage.
Methods: Buckwheat, rich in total phenols (TP, 33 g/kg dry matter [DM]), was harvested at the end of the milk stage and ensiled in 40 kg plastic bags after wilting (294 g/kg silage DM). A total of 18 growing lambs (21.6±1.2) were individually fed isonitrogenous and isoenergetic total mixed rations (TMR) for 75 d that either contained buckwheat or maize silage at DM proportions of 0.50. At the end of feeding trail all lambs were slaughtered to assess carcass characteristics and meat quality.
Results: Buckwheat silage increased ($p<0.01$) the DM intake of lambs as compared to maize silage, but had no effects ($p>0.05$) on live weight gain and feed efficiency. Carcass weight, dressing percentage, meat pH, water holding capacity, cooking loss, shear force (kg/cm^2), and total viable bacteria count of meat did not differ ($p>0.05$) between the treatments. However, TP content of meat increased ($p<0.001$) by feeding buckwheat TMR. Feeding buckwheat TMR also decreased ($p<0.05$) the b* values of meat.
Conclusion: The results provide that buckwheat silage is palatable and could successfully include TMR of growing lambs with no adverse effects on performance, carcass and meat quality. Additionally, feeding buckwheat silage to lambs offers increased TP in meat.

Keywords: Buckwheat Silage; Lamb; Meat Quality; Phenolic Compounds

INTRODUCTION

Common buckwheat (*Fagopyrum esculentum* Moench) has been a crop of secondary importance in many countries and primarily considered for grain production [1]. However, buckwheat may also offer substantial forage production in early spring and autumn where Mediterranean climate prevails.

Intake, chemical composition and nutrient availability all could affect feeding values of buckwheat. Because buckwheat has a higher total phenolic (TP) content [2,3], feeding buckwheat to ruminants could reduce intake or could result in reduced performance, as high TP in feeds could affect feeding value of feed by showing anti-nutritive or even toxic propertied depending on its form [4]. Short term studies with dairy cows [5,6] showed there are no negative effects from including forage buckwheat in diets of dairy cows, yet there is no sufficient information feeding buckwheat to fattening lambs.

Feeding feed sources rich in TP can improve the quality of ruminant products by elevating TP content of meat [7] or milk [8]. This is important because TP in plant sources show high antioxidant properties and protects cells from oxidative damages; thereby protecting human beings from health problems mostly related to cancer [9,10]. Holasova et al [2] showed a significant relationship (R^2 = 0.99) between TP in buckwheat material and antioxidant activity. Therefore, inclusion of forage buckwheat to ruminant diets may also offer improved product quality.

Thus, the main objective of this study was to evaluate effects of buckwheat silage on intake, performance, carcass characteristics and meat quality of lambs as compared to maize silage which is commonly used a forage source with high feeding values.

MATERIALS AND METHODS

Silage production

Buckwheat (*Fagopyrum esculentum* Moench) was sown on the 29th of August 2013 at experimental fields of Adnan Menderes University, Faculty of Agriculture (37° 45′ N, 27° 45′ E, 38 m above sea level). It was harvested 49 d after from sowing giving a stubble height of 5 cm when the most of the seed were in milk stage. After wilting approximately 20 h, forage buckwheat was chopped with a forage cutter (1 to 2 cm) and ensiled in plastic bags using vacuum without additives. Approximately 40 to 45 kg fresh material was ensiled in a bag. A total of 25 bags were produced and stored 7 to 9 months under shelter. Maize silages used in experiment were taken from one of the farm bunker silos. Approximately 5 to 10 cm middle of the vertical face of maize silages was taken daily. Silages were sampled weekly, dried at 55°C, and composed equally for later chemical analysis.

Feeding experiment

A total of homogeneous 18 weaned (2.5 to 3 month of age; 21.6±1.2 kg body weight) male Karya lambs were fed in individual pens (1.2×1.7 m) equipped with plastic feeder and water container after approval by the Animal Research Ethics Committee of Adnan Menderes University with a number of 050.04/2012/053. Lambs were randomly divided into two equal groups and fed individually for 63 days in three periods each lasting for 21 d after 12-d acclimation in May to July 2014.

Buckwheat or maize silages were mixed with one of two assigned concentrates prepared according to nutritive values of silages to make the two dietary treatments isonitrogenous and isoenergetic and were fed as a total mixed ration (TMR). The silage:concentrate ratio was 50:50 on a dry matter (DM) basis. The ingredients and chemical composition of two TMR and silages are presented in Table 1 and Table 2, respectively. The TMRs were prepared daily and offered *ad libitum* once a day (0900), after refusals removed. The TMR offered and refusals were recorded, sampled and dried 4 d in a week. These weekly samples were equally pooled and analyzed for determining DM and nutrient intake. Individual fecal grab samples from four lambs were also collected once a d from d 57 to 61 of experiment. The 5-d individual dried samples equally pooled for each animal and analyzed to measure apparent digestibility of nutrients. Lamb were weighed 21 d intervals following being fasted for 12 h. Average live weight gain (LWG) was calculated from the change in weight between each LW measurement date. Dividing daily DM intake (DMI) by daily LWG gave the feed conversion ratio.

Table 1. Ingredient compositions of the experimental TMR (g/kg DM)

Ingredient	Maize TMR	Buckwheat TMR
Maize silage	500	-
Buckwheat silage	-	500
Maize grain	209	366
Soybean meal	125	120
Cotton seed meal	152	-
Limestone	10	10
Salt	2.5	2.5
Vitamin-mineral mix[1)]	1.0	1.0

TMR, total mixed ration; DM, dry matter.
[1)] Each kilogram contains: 1,300,000 IU vitamin A, 260,000 IU vitamin D_3, 3,000 mg vitamin E, 120,000 mg niacin, 5,000 mg Mn, 5,000 mg Fe, 5,000 mg Zn, 1,000 mg Cu, 15 mg Co, 80 mg I, and 15 mg Se.

Carcass traits

All lambs were weighted and slaughtered after 63 d of experimental period. Carcasses were weighed immediately after evisceration and removal of head and internal organs, and again after being kept –4°C for 24 h. The *M. longissimus dorsi* (MLD) between the 11th and 13th ribs of each lambs were removed from the left side of the carcass, vacuum-packed and stored –20°C for further analysis. A 15 g of meat from each lamb was also kept –4°C in refrigerator for 7 d to measure total viable

Table 2. Nutritive value of the experimental TMR and silages (g/kg DM, if otherwise not stated)

Nutrient	Maize TMR	Maize silage	Buckwheat TMR	Buckwheat silage
Dry matter (g/kg)	457	304	447	294
Organic matter	936	941	921	898
Crude protein	150	75	150	127
NDIN (% in total N)	9.2	8.4	9.9	12
ADIN (% in total N)	4.0	5.6	3.9	5.9
Ether extract	32	26	29	29
NDF	382	509	290	472
ADF	222	273	215	381
Lignin	36	39	55	95
Hemicellulose	161	236	75	91
Cellulose	185	234	160	286
Non-Fiber carbohydrates	372	331	452	270
ME (Mcal/kg)	2.35	2.02	2.36	1.83
Total phenols*	15	12	23	33
Non-tannin phenols*	7.8	6	18	27
Condensed tannins*	0.1	0.1	0.2	0.3

TMR, total mixed ration; DM, dry matter; NDIN, neutral detergent insoluble nitrogen; ADIN, acid detergent insoluble nitrogen; NDF, neutral detergent fiber; ADF, acid detergent fiber; ME, metabolizable energy.
* Expressed as tannic acid equivalent.

bacteria (TVB) count.

Analytical procedures

Feed analysis: Samples of silages, TMR, refusals and feces were dried in an air-forced oven at 55°C. The dried samples ground to pass a 2-mm screen (MF 10 B, IKA Werke, Staufen, Germany). The DM, ash, ether extract (EE) and crude protein (CP) content were determined according to AOAC [11]. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were assayed according to the methods prescribed by Van Soest et al [12] using an Ankom$^{200/220}$ Fiber Analyzer (Ankom Technology, Macedon, NY, USA). The NDF and ADF values were expressed inclusive of residual ash. Lignin was determined by incubation of ADF residues in diluted H_2SO_4. Non-fiber carbohydrates (NFC) were: 100 – NDF – ash – CP – EE. The NDF and ADF residues were further analyzed for their CP content. The metabolizable energy (ME) of feedstuff and TMR were calculated according to NRC [13].

The TP, non-tannin phenol (NTP) and condensed tannin (CT) content of TMR and experimental silages were analyzed according the method of Makkar [14], and were expressed as tannic acid equivalent. The pH of silages was determined in filtrate of 20 grams of sampled silages with 180 mL of distilled water with a pH meter (HI 2211 pH/ORP Hanna instruments, Leighton Buzzard, Bedfordshire, UK). Apparent digestibility of nutrients was determined indirectly using acid–insoluble ash as an indigestible dietary marker, as described by Van Keulen and Young [15].

Meat analysis: The pH and color parameters were determined at 0 h after slaughtering (pH_0) and at 24 h after post-slaughtering (pH_{24}) with 3 measurements. The pH was mea sured directly on the MLD with a digital pH meter, equipped with penetrating electrode and thermometer (HI83141, Hanna instruments, USA), whereas the L* (brightness), a* (redness), and b* (yellowness) values were measured on the cross-sectional area of MLD with a spectrocolorimeter (Konica Minolta CR-400, Minolta Camera, Osaka, Japan), which was calibrated with a white standard. Water holding capacity (WHC) and cooking loss (CL) were performed according to Honikel [16]. Shear force determined as kg/cm^2 on the meat samples treated at 75°C for 20 min, with a Zwick/Roell texture analysis test device (equipped with V-shaped knife of a Warner-Bratzler), with three measurements.

Ten g of defrosted meat samples were homogenized with distilled water in a volume of 1:10 w/v for estimation of TP content of meat. The 2 mL of the homogenized was mixed with 6 mL of methanol and centrifuged at 3,000×*g* for 20 min. The 0.1 mL supernatant was then moved into 10 mL test tube, and in sequence, 0.4 mL distillated H_2O, 0.25 mL of Folin-Ciocalteu reagent and 1.25 mL of the sodium carbonate solution was added and vortexed. The tubes were incubated at dark for 40 min and transferred to spectrophotometer tube. The absorbance was recorded at 725 nm (V-1200 Spectrophotometer, VWR International bvba, Leuven, Belgium), calculated as described by Makkar [14]. The TP content of meat expressed as tannic acid equivalents.

The TVB count was performed on meat kept 4°C for 7 d in refrigerator. Ten g of meat was homogenized with peptone water (1% Merch KGaA, Darmstadt,Germany) in a volume of 1:10 w/v. Diluted meat samples were counted on plate count agar (Merc KGaA, Germany), which were incubated at 30°C for 48 h.

Statistical analysis

Apparent digestibility, carcass characteristics and meat quality values of lambs fed maize and buckwheat TMR were compared by independent *t* test, while nutrient intake and performance data were analyzed by analysis of variance in a factorial completely randomized design accounted for main effect of TMR, period and its interactions using SPSS 10 [17]. When the F-value was significant, means were separated by Fisher's protected least significant difference test. Significance was declared at $p<0.05$, $p<0.01$, $p<0.001$.

RESULTS

The nutritive value of silages and total mixed ration

The DM content of the silages was similar, yet buckwheat silage had higher pH values (Table 2). The main nutritional differences of silages were observed in their ash, CP and fiber content. Buckwheat silage had 73% higher ash and 69% higher CP content than maize silage (102 vs 59 and 127 vs 75 g/kg DM, respectively), but had higher ADF (381 vs 273 g/kg) and lignin (9.5 vs 3.9 g/kg) content, despite its NDF (509 vs 472 g/kg) the contents appeared to be comparable to maize silages. The TP content of buckwheat silage was considerably higher than maize silage (33 vs 12 g/kg). As a result of nutrient differences between silages, ME content of buckwheat silages was calculated as 10% lower than maize silage.

The TMR fed to lambs was formulated to be isonitrogenous and isoenergetic. However, addition of 152 g/kg cotton seed meal high in NDF (577 g/kg) to maize TMR resulted in 32% higher NDF content of maize TMR compared to buckwheat TMR, yet buckwheat TMR had 53% higher lignin level in a similar ADF content with maize TMR. Having higher maize grain, buckwheat TMR had 22% higher NFC content than maize TMR. The TP, NTP, and CT content of buckwheat TMR was also higher than the maize TMR, as half of the contents of buckwheat silage was rich in these secondary components. But, despite buckwheat silages having nearly 3-fold higher TP than maize silage; TP content of buckwheat TMR was only 1.5-fold higher than the maize TMR.

Nutrient intake and performance of lambs

Table 3. Dry matter and nutrient intake, and performance of lambs fed maize TMR or buckwheat TMR

	Periods (*P*)×TMR (R)[1)]						SEM	p value		
	1		2		3					
	M	B	M	B	M	B		*P*	R	*P*×R
Intake (g/d)										
Dry matter	817	854	902	958	921	1029	34.0	0.020	0.001	0.571
Dry matter (g DM/100 g LW)	3.5	3.6	3.3	3.5	3.0	3.3	0.13	0.014	0.037	0.830
Organic matter	774	758	855	850	873	913	31.4	0.793	0.793	0.647
Crude protein	123	131	136	147	139	158	5.2	0.001	0.005	0.553
Performance										
LWG (g/d)	186	185	174	184	174	176	12.9	0.704	0.725	0.916
FCR	4.5	4.7	5.4	5.4	5.6	6.2	0.48	0.029	0.514	0.869

TMR, total mixed rations; SEM, standard error of the mean; DM, dry matter; LW, live weigh; LWG, live weigh gain; FCR, feed conversion ratio (g DMI/g LWG); DMI, dry matter intake.
1) M: maize TMR; B: Buckwheat TMR.

The TMR×period interaction did not occur (p>0.05) for intake variables (Table 3). Overall, DMI either g/d or g DM per g live weight of lambs fed buckwheat TMR were greater (p<0.05) than lambs fed maize TMR during the whole experiment. However, higher DMI did not resulted in higher organic matter (OM) intake which was found similar (p>0.05) in both groups. Both groups of lambs gained similar (p>0.05) live weight, with no (p>0.05) period×TMR interaction. The efficiency of TMR was the highest (p<0.05) in first period with a similar (p>0.05) value in groups through the experiment.

Carcass and meat quality

Carcass parameters are presented at Table 4. After 63 d experimental period, all lambs from both group slaughtered at same (p>0.05) final live weight (32.9 kg both). Lambs fed maize or buckwheat TMR also produced similar (p>0.05) hot and cold carcasses, with a similar (p>0.05) dressing percentage (DP).

Determined meat quality parameters are given in Table 5. The pH of MLD of lambs at 0 and 24 h after slaughtering, WHC, CL, shear force and TVB count were not different (p>0.05) between the groups. The color indices of MLD of lambs also did not differ between the groups (p>0.05) at 0 and 24 h after slaughtering, except for the b* values at 24 h. $Yellowness_{24}$ of MLD of lambs fed buckwheat TMR was lower (p<0.05) than yellowness24 of MLD of lambs fed maize TMR. Feeding buckwheat TMR increased (p<0.001) the TP content of meat by 68% compared to feeding by maize TMR (33.1 vs 19.7 mg tannic acid equivalent/kg meat).

Table 4. Final live weight and carcass parameters of lambs fed maize or buckwheat TMR

Item	Maize TMR	Buckwheat TMR	SEM	p-value
Final live weight (LW, kg)	32.9	32.9	0.91	0.989
Hot carcass weight (kg)	15.1	14.9	0.50	0.770
Cold carcass weight (kg)	14.7	14.5	0.50	0.727
Dressing percentage (kg/100 kg LW)	44.7	44.0	0.74	0.514

TMR, total mixed rations; SEM, standard error of the mean.

DISCUSSION

Nutritive value of buckwheat silage

The pH of maize and buckwheat silages was satisfactory for silage with DM content of 300 g/kg according to Weissbach [18]. The major nutrient contents of buckwheat silage were similar to the findings of Amelchanka et al [5] with a similar CP and energy values. The TP content of buckwheat silage was also similar to reported value by Amelchanka et al [5], but

Table 5. Meat quality of MLD of lambs fed maize or buckwheat TMR

Item	Maize TMR	Buckwheat TMR	SEM	p-value
pH_0	6.4	6.4	0.08	0.786
pH_{24}	5.7	5.7	0.01	0.312
Water holding capacity (%)	24.1	24.8	1.31	0.701
Cooking loss (%)	26.6	23.9	1.84	0.325
$Lightness_0$ (L*)	39.5	42.9	1.86	0.215
$Redness_0$ (a*)	15.9	13.7	0.76	0.065
$Yellowness_0$ (b*)	–3.8	–7.0	1.31	0.103
$Chroma_0$ (C*)	16.1	16.4	0.78	0.789
$Lightness_{24}$ (L*)	41	43	1.3	0.499
$Redness_{24}$ (a*)	16.9	16.0	0.63	0.350
$Yellowness_{24}$ (b*)	–1.5	–3.6	0.54	0.016
$Chroma_{24}$ (C*)	16.5	17.0	0.59	0.563
Shear force (kg/cm^2)	3.05	2.82	0.46	0.735
Total viable bacteria (log cfu/g)	6.38	6.44	0.21	0.846
Total phenol (mg TA/kg meat)	19.7	33.1	0.99	0.001

MLD, *M. longissimus dorsi*; TMR, total mixed rations; SEM, standard error of the mean; TA, tannic acid equivalents.

lower than the value (97.3 g/kg) reported by Kälber et al [6]. It was notable that the majority of the fiber (NDF) of buckwheat silage was composed of cellulose rather than hemicelluse, which is in line with the reports of Amelchanka et al [5] and Kälber et al [6]. This was interesting because, generally hemicellulose constitutes higher values than cellulose in cereal forages, as was found in maize silage in this experiment.

Nutrient intake and performance of lambs

The primary reason for using the high forage level in this experiment was to make a better comparison of buckwheat silages with a commonly used forage source in terms of its palatability for a long term study. Feeding dairy cows at low (10%, 5) or high (46%, 6) levels of dietary buckwheat silages showed no effect on the DMI and milk yield in relatively short term experiments. The DMI in g/d and relative to body weight was greater in lambs fed buckwheat TMR in the current experiment. It is possible that lambs fed buckwheat TMR consumed more DM due to their TMR having less, but a more digestible fiber in this experiment (Apparent digestibility of DM, OM, CP, and NDF of buckwheat and maize TMR was presented in previous paper as: 627 to 703; 636 to 719; 557 to 645; and 441 to 525, respectively; [19]). This is first data with buckwheat silages showing that a high level of buckwheat silages will be well accepted by lambs and applicable for commercial practice.

Higher DM and CP intake of lambs fed buckwheat TMR did not result in improved LWG. Rodriquez et al [20] and Ponnampalam et al [21] were also reported that higher CP intake did not show any improvements in LWG. The most possible explanation is that higher CP intake could not be supported by enough energy intake for muscle growth in this experiment because of high forage level. Alternatively, possible high performance could be blocked by production level of local breed, whose LWG is reported as 182 g/kg even on concentrate feedlot [22]. This is also showed that both groups of lambs had a good growth performance especially with feeding a diet proportionally equal forage: concentrate and could be better if more productive breed were used.

Carcass and meat quality

In general, differences in carcass weight and DP related to feeding were reported mainly based on feeding different forage: concentrate ratios [23-26]. This generally resulted in heavier and more developed digestive tract in lambs fed a higher forage ratio, and relevant energy intake. Therefore, lambs fed the same forage: concentrate ratio in this experiment grew with a similar growth rate, slaughtered at the same live weight, and produceed similar carcass yield. Both group of lambs showed similar DP reported by Demirel et al [27] for local breed fed forage based ration.

The pH after 24 h slaughtering reached a desired level with a similar value in both groups. This showed that slaughtering condition was stress-free, and required glycogen to drop pH not depleted during slaughtering process. Hughes et al [28] reported that correlation between WHC and CL could be high, and these two parameters were also related to meat pH [29]. Shear force of MLD of both groups was also similar, and was very low as reported by Francisco et al [30], indicating high tenderness of MLD. These outcomes suggest that effects of feeding two different forage sources on meat technological quality parameters will be limited, and suggest meat juiciness and tenderness related to this parameter will also be similar.

Meat color is quite important in Turkey and affects customer preferences, and as in Mediterranean countries, pale and pink color lamb meat is preferred [31]. The lightness is related to structural attributes of the muscle, whereas color attributes (redness and yellowness) tend to be strongly associated with the pigment myoglobin [28]. Therefore, given the both group of lambs had the similar structural attributes (e.g. carcass profile and pH), their lightness values were also similar. However, the lower yellowness value of MLD of lambs fed buckwheat TMR at 24 h after slaughtering could result from reduced reduction of metmyoglobin to oxymyoglobin due to having more total phenol. This is suggested, because Miura et al [32] reported that cysteine-coupled polyphenols such as cysteinyl caffeic acids can be used as preserving agents for retaining the fresh meat color, because of their powerful reducing effect on metmyoglobin that changes the color of meat from brown to the more desirable bright red.

Inclusion of 500 g/kg buckwheat silages to buckwheat TMR increased TP content of meat of lambs, and this was correlated to increase TP in buckwheat TMR. This was in line with the finding of Kotsampasi et al [7], who reported increased TP content of meat of lambs after inclusion of pomegranate by-product silages rich in TP. Similar carryover effects were also observed in dairy cows fed buckwheat silages [6]. Therefore, it is certain that inclusion of buckwheat silages into ruminant diet increases these bioactive compounds in their product, and this is promising for promoting human health.

Microbial count (TVB) was performed on meat kept +4°C for 7 d in refrigerator to investigate effects of high TP on TVB count. Lower TVB count of meat of lambs fed buckwheat TMR was expected because of finding of Maqsood et al [33], who reported lower mesosphilic bacterial count of camel meat after treating tannic and gallic acids and catechin, and lower psychrophilic bacterial count of camel meat after treating with tannic and gallic acids after 9 d of refrigerated storage. However, high TP content did not affect TVB count of meat of lambs fed buckwheat TMR in this experiment. This outcome suggests having high TP will not show similar positive effects as treating meat with phenolic compounds for storage.

CONCLUSION

The results of this study provide evidence that buckwheat silage is suitable for long term feeding because it is palatable and moderately high in digestibility, has moderate nutrient content (moderately high CP and moderate cell wall content when compared to common forage source) and has no adverse effect on performance and meat quality. On the contrary, inclusion of buckwheat silage to ruminant diet offers elevated health benefits of a bioactive phenolic compound content of meat.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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