Iranian Journal of Applied Animal Science

Effect of Wheat Straw and Molasses Supplementation on Quality, Lamb Performance, and Digestibility of Forage Turnip (*Brassica rapa*) Silage

Research Article

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Received on: 8 Jun 2020
Revised on: 16 Nov 2020
Accepted on: 15 Dec 2020
Online Published on: Sep 2021

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Online version is available on: www.ijas.ir

ABSTRACT

This study was conducted to determine effects of wheat straw (WS) and molasses (M) supplementation on the quality of forage turnip (*Brassica rapa*) silage, and its feeding effects on lamb performance and nutrient digestibility. In experiment I, forage turnip was ensilaged with the addition of WS (0%, 7%, 10%, and 15%) and M (0%, 1%, 2%, and 3%). Supplementation with M improved the silage quality, fermentation parameters, *in vitro* organic matter digestibility, and metabolizable energy values of the forage turnip silages (P<0.01). In experiment II, there were no significant differences among the treatment groups in terms of final body weight. Total weight gain or daily weight gain from the lamb fed with maize silage (MS) was found to be higher than in the forage turnip + 3% M (FTM) group and forage turnip + 7% WS + 2% M (FTSM) groups (P<0.05). Silage intake of the dry matter MS was higher than in the FTM and FTSM silage groups (P<0.05). Dry and organic matter digestibility of the MS were higher than those of the FTM and FTSM silages, while the crude protein digestibility of the MS was lower than those of the FTM and FTSM silages (P<0.05). The crude fiber (CF), acid detergent fiber (ADF), and neutral detergent fiber (NDF) digestibility of the FTSM silage was higher than those of the MS and FTM silages (P<005). As a result, forage turnip (*Brassica rapa*) can be ensiled by adding 7% or 10% WS and 1%, 2%, or 3% M, and it can be a source of an alternative forage for ruminants.

KEY WORDS digestibility, forage turnip (*Brassica rapa*), live weight gain, silage.

INTRODUCTION

Good quality forage instead of plant residues, such as stalk, straw, etc., is of great importance in order to increase yield in livestock enterprises. *Brassica* species are among the alternative forage plants commonly produced and used in order to supply forage requirements during limited forage production in different regions of the world. The leaves of turnip (*Brassica rapa*), rape (*Brassica napus* ssp. *oleifera*), and cabbage (*Brassica oleracea*) have gained importance among the plant species used as forage plant source (Ayres and Clements, 2002). Forage brassicas are relatively low in dry matter (DM) content, but their total DM production per unit area is high compared with forage grasses. In addition, crude protein (CP) levels are generally high, ranging from 150 to 250 g kg^{-1} DM in the leaf and 80-150 g kg^{-1} DM in the roots (Keogh *et al.* 2012). Forage brassicas are generally used in situations where livestock have a high nutrient demand (Neilsen *et al.* 2008). In recent years, a forage turnip variety (*Brassica rapa*), known as lenox in Turkey, has increased in production and cultivation, to be used as a forage source for ruminant nutrition. There are a limited number of studies on the ensiling of forage turnip (*Brassica rapa*) plants and these studies have reported that forage turnip can be ensilaged with no additives or together with straw, grains, and molasses (M), and that these silages have been reported as having high-quality silage characteristics (Hart and Horn, 1987; Cetin and Arslan Duru, 2020; Gumus *et al*. 2020). However, no detailed studies investigating the forage turnip silage quality and its effects on lamb performance and apparent digestibility parameters have been found. The aim of this study was to determine the effects of the addition of different levels of wheat straw (WS) and M to forage turnip silage on the fermentation quality, lamb performance, and nutrients digestibility.

MATERIALS AND METHODS

Forage turnip (*Brassica rapa*) was used as silage material in the current study. This study was designed as 2 experiments. Experiment I, was conducted in the first year (2017) of the study, to preserve forage turnip by ensiling it via the addition different levels of WS and M to improve the fermentation quality of silages. Experiment II was conducted in the second year (2018) of the study to determine the lamb performance and apparent digestibility of the forage turnip + 3% M (FTM) and forage turnip + 7% WS + 2% M (FTSM) silages, which were of the highest quality, based on the results of experiment I of this study.

Experiment I

In experiment I, forage turnip was harvested at the full flowering and encapsulation period. The WS and M were used to increase the dry matter (DM) and water-soluble carbohydrate (WSC) contents of the silages. Experiment I was designed as a 4 × 4 factorial design, WS (0%, 7%, 10%, and 15%) and M (0%, 1%, 2%, and 3%) were added to the forage turnip on a fresh basis and homogeneously mixed, and a total of 16 silage groups were prepared. The mixtures were packed tightly in 1.5-L glass jars with 5 replicates per treatment. The chemical composition of forage turnip, WS, and M used as the silage material in experiment I are given in Table 1.

The jars were stored for 60 days at room temperature (22 ˚C) and then opened after 60 days of ensiling. In experiment I, the pH values of the silages were immediately measured (Polan *et al.* 1998). Volatile fatty acid and lactic acid analysis were determined by high-performance liquid chromatography according to the procedure of Suzuki and Lund (1980). The ammonia nitrogen rate in the total nitrogen (NH_3-N/TN, %) content was determined according to the procedure described by the association of official analytical chemistry (AOAC, 1990) and the silages were subjected to the aerobic stability test (determination for CO_2 production values) for 5 days in the system developed by Ashbell *et al.* (1991). The buffering capacity (BC) of forage turnip was determined according to the method of Playne and Mcdonald (1966).

The WSC value was determined according to the procedure described by Dubois *et al*. (1956). Dry matter (DM) and crude protein (CP) contents of the forage turnip material, WS, M, and all of the silages were determined using the procedure of the AOAC (2005). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were measured according to the procedure of Van Soest *et al*. (1991). The *in vitro* gas production technique (Menke *et al.* 1979) was used to determine the *in vitro* organic matter digestibility (IVOMD) values and the metabolizable energy (ME) values were calculated using the equations of Menke *et al.* (1988).

Experiment II

In experiment II, the FTM and FTSM silage groups were selected for the lamb performance and apparent digestibility trials, as they had a highest quality based on the results of experiment I. In experiment II, the effects on the performance and digestibility parameters of the FTM and FTSM silages were compared with those of maize silage (MS), which is the most commonly used forage in ruminant nutrition. The chemical composition of the forage turnip, WS, M, commercial finisher concentrate (FC) feed, and silages (FTM and FTSM) used for the lamb performance and apparent digestibility experiment (Experiment II) are presented in Table 2. The pH, NH_3-N/TN, CO_2, and organic acid (acetic, propionic, lactic, and butyric acid) contents of the FTM and FTSM silages are presented in Table 3.

In Experiment II, all of the silages (MS, FTM, and FTSM) were prepared in plastic silage bags (40 kg capacity). A total of 36 fat-tailed Awassi male lambs (34±1.4 kg), aged 4-5 months, were used as the experimental animals in experiment II. At the beginning of the experiment, the lambs were individually weighed, identified, vaccinated against endemic infectious diseases, treated against internal and external parasites, and a recommended dose of vitamin A, D and E was administered via intramuscular injection. The feeding trial was performed in 4 subgroups, including 3 animals in each silage group. In each subgroup, the animals were allowed to drink water *ad libitum*. The lambs consumed the MS, FTM, and FTSM silages for 10 days to allow adaptation to the experimental silages. All of the groups were fed twice a day, at 07:00 and 17:00 h, after removing the refusals from the previous day. The lamb performance trial lasted for 60 days, and the live weight of the lambs was recorded every 15 days before the morning feeding.

The total DM requirements of the trial animals were estimated as 3% of their live weights. All of the groups consumed a FC and WS at a rate of 60% and 10% of the DM needs for each period. The silages were provided (MS, FTM, and FTSM) *ad libitum*.

Table 1 Chemical composition of feeds used in the ensiling of forage turnip (*Brassica rapa*) silages used in experiment I

Items	DM	CP	ADF	NDF	BC	WSC
Forage turnip	18.06	10.35	38.71	42.14	184	81.6
Wheat straw	95.65	3.97	44.14	66.80	-	-
Molasses	77.86	10.24	-	-	-	-

DM: dry matter, %; CP: crude protein, % DM; ADF: acid detergent fiber, % DM; NDF: neutral detergent fiber, % DM; BC: buffering capacity, mEq/kg DM and WSC: water-soluble carbohydrate, g/kg DM.

Table 2 Chemical composition of feed used in the lamb performance and apparent digestibility trials

Treatment	DM	OM	CP	CF	ADF	NDF	BC	WSC
FT	25.08	79.60	15.13	32.96	46.99	57.06	220	71.9
WS	93.54	83.91	4.53	41.12	47.98	72.42	-	-
M	77.20	63.86	15.69	-	-	-	-	-
FC	92.12	84.11	18.91	12.81	10.40	30.79	-	-
Silages								
MS	32.23	84.64	9.37	29.99	31.39	46.51		
FTM	23.65	75.48	15.08	29.07	40.08	44.48		
FTSM	24.35	78.00	12.70	32.60	43.63	51.22		

DM: dry matter; OM: organic matter % DM; CP: crude protein, % DM; CF: crude fiber, % DM; ADF: acid detergent fiber, % DM; NDF: neutral detergent fiber, % DM; BC: buffering capacity, meq/kg DM and WSC: water-soluble carbohydrate, g/kg DM.
FT: forage turnip; WS: wheat straw; M: molasses; FC: commercial finisher concentrate feed; MS: maize silage; FTM: forage turnip + 3% M silage; FTSM: forage turnip + 7% WS + 2 % M silage.

Table 3 Fermentation characteristics of the silages used in the lamb performance and apparent digestibility trials

Silages	pH	NH_3-N/TN	CO_2	LA	AA	PA	BA
MS	3.64^b	10.52	65.47^a	31.26^a	13.75	1.19	-
FTM	4.33^a	12.09	5.93^b	22.86^b	12.91	-	-
FTSM	4.43^a	13.30	6.63^b	18.34^b	15.02	-	-
SEM	0.740	0.622	5.436	1.339	0.452	0.139	-

NH_3-N/TN: ammonia nitrogen rate in total nitrogen content %; CO_2: carbon dioxide formation, g/kg DM; LA: lactic acid, g/kg DM; AA: acetic acid, g/kg DM; PA: propionic acid, g/kg DM and BA: butyric acid, g/kg DM.
MS: maize silage; FTM: forage turnip + 3% M; FTSM: forage turnip + 7% WS + 2% M and SEM: standard error of the mean.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).

Refusal silages were weighed and sampled for DM determination before removing them and the silage consumption values of each subgroup were determined daily. In experiment II, the total weight gain (TWG), daily weight gain (DWG), silage intake (SI), and feed conversion ratio (FCR) parameters were determined.

After the lamb performance trial, the apparent digestibility trail was performed based on the method reported by Van Es and Van der Meer (1980) to determine the nutrient digestibility of the MS, FTM, and FTSM silages previously used in the lamb performance trial. A total of 12 fat-tailed Awassi male rams (45.6±1.45 kg), aged 7 months, were used for this trial (4 rams were used in each silage group).

The rams were randomly allocated into different silage treatment groups and subjected to a 31-day trial period consisting of a 10-day diet adaptation period, 10-day feed intake estimation, 4-day (85%) *ad libitum* SI period, and 7-day feces collection period (Cochran and Galyean, 1994).

During the collection period, the rams were fed the experimental silages (MS, FTM, and FTSM) at a level of 85% ad libitum intake in 2 equal portions, at 07:00 and 17:00 h. The animals always had free access to water. The rams were fitted with specialized harnesses and bags that facilitated the collection of feces. Feces were collected daily after excretion and bulked for the total weight determination and then a 10% representative sample was taken to produce running composite samples for the individual animals.

The silages (MS, FTM, and FTSM) used in the apparent digestibility trail and fecal samples were preserved in sealed polyethylene bags and stored in a freezer at –20 ˚C until chemical analyses. The DM and CP contents of the silages (MS, FTM, and FTSM) and feces were determined using the procedure of the AOAC (2005), and the crude fiber (CF) value was determined according to the procedure of Crampton and Maynard (1983).

The NDF and ADF analyses were performed based on the method of Van Soest *et al*. (1991). The DM digestibility (DMD), organic matter digestibility (OMD), CP digestibility (CPD), CF digestibility (CFD), NDF digestibility (NDFD), and ADF digestibility (ADFD) values of the silages were calculated.

This study was conducted in accordance under board resolution number 2017/08/01 of the Harran University Animal Experiments Local Ethics Committee (HRÜ-HADYEK).

Statically analysis

The treatments in Experiment I were arranged as a 4 × 4 factorial, and the treatment sum of squares were separated into main effects (WS and M level) and their interactions. The means were compared using the Duncan multiple comparison test (SPSS, 2011). In Experiment II, the results of the lamb performance and apparent digestion experiment were analyzed according to one way analysis of variance analysis using the SPSS program (SPSS, 2011) The Duncan multiple comparison test was used in determining the differences among the groups.

RESULTS AND DISCUSSION

Experiment I

In experiment I, the effects of the WS and M supplementation on the chemical composition of the forage turnip silage were determined and are presented in Table 4.

Increasing levels of WS and M increased the DM content of the silages (P<0.01). NDF values of the silages increased with the WS level, but decreased with an increasing level of M (P<0.01). IVOMD and ME values of the silages decreased with the WS level, but increased with an increasing level of M (P<0.01). The pH, NH_3-N/TN, CO_2, and organic acid (acetic, propionic, lactic, and butyric acid) contents of the forage turnip silages are presented in Table 5.

When compared with the control, the pH values of the silages increased with the WS level, but decreased with increasing levels of M (P<0.01). The silage NH_3-N/TN values varied depending on the addition of different levels of WS and M, while the NH_3-N/TN values decreased with an increasing level of M (P<0.01). The increasing addition of WS decreased the CO_2 production in the silages and improved the aerobic stability values (P<0.01). Lactic acid values of the silages increased with increasing levels of M (P<0.01).

Experiment II

In experiment II, the growth performance, SI, and FCR of lambs that consumed the MS, FTM, and FTSM silages were determined and are presented in Table 6. At the end of the 60-day lamb performance experiment, the TWG, DWG, and DM SI values of the lambs fed MS were higher than in those fed the FTM and FTSM silages (P<0.05). Nutrient digestibility of the MS, FTM, and FTSM silages are presented in Table 7. There were significant differences among the silage groups in terms of the DMD, OMD, CPD, CFD, ADFD, and NDFD. Although the DMD and OMD of the MS silage were higher than those of the FTM and FTSM silages, the CPD of the MS silage was lower than those of the FTM and FTSM silages (P<0.05). The CFD, ADFD, and NDFD of the FTSM silage were higher than those of the MS and FTM silages (P<005).

In experiment I, the DM values of the silages ensilaged with WS and M were higher than those of the control silage. These differences in the DM content of the silages were probably due to the higher DM values of the WS and M than the silage material (Sibanda *et al*. 1997). In Experiment I, increasing M levels increased the CP content of the silage, and this result can be associated with the fact that the CP value of the M was higher than that of the WS, and the plant proteins were protected from proteolysis due to the WSC source provided to the silages with the addition of M (Slottner and Bertilsson, 2006). The ADF and NDF values of the silages decreased with the addition of M, and this result may have been due to increased ADF, NDF and CF degradation as a result of lactic acid fermentation (Bolsen *et al*. 1996). The IVOMD and ME values of the silages increased with the addition of M and decreased with the addition of WS. This result can be explained by the fact that the nutrient and WSC content of the M was higher than that of the WS. The pH value of quality silage is acceptable in the range of 3.5-4.2, and this value for legume silages are in the range of 4.0-5.0 (Rondahl *et al*. 2011). In experiment I, the pH values of the silages prepared by adding different levels of WS and M were found within the acceptable pH values for legume silages (Rondahl *et al*. 2011). The decrease in the pH values and increase in the lactic acid values with the addition of M were considered to be due to the high WSC content of the M (Singh *et al*. 1985). In experiment I, the findings that the silages assessed had high lactic and acetic acid values, low pH, and acceptable NH_3-N/TN values demonstrated that the desired silage fermentation occurred (Nadeau *et al*. 2000). The silage NH_3-N/TN value of good quality silages is expected to be lower than 11% (Carpintero *et al*. 1969). The NH_3-N/TN values determined from all of the silages in the present study were found to be lower and close to the upper limit reported by Carpintero *et al*. (1969). When silage is opened, anaerobic conditions convert to aerobic conditions and some microorganisms that cannot grow within the optimal silage fermentation process start to grow and cause the silage to spoil (McDonald *et al*. 1991; Wilkinson and Davies, 2012).

Table 4 Effect of wheat straw (WS) and molasses (M) on chemical composition of forage turnip silages prepared in experiment I

WS level, %	DM	CP	ADF	NDF	IVOMD	ME
0	19.23[d]	10.63[a]	44.91	48.50[c]	52.80[a]	8.12[a]
7	22.36[c]	9.42[b]	44.78	54.64[b]	51.24[b]	7.83[b]
10	23.66[b]	9.04[c]	44.92	54.18[b]	50.88[b]	7.75[b]
15	25.93[a]	8.56[d]	44.62	55.95[a]	49.20[c]	7.48[c]
M level, %						
0	22.11[d]	8.91[c]	46.31[a]	54.59[a]	49.31[b]	7.51[b]
1	22.44[c]	9.67[a]	45.38[b]	53.59[b]	51.23[a]	7.84[a]
2	23.13[b]	9.52[b]	43.82[c]	53.03[c]	51.81[a]	7.92[a]
3	23.49[a]	9.55[ab]	43.72[c]	52.06[d]	51.77[a]	7.91[a]
SEM	0.283	0.098	0.177	0.356	0.240	0.040
Effects						
WS	**	**	NS	**	**	**
M	**	**	**	**	**	**
Interaction	**	**	**	**	**	**

DM: dry matter, %; CP: crude protein, % DM; ADF: acid detergent fiber, % DM; NDF: neutral detergent fiber, % DM; IVOMD: *in vitro* organic matter digestibility, % and ME: metabolisable energy, MJ/kg DM.
** (P<0.01).
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
NS: non significant.
SEM: standard error of the means.

Table 5 Effect of wheat straw (WS) and molasses (M) on the fermentation characteristics of the forage turnip silages prepared in experiment I

WS level, %	pH	NH_3-N/TN	CO_2	LA	AA	PA	BA
0	4.33[c]	10.90[ab]	7.19[a]	56.74[a]	36.31[b]	0.50[b]	0.38[a]
7	4.41[b]	11.16[a]	6.30[b]	43.49[b]	38.18[a]	0.82[a]	0.11[c]
10	4.43[b]	10.79[ab]	6.04[b]	39.85[c]	36.49[ab]	0.46[b]	0.11[c]
15	4.46[a]	10.41[b]	4.48[c]	32.35[d]	34.29[c]	0.44[b]	0.20[b]
M level, %							
0	4.57[a]	11.91[a]	4.69[c]	35.34[c]	34.16[b]	0.22[d]	0.80[a]
1	4.42[b]	11.01[b]	6.52[ab]	42.58[b]	37.23[a]	0.53[c]	0.00[b]
2	4.32[c]	10.35[c]	6.71[a]	46.73[a]	36.42[a]	0.68[b]	0.00[b]
3	4.32[c]	9.99[c]	6.09[b]	47.77[a]	37.46[a]	0.81[a]	0.00[b]
SEM	0.015	0.218	0.190	1.235	0.396	0.035	0.046
Effects							
WS	**	*	**	**	**	**	**
M	**	**	**	**	**	**	**
Interaction	**	**	**	**	*	**	**

NH_3-N/TN: ammonia nitrogen rate in total nitrogen content %; CO_2: carbon dioxide formation, g/kg DM; LA: lactic acid, g/kg DM; AA: acetic acid, g/kg DM; PA: propionic acid, g/kg DM and BA: butyric acid, g/kg DM.
* (P<0.05) and ** (P<0.01).
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

In this period, undesirable microorganisms consume WSCs and lactic acid, and cause DM and nutrient losses (Woolford, 1990). As a result, the silage starts to spoil due to CO_2, temperature, and water increases in the silo (Jatkauskas *et al*. 2013). An increase in CO_2 production negatively affects the aerobic stability of the silage (Wilkinson and Davies, 2012). The CO_2 values increased with the addition of M, and this result could have been due to the high WSC content of the M, which is a nutritional source for mold and yeasts.

The lactic acid value of the silages decreased with the addition of WS, but increased with the addition of M. The most important source of energy used by lactic acid bacteria during ensilage is WSC, and therefore, the addition of M increases the lactic acid level of silages (McDonald *et al.* 1991).

In this study, a high level of acetic acid was determined in the silages. This result may have been due to the low DM content of the silages, in which heterofermentative bacteria were more active (Kung, 2010).

Table 6 Effect of the silage type on the growth performance, silage intake (SI) and feed conversion ratio (FCR)

Silages	IBW	FBW	TWG	DWG	SI	FCR
MS	34.02±1.74	47.23±1.78	13.21±0.30[a]	220.42±5.03[a]	552.17±33.1[a]	8.09±0.62
FTM	33.93±1.21	44.34±1.15	10.41±0.63[b]	173.08±10.36[b]	444.24±27.9[b]	9.30±0.53
FTSM	34.04±1.33	45.22±1.41	11.19±0.69[b]	186.42±11.53[b]	408.06±6.0[b]	7.91±0.17
P-value	0.998	0.371	0.004	0.004	0.008	0.138

IBW: initial body weight, kg; FBW: final body weight, kg; TWG: total weight gain, kg; DWG: daily weight gain, g; SI: silage intake, DM basis and FCR: feed conversion ratio.
MS: maize silage; FTM: forage turnip + 3% M; FTSM: forage turnip + 7% WS + 2% M.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).

Table 7 Effect of the silage type on the nutrient digestibility

Silages	DMD	OMD	CPD	CFD	ADFD	NDFD
MS	62.71[a]	64.08[a]	54.08[b]	57.97[b]	41.39[b]	49.19[b]
FTM	52.24[c]	58.49[b]	65.61[a]	59.98[b]	37.94[b]	44.77[c]
FTSM	56.73[b]	60.38[b]	62.52[a]	64.52[a]	50.57[a]	56.25[a]
SEM	1.553	0.899	2.061	1.051	2.001	1.733

DMD: dry matter digestion, %; OMD: organic matter digestion, %; CPD: crude protein digestion, %; CFD: crude fiber digestion, %; ADFD: acid detergent fiber digestion, % and NDFD: neutral detergent fiber digestion, %.
MS: maize silage; FTM: forage turnip + 3% M and FTSM: forage turnip + 7% WS + 2% M.
The means within the same column with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Some studies have reported that acetic acid inhibits the formation of yeasts and fungi, and increases aerobic stability after the opening of silage (Danner *et al*. 2003). Butyric acid was determined in the control and silages in which WS was added. Butyric acid bacteria generally cannot grow in an environment where the pH value is below 4.5, while lactic acid bacteria are dominant within the pH range of 3.80-4.20, and proliferation and activity of the bacteria that produce butyric acid becomes impossible in this case (McDonald, 1981). The pH value should be in the range of 4.30-4.50, lactic acid content should be at 6-8%, acetic acid should be at 2-3%, propionic and butyric acid should be lower than 0.5% DM, and the NH_3-N/TN value should be approximately 10-15% DM for good quality legume silages (Kung *et al*. 2018). For the silages prepared in experiment I, the pH, NH_3-N/TN, lactic acid, acetic acid, propionic acid, and butyric acid values were generally compatible with those reported by Kung *et al*. (2018).

Experiment II

The DM, CP, ADF, and NDF contents of the forage turnip silages in experiment II were found to be different from the values in experiment I. This difference can be explained by the difference in the structures of the soil, fertilization, vegetation, and harvesting period, and more importantly, because the harvest and ensilage of the forage turnip in experiment II occurred 1-2 weeks late due to the continuous spring rainfall in 2018. The DM content of the FTM and FTSM silages prepared for the lamb performance and apparent digestion trials was lower than that reported by Hart and Horn (1987). This difference can be attributed to the differences in the additives used in the silage preparation, vegetation period, and the difference in the plant varieties chosen. The lactic acid content (22.86 g/kg DM) of the FTM silage prepared in the silage bags and used in the lamb performance and apparent digestion trials was found to be in the acceptable range (2% or 20 g/kg DM) for legume plant silages reported by Seglar (2003). Hart and Horn (1987) reported that the lactic acid contents of forage turnip silage prepared with the addition of WS were within the range of 46.90-74.90 g/kg DM and these values were higher than those determined in the current study (19.80-30.90 g/kg DM). In this study, the lactic acid values were found to be similar to those reported by Cetin and Arslan Duru (2020). Although Hart and Horn (1987) found butyric acid (0.25 and 2.30 g/kg DM) in their forage turnip silages prepared by adding WS, butyric acid was not determined in the FTM and FTSM silages herein. The absence of butyric acid in the FTM and FTSM silages indicated the high fermentation quality of these silages. The pH and NH_3-N/TN values of the FTM and FTSM silages were determined to be higher than the silages prepared in Experiment I, but the lactic and acetic acid values were determined to be lower. This result might have been associated with excess air that remained inside of the plastic silage bags used in experiment II. Additionally, the high BC of the forage turnip used as the silage material in experiment II might have been effective on this result (Gutiérrez *et al*. 2003). The high BC of legume forage plants associated with the DM and WSC content causes these plants to encounter ensilage difficulties (Davies *et al*. 1998). The CO_2 formation value (65.47 g/kg DM) of the MS used in Experiment II was determined to be higher than the those of the FTM and FTSM silages (5.93-6.63 g/kg DM). It has been reported that legumes that have low DM and WSC contents have more resistance against aerobic deterioration, while silages prepared from plants with high WSC contents are more sensitive to aerobic deterioration (Woolford, 1978). Due to the high WSC contents in the silages prepared from the maize plants, the development of yeasts and fungi, which cause aerobic deterioration, increased significantly (Weinberg *et al.* 1993; Wilkinson and Davies, 2012).

The SI values of the MS were higher than those in the FTM and FTSM silages (P<0.05). The lower DM intake from the FTM and FTSM silages may have been associated with the palatability of the silages. Forage intake may be restricted by the time required for cell rupture and the release of water for passage from the rumen (Robinson *et al.* 1990). Verite and Journet (1970) reported that when water content of fresh perennial ryegrass and forage legumes was greater than 75-85%, forage DM intake decreased in cattle. Finally, a reduction in total DM intake may also be associated with the presence of a free amino acid called S-methyl-L-cysteine sulphoxide, which occurs in all brassicas. When fermented within the rumen, S-methyl-L-cysteine sulphoxide can cause haemolytic anaemia and depressed DM intake (Barry and Manley, 1985; Keogh *et al.* 2009). Several researchers have reported that the lower palatability of legumes was associated with the fermentation quality of the legume silages, resulting in higher acetic acid contents, and the degradation of amino acids affects silage fermentation negatively; hence, the silage consumption decreased due to this reason (Whittenbury *et al.* 1967; Wilkins *et al.* 1971). MS is a feed with a low amount of physically effective fiber (peNDF) (Mertens *et al.* 1994).

Although not detected in the current research, the peNDF level of forage turnip and WS is thought to be higher than that of MS. It is also known that feeds with a high amount of peNDF have an increased length of stay in the digestive tract, which causes a decrease in feed consumption. In addition, when the NDF ratio exceeds 32% DM, the feed intake is limited by the rumen capacity (Khafipour *et al.* 2009). Although there were no significant differences between the acetic acid values of the silages (MS, FTM, and FTSM) used in experiment II, it was determined that the acetic acid value of the FTSM silage was numerically higher than those of the MS and FTM silages. The SI value of the FTSM silage was determined to be low in the lamb performance trial. This result can be explained due to the fact that the acetic acid values were high in the FTSM silage. High acetic acid concentrations in silage are associated with reduced feed intake by ruminants (Steen *et al.* 1998). Despite the fact that no statistical differences were found among the groups, the highest FCR value was determined in the FTSM silage, while the lowest was determined in the FTM silage.

In the apparent digestion trial, the DMD and OMD values of the MS silage were higher than those of the FTM and FTSM silage (P<0.05). The high DMD and OMD values of MS silage were possibly associated with the grain content of the MS. It is well known that MS consists of grains to some extent, which is more digestible than the other part of the silage (Wheaton *et al.* 1993). Hart and Horn (1987) reported that the OMD values of forage turnip silage prepared with or without the addition of WS were within the range of 63.00-62.00%, which were similar to the values of FTM and FTSM silages in the present study (58.49-60.38%). The ADFD values of the FTM and FTSM silages (37.94-50.57%) were found to be lower than the ADFD values (61.90-82.20%) reported by Hart and Horn (1987). The reason for the increase in the ADF and NDF digestibility may have been due to the combination of straw with the M in this group of silage. Studies have shown that M-treated straw weakens cellulose bonds. Thus, it has been reported that the NDF-ADF digestibility of the straw increases, and the NDF-ADF digestibility also significantly increases in total mixture ration, where M-treated straw is added (Hassan *et al.* 2011). On the other hand, when the NDF ratio rises above 32% DM, the environment in the rumen shifts towards cellulotic microorganisms, which may lead to an increase in ADF-NDF digestibility (Khafipour *et al.* 2009).

CONCLUSION

This study demonstrated that forage turnip can be ensilaged after the full flowering and encapsulation period with a high DM content in order to increase the silage quality and decrease silo water losses. Alternatively, WS (7% or 10%) and M (1%, 2%, or 3%) may be added to elevate the DM content and the silage quality as an alternative roughage source for the feeding of ruminants. Further studies are needed in order to reveal whether forage turnip (*Brassica rapa*) can be ensilaged by adding different additives and determine the effect of forage turnip silages on the performance and feeding economy of dairy and beef cattle.

ACKNOWLEDGEMENT

The authors thank the Harran University Scientific Research Projects Coordination for funding the research (Project number: HUBAP-18011).

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