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Evaluating the effects of different silage additives on silage quality and in vitro digestion values of the silages of leguminous and gramineous forage plants grown without fertilizer and irrigation in central Anatolian arid conditions

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Abstract: The objective of this study was to determine the effects of molasses, and bacterial inoculants on silage quality, fermentation characteristics, nutrient contents, and in vitro digestibility of different forage species grown at terrestrial climate of Central Anatolia without any artificial fertilizer usage and irrigation. Forage peas (*Pisum arvense L.*), Hungarian vetch (*Vicia pannonica Crantz*), rye grass (*Lolium multiflorum Lam.*) and triticale (*xTriticosecale Wittmack*) harvested at the dough stage of triticale and conserved in 1.5 kg jars. Silages were treated with no additive (control silage), 5% molasses and 10 g/t bacterial inoculant. Sensory, pH, organic acid, chemical analyses and in vitro digestibility of all silages were determined Forage peas silage had the highest lactic and acetic acid concentrations among all silages. Addition of both molasses and inoculant did not affect the lactic acid (LA) contents of silages ($p > 0.05$), but both them increased acetic acid contents ($p < 0.05$). Ammonia-N concentrations were higher in forage peas silage compared with other silages ($p < 0.05$). The concentrations of dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), acid detergent fiber (ADF) and crude protein (CP) were significantly different among silages ($p < 0.05$). The addition of molasses significantly reduced the silage OM, NDF and ADF contents ($p < 0.05$). In vitro OM digestibilities and energy values of silage were significantly different among silages made from different forages ($p < 0.05$), but not affected by silage additives. It can be concluded that high quality silage can be prepared from legume forages such as peas and vetch and small cereal grains such as rye and triticale grown without fertilizer usage and irrigation in central Anatolian arid conditions without any silage additive application, and but silage additive use may improve silage quality.

Key words: Forage peas, Hungarian vetch, rye grass, triticale, silage, silage additives, molasses, bacterial inoculant, in vitro digestibility

1. Introduction

Approximately 50% to 70% of total farming expenses in Turkey is feed cost [1]. Value-added livestock enterprises have to be integrated with existing cropping enterprises to reduce feed cost and be able to settle a sustainable farming system for moderate-sized family farms. The lack of cheap, abundant and high-quality forage production is the major problem for Turkish dairy and beef production, especially in Central Anatolia region. Since the Central Anatolia region has arid climatic conditions, forage crops which can grow in arid climatic conditions becomes even more important. Among legumes, Hungarian vetch in the Central Anatolia region, and forage peas in different regions of Turkey productions have started to become very popular. Similarly, rye grass and triticale have also started to be widely produced in Turkey as the source of alternative high-quality forages. Since so much water is not needed for the production of these forages, these forages can be grown in the arid conditions of the Central Anatolia region without any problem. Indeed, cereal type plants such as barley, wheat, rye triticale and rye grass and leguminous forages such as Hungarian vetch, hairy vetch, hairy fruit vetch and forage peas have yielded successful results in determining the species to be used in the preparation of winter and drought-resistant mixtures [2–4].

Forages have traditionally conserved as hay in the region. Hay-making, on the other hand, causes a loss of nutrients, especially in legumes, due to too much leaf loss. Therefore, conserving these plants as silage can reduce nutrient loss. In silage making, the way to minimize the nutrient-losses in silage is to reduce the silage pH level between 3.8 and 4.2 as fast as possible. However, it is very difficult to achieve this when legumes are used as silage material due to their low buffering capacity [5]. Thus,

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silage additives such as formic acid, molasses and bacterial inoculant have been added into silage material in order to accelerate the pH decrease [6].

The objective of this study was to determine the effects of molasses, and bacterial inoculant as silage additives on silage quality, fermentation characteristics, nutrient contents, and in vitro digestibilities of different forage species grown at terrestrial climate of Central Anatolia without any artificial fertilizer usage and irrigation.

2. Material and methods

2.1. Experimental location

This study was carried out at the experimental station in Kırıkkale University Campus. The trial area is in the northwest of Central Anatolia (39°53'N, 33°26'E) and its altitude is 756 m. Kırıkkale province has terrestrial climate characteristics and has an annual rainfall average of 405 mm.

The Central Anatolia region has continental climate zone. In this region, according to the long term mean value, winters are cool and rainy, and summers are hot and dry. Throughout the growing period, the precipitation values of the December and June were above while October, January and February precipitation values were below than the long-term average (Figure 1). A total rainfall was 314.3 mm during the growing period. Temperature values have remained around the long-term average (Figure 2).

The soils of the trial fields are clayey (37.07%), sandy (39.17%) and loamy (23.76%), slightly alkali (pH = 7.73), salt-free [0.10 EC (dS/m)], moderately calcareous (12.15%), poor in organic matter (1.33%), and enough in terms of available potassium (216 ppm). The soil had low nitrogen and phosphorous content 0.18% and 3.13 ppm, respectively.

2.2. Experimental design

In the experiment, Hungarian vetch (*Vicia pannonica L.*), Triticale (*xTriticosecale* Wittmack), Rye gras (*Lolium*

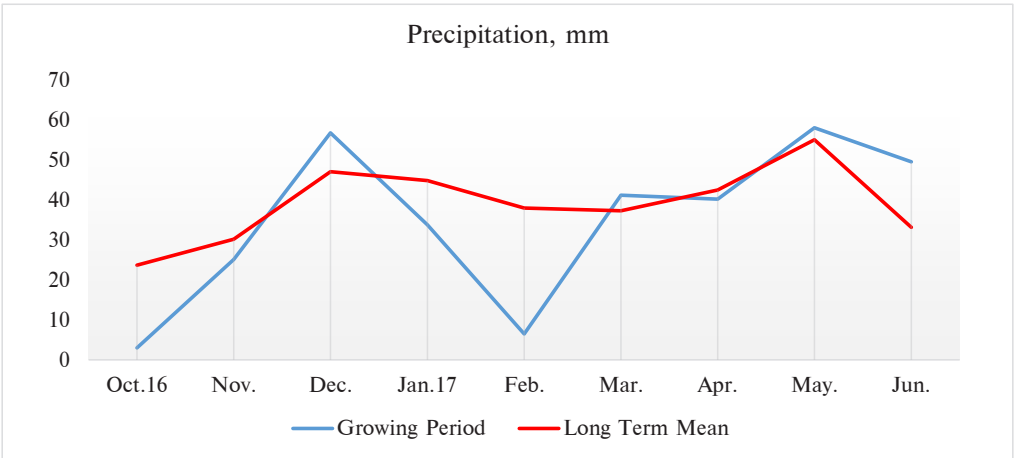

Figure 1. Monthly precipitation values during the growing season (Turkish State Meteorological Service).

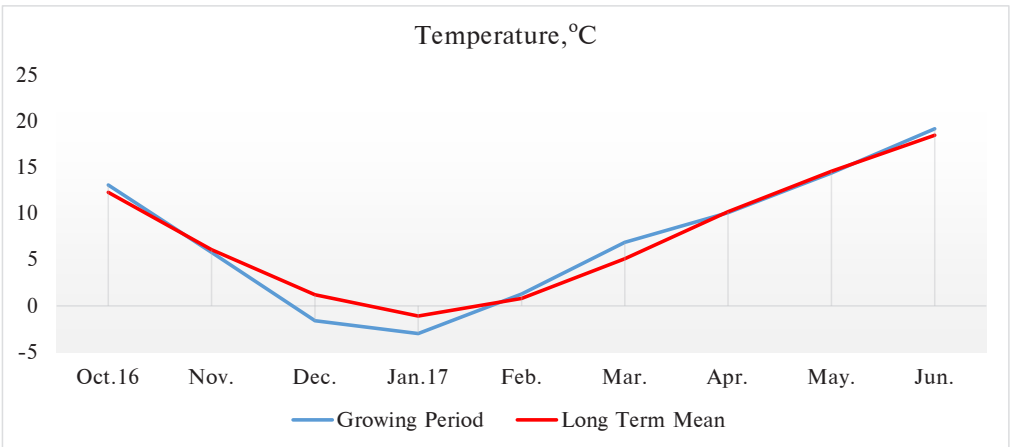

Figure 2. Monthly temperature values during the growing season (Turkish State Meteorological Service).

multiflorum L.) and Forage pea (*Pisum sativum var. arvense*) were planted in for winter. The trial was planned in 3 replications on 5 m × 1.5 m parcels. Plants were seeded as Hungarian vetch 10 kg/da, Forage pea 15 kg/da, Rye grass 6 kg/da and Triticale 24 kg/da. Ten rows were planted in each parcel, the seeds were planted sequentially in planting and the row spacing was 15 cm. Fertilization and irrigation have not been applied to the parcels.

Because triticale matured earlier so the harvest was made at dough stage of triticale's seeds. The harvest was done manually in 1 m^2 areas from each parcel. After harvesting forages, about 10 kg of fresh material from each forage species was chopped to a size of 2–3 cm, then, was spread on a clean area of 1 × 2 m and the silage additives were applied in this way and the material was ensiled into the 1.5 L jars.

Three different silages were prepared from each chopped forage species. Silage treatments included control (no additives), 5% molasses, and 10 g/t inoculant (at 1.25 × 10^{11} CFU/g of fresh forage). Innoculant used in the study was obtained from DuPont Pioneer Company, 1188 silage inoculant that contains;

(*Lactobacillus plantarum* LP286 DSM 4784 ATCC 53187 : 2.5 × 10^{10} CFU/g

Lactobacillus plantarum LP318 DSM 4785 : 2.5 × 10^{10} CFU/g

Lactobacillus plantarum LP319 DSM 4786 : 2.5 × 10^{10} CFU/g

Lactobacillus plantarum LP346 DSM 4787 ATCC 55943 : 2.5 × 10^{10} CFU/g

Enterococcus faecium SF301 DSM 4789 ATCC 55593 : 1.25 × 10^{10} CFU/g

Enterococcus faecium SF202 DSM 4788 ATCC 53519 : 1.25 × 10^{10} CFU/g). Silages were prepared (quadruplicate) in 1.5 L jars with tight lids. A total of 48 silage samples, 12 silages for each forage species, were prepared. Ensiling was done by hand-stamping. After ensiling, each jar was sealed off tightly with a lid. The silages were stored for 60 days in a dark room with a temperature ranging from 20 to 25 °C. After 60 days of ensiling, all of the silage samples were opened to determine physical characteristics, pH, organic acids and nutrient compositions.

2.3. Physical and chemical analyses

Physical analyses such as smell, structure and colour of silages were scored by three specialists according to DLG [7]. Then, the silage filtrate was obtained by hydration of an approximately 25 g wet ensilage material with 100 mL distilled water using a blender for 10 min. The pH value was determined using digital pH meter [8]. Then, the filtrate was filtered through filter paper and stored for organic acid analysis at –20 °C. Ammonia-N concentrations of the silages were determined with Kjeldahl distillation method using the filtrate [9].

The lactic acid (LA) content in silage fluid was determined according to a modified spectrophotometric method [10] by Barnett [11]. The amount of LA in the sample fluid was calculated as lactate equivalent from the calibration curve (R^2 = 0.95) of standard lithium lactate (0.312 – 160 µg/mL). The LA content percentage in silage DM was calculated. The 1.5 mL of silage fluid mixed with 0.3 mL of metaphosphoric acid (25%, w/v) in a microcentrifuge tube was centrifuged at 15000 rpm for 15 min. The supernatant was taken from a gas chromatograph vial. The analysis of organic acids [(AA), butyric (BA) and propionic (PA)] in silage fluid was made by using a gas chromatograph device (GC, Thermo Trace 1300, Thermo Scientific, USA) with an autosampler (Thermo AI - 1310, Thermo Scientific, USA) [12]. According to the retention time and peak area in chromatograms, the concentrations (mmol/L) of organic acids were identified using the Xcalibur software program. The percentages of organic acid concentrations in DM of silage were calculated.

To determine the dry mater (DM) of each silage samples, the remaining silage materials in the jar were weighed and first air-dried, then, the subsamples of air-dried samples were oven-dried at 65 °C for 72 h. All of the chemical analyses were run on dried samples. First, all of dried silage samples were ground to pass through a 1 mm screen and run for determination of ash, crude protein (CP) [13], neutral detergent fibre (NDF) [14], acid detergent fibre (ADF) [15] concentrations using Daisy (ANKOM) machine.

2.4. Determination of in vitro dry matter digestibilities and energy values

In vitro dry matter digestibilities (IVDMD) of samples were determined according to the procedure described by Tilley and Terry [16], as modified by Marten and Barnes [17]. Ruminal fluid from an alfalfa-fed ruminally cannulated Holstein cow was hand collected and strained through 4 layers of cheesecloth before using as the inoculant for the IVDMD determination. Metabolizable energy (ME, Mcal/kg) and net energy for lactation ($NE_{L,}$ Mcal/kg) values were calculated using the following equations [18]:

ME, (Mcal/kg) = Digestible energy × 0.82

NE_L (Mcal/kg)= 0.00245 × TDN – 12. (TDN = Total digestible nutrients)

2.5. Statistical analysis

All data were subjected to analysis of variance using general linear model procedure of SAS [19]. Effects of forage species, silage additives were determined. Interaction between forage species and silage additives were also determined. Mean treatment differences were separated by Tukey's multiple range tests with a level of statistical significance of 5% [20].

3. Results

As a physical quality criterion of silages, the sensory analyses of the silages (smell, structure and colour) are presented in Table 1. When both types of forages and silage additives were compared with each other in terms of visual and physical characteristics; no statistically significant differences were observed among the groups ($p > 0.05$), except triticale. Addition of silage additives improved colour of triticale silage ($p < 0.05$). Total quality score of the silages ranged from 17.5 to 20.0. While Flieg points were significantly different among forage types ($p < 0.05$), addition of silage additives had no significant effect on Flieg points.

Parameters related with fermentation such as pH, organic acids and NH_3-N concentrations of silages are shown in Table 2. Forage pea had the highest lactic (and acetic acid concentrations among all silages. Addition of silage additives did not affect the lactic acid contents

Table 1. Physical properties, scoring and quality classes of silages.

Forage species	Odour (point)	Structure (point)	Color (point)	Total (point)	Flieg (point)
Forage peas	12.67 ± 0.47	4.00 ± 0.00	2.00 ± 0.00	18.67 ± 0.47	98.30 ± 1.90[b]
Hungarian vetch	14.00 ± 0.00	3.83 ± 0.17	1.92 ± 0.08	19.75 ± 0.25	105.30 ± 2.74[ab]
Rye grass	12.33 ± 0.60	4.00 ± 0.00	1.92 ± 0.08	18.33 ± 0.60	96.23 ± 6.70[b]
Triticale	12.83 ± 0.60	3.83 ± 0.11	1.83 ± 0.11	18.50 ± 0.86	117.74 ± 4.36[a]
p value	1.45	0.40	0.50	0.36	0.01
Additives					
Control	13.00 ± 0.41	3.88 ± 0.09	1.81 ± 0.10	18.75 ± 0.40	101.73 ± 3.33
Innoculant	13.50 ± 0.34	4.00 ± 0.00	2.00 ± 0.00	19.50 ± 0.34	106.96 ± 3.02
Molasses	12.37 ± 0.69	3.87 ± 0.13	1.94 ± 0.06	18.19 ± 0.69	104.48 ± 5.86
p value	1.17	0.48	0.14	0.22	0.63
Plant species × Additives	0.93	0.14	0.15	0.95	0.56
Forage pea					
Control	13.00 ± 0.58	4.00 ± 0.00	2.00 ± 0.00	19.00 ± 0.58	92.15 ± 2.72
Innoculant	13.00 ± 1.00	4.00 ± 0.00	2.00 ± 0.00	19.00 ± 1.00	102.17 ± 2.40
Molasses	12.00 ± 0.91	4.00 ± 0.00	2.00 ± 0.00	18.00 ± 0.91	100.57 ± 2.67
p value	0.74	1.00	1.00	0.74	0.62
Hungarian vetch					
Control	14.00 ± 0.00	4.00 ± 0.00	2.00 ± 0.00	20.00 ± 0.00	103.95 ± 5.59
Innoculant	14.00 ± 0.00	4.00 ± 0.00	2.00 ± 0.00	20.00 ± 0.00	105.79 ± 3.80
Molasses	14.00 ± 0.00	3.50 ± 0.50	1.75 ± 0.25	19.25 ± 0.75	106.17 ± 6.03
p value	1.00	0.06	0.31	0.85	0.98
Rye grass					
Control	12.00 ± 1.16	4.00 ± 0.00	1.75 ± 0.25	18.00 ± 1.16	100.08 ± 10.09
Innoculant	13.00 ± 1.00	4.00 ± 0.00	2.00 ± 0.00	19.00 ± 1.00	103.02 ± 4.59
Molasses	12.00 ± 1.16	4.00 ± 0.00	2.00 ± 0.00	18.00 ± 1.16	85.59 ± 17.68
p value	0.74	1.00	0.31	0.74	0.24
Triticale					
Control	13.00 ± 1.00	3.50 ± 0.29	1.50 ± 0.29[b]	18.00 ± 0.82	110.77 ± 4.51
Innoculant	14.00 ± 0.00	4.00 ± 0.00	2.00 ± 0.00[a]	20.00 ± 0.00	116.87 ± 9.72
Molasses	11.50 ± 2.50	4.00 ± 0.00	2.00 ± 0.00[a]	17.50 ± 2.50	125.58 ± 7.55
p value	0.25	0.06	0.01	0.22	0.40

[ab]: Means in a column with different superscripts are different ($p < 0.05$).

Table 2. Fermentation parameters of silages, DM%.

	pH	LA	AA	PA	BA	Ammonia-N
Forage species						
Forage peas	4.17 ± 0.03^{b}	3.36 ± 0.14^{a}	0.31 ± 0.02^{a}	0.003 ± 0.000	0.001 ± 0.003	0.97 ± 0.04^{a}
Hungarian vetch	4.35 ± 0.06^{ab}	1.34 ± 0.08^{b}	0.27 ± 0.02^{a}	0.004 ± 0.001	0.001 ± 0.001	0.83 ± 0.02^{b}
Rye grass	4.54 ± 0.14^{a}	1.03 ± 0.13^{b}	0.14 ± 0.01^{b}	0.007 ± 0.002	0.007 ± 0.005	0.66 ± 0.02^{c}
Triticale	4.36 ± 0.05^{ab}	1.25 ± 0.09^{b}	0.18 ± 0.04^{b}	0.006 ± 0.001	0.001 ± 0.005	0.79 ± 0.03^{b}
p value	0.02	0.001	0.001	0.13	0.21	0.001
Additives						
Control	4.38 ± 0.05	1.76 ± 0.26	0.18 ± 0.03^{b}	0.004 ± 0.001	0.001 ± 0.000	0.79 ± 0.05
Innoculant	4.31 ± 0.06	1.70 ± 0.25	0.29 ± 0.02^{a}	0.005 ± 0.001	0.004 ± 0.003	0.84 ± 0.04
Molasses	4.37 ± 0.11	1.80 ± 0.27	0.21 ± 0.02^{b}	0.006 ± 0.001	0.003 ± 0.001	0.80 ± 0.02
p value	0.70	0.71	0.001	0.57	0.70	0.25
Plant species × Additives	0.15	0.15	0.001	0.73	0.72	0.03
Forage pea						
Control	4.29 ± 0.038	3.39 ± 0.16	0.29 ± 0.02	0.002 ± 0.004	0.004 ± 0.000	0.99 ± 0.09
Innoculant	4.08 ± 0.045	3.25 ± 0.32	0.34 ± 0.03	0.003 ± 0.001	0.000 ± 0.000	1.01 ± 0.07
Molasses	4.13 ± 0.039	3.44 ± 0.30	0.29 ± 0.03	0.003 ± 0.004	0.002 ± 0.001	0.91 ± 0.04
p value	0.53	0.77	0.26	0.95	0.96	0.25
Hungarian vetch						
Control	4.43 ± 0.055	1.40 ± 0.07	0.24 ± 0.02	0.002 ± 0.001	0.001 ± 0.000	0.88 ± 0.02
Innoculant	4.38 ± 0.140	1.24 ± 0.13	0.32 ± 0.03	0.003 ± 0.001	0.000 ± 0.000	0.79 ± 0.05
Molasses	4.24 ± 0.077	1.38 ± 0.21	0.26 ± 0.04	0.001 ± 0.001	0.001 ± 0.002	0.80 ± 0.02
p value	0.61	0.81	0.06	0.55	0.91	0.31
Rye grass						
Control	4.43 ± 0.17^{b}	0.87 ± 0.06	0.16 ± 0.03	0.008 ± 0.004	0.001 ± 0.002	0.61 ± 0.03
Innoculant	4.34 ± 0.10^{b}	0.81 ± 0.09	0.17 ± 0.01	0.007 ± 0.003	0.014 ± 0.014	0.67 ± 0.02
Molasses	4.84 ± 0.35^{a}	1.42 ± 0.33	0.09 ± 0.01	0.005 ± 0.002	0.005 ± 0.002	0.70 ± 0.04
p value	0.03	0.06	0.051	0.70	0.14	0.37
Triticale						
Control	4.39 ± 0.043	1.39 ± 0.20	0.02 ± 0.00^{c}	0.004 ± 0.002	0.001 ± 0.000	0.68 ± 0.02^{b}
Innoculant	4.42 ± 0.123	1.44 ± 0.07	0.33 ± 0.03^{a}	0.005 ± 0.003	0.002 ± 0.001	0.89 ± 0.03^{a}
Molasses	4.25 ± 0.063	0.93 ± 0.05	0.20 ± 0.02^{b}	0.009 ± 0.001	0.002 ± 0.000	0.79 ± 0.03a^{b}
p value	0.65	0.15	<0.001	0.28	0.99	0.01

LA: Lactic acid; AA: Acetic acid; PA: Propionic acid; BA: Butyric acid; N: Nitrogen.
$^{a, b, c}$: Means in a column with different superscripts are different ($p < 0.05$).

of silages ($p > 0.05$) but increased acetic acid contents, especially inoculant addition ($p < 0.05$). There was also plant type × inoculant interaction on acetic acid contents ($p < 0.05$). Both propionic and butyric acid contents were very low and similar among forages ($p > 0.05$). They were also not affected by silage additives ($p > 0.05$). Ammonia-N concentrations were higher in forage peas silage compared with other silages ($p < 0.05$). However, addition of silage additives had no effect on silage NH_3-N concentrations.

Chemical compositions of silages are given in Table 3. The concentrations of DM, OM, NDF, ADF, and CP were significantly different among silages ($p < 0.05$). The addition of molasses into silages significantly reduced the silage OM, NDF, and ADF contents ($p < 0.05$).

In vitro OM digestibilities and energy values of silage were significantly different among silages made from

Table 3. Chemical contents of silages, DM%.

Forage species	DM	Ash	OM	CP	NDF	ADF
Forage peas	29.38 ± 0.43^{b}	7.31 ± 0.64^{ab}	92.78 ± 0.65^{ab}	13.88 ± 0.24^{a}	36.55 ± 1.23^{d}	23.91 ± 0.49^{c}
Hungarian vetch	38.28 ± 1.17^{a}	6.55 ± 0.25^{b}	93.20 ± 0.34^{a}	12.72 ± 0.32^{b}	43.81 ± 1.08^{c}	29.94 ± 0.75^{b}
Rye grass	35.95 ± 0.76^{a}	6.27 ± 0.25^{b}	93.73 ± 0.25^{a}	6.44 ± 0.22^{c}	47.38 ± 0.63^{b}	28.35 ± 0.61^{b}
Triticale	39.53 ± 1.53^{a}	7.96 ± 0.43^{a}	92.04 ± 0.43^{b}	7.37 ± 0.25^{c}	52.24 ± 1.20^{a}	32.83 ± 1.45^{a}
p value	0.001	0.001	0.001	0.001	0.001	0.001
Additives						
Control	34.94 ± 1.15	6.48 ± 0.37^{b}	93.34 ± 0.41^{a}	10.05 ± 0.91	47.16 ± 1.77^{a}	31.09 ± 1.40^{a}
Innoculant	35.11 ± 1.40	6.45 ± 0.24^{b}	93.61 ± 0.25^{a}	10.15 ± 0.91	44.99 ± 1.82^{ab}	28.50 ± 0.92^{b}
Molasses	37.31 ± 1.41	8.14 ± 0.40^{a}	91.86 ± 0.40^{b}	10.11 ± 0.76	42.84 ± 1.40^{b}	26.69 ± 0.65^{c}
p value	0.11	0.001	0.001	0.95	0.001	0.001
Plant species × Additives	0.20	0.001	0.001	0.20	0.07	0.001
Forage pea						
Control	29.32 ± 0.87	5.63 ± 0.53^{b}	94.37 ± 1.06^{a}	13.98 ± 0.72	38.00 ± 2.34	24.90 ± 0.88
Innoculant	28.44 ± 0.30	6.21 ± 0.43^{b}	94.04 ± 0.90^{a}	14.47 ± 0.83	35.42 ± 2.03	23.04 ± 0.68
Molasses	30.38 ± 0.76	10.08 ± 0.29^{a}	89.92 ± 0.57^{b}	13.20 ± 0.44	36.24 ± 2.41	23.80 ± 0.90
p value	0.73	0.001	0.001	0.14	0.47	0.41
Hungarian vetch						
Control	38.97 ± 1.98	6.43 ± 0.44	92.82 ± 1.67	13.02 ± 0.89	47.98 ± 0.50^{a}	32.83 ± 0.59^{a}
Innoculant	37.94 ± 2.92	6.57 ± 0.56	93.43 ± 1.13	12.34 ± 1.78	42.59 ± 0.82^{b}	29.60 ± 0.71^{b}
Molasses	37.93 ± 1.55	6.66 ± 0.44	93.34 ± 0.88	12.80 ± 0.46	40.85 ± 1.64^{b}	27.37 ± 0.60^{b}
p value	0.89	0.95	0.67	0.55	0.005	0.001
Rye grass						
Control	36.04 ± 1.64	5.48 ± 0.37	94.52 ± 0.74	6.43 ± 0.97	46.73 ± 1.34	28.13 ± 1.22
Innoculant	34.71 ± 0.66	6.34 ± 0.27	93.66 ± 0.53	6.16 ± 0.76	49.42 ± 0.55	30.12 ± 0.52
Molasses	37.10 ± 1.48	7.00 ± 0.31	93.00 ± 0.63	6.73 ± 0.66	46.00 ± 0.36	26.81 ± 0.72
p value	0.62	0.09	0.13	0.66	0.25	0.07
Triticale						
Control	35.41 ± 1.70^{b}	8.36 ± 0.61^{a}	91.64 ± 1.23^{b}	6.76 ± 0.38	55.92 ± 1.02^{a}	38.49 ± 1.35^{a}
Innoculant	39.34 ± 2.55^{ab}	6.70 ± 0.73^{b}	93.30 ± 1.46^{a}	7.61 ± 0.97	52.52 ± 1.84^{ab}	31.23 ± 1.36^{b}
Molasses	43.84 ± 2.12^{a}	8.82 ± 0.52^{a}	91.18 ± 1.04^{b}	7.74 ± 0.91	48.28 ± 1.26^{b}	28.76 ± 1.52^{b}
p value	0.01	0.01	0.02	0.25	0.004	0.001

DM: Dry matter; OM: Organic matter; CP: Crude protein; NDF: Neutral detergent fibre; ADF: Acid detergent fibre.
$^{a, b, c.}$: Means in a column with different superscripts are different ($p < 0.05$).

different forages ($p < 0.05$; Table 4). Even though addition of silage additives had no significant effect ($p > 0.05$), there was a significant forage type × additives interaction on IVDOM and energy values ($p < 0.05$).

4. Discussion

The main goal of silage making with higher quality is to minimize dry matter losses and maintain the maximum aerobic stability and nutritive value using modern technologies. The quality of silages can be evaluated by both physical (sensory) and chemical analyses.

The sensory analyses such as smell, structure, and colour of the silages, which were performed by three experts, were classified into the first (perfect quality) class. Almost, all of the silage had a specific smell which were pleasant, pickle-like and not extremely strong; had no disliked smells like that of butyric acid, yeast and ammonia. Since all of the silages in control group had the

Table 4. In vitro OMD and energy values of silages.

Forage species	IVDOM, OM%	ME, (Mcal/kg)	NEL, (Mcal/kg)
Forage peas	65.17 ± 0.57[b]	2.87 ± 0.02[b]	1.47 ± 0.02[b]
Hungarian vetch	62.88 ± 0.88[b]	2.77 ± 0.04[b]	1.42 ± 0.02[b]
Rye grass	57.41 ± 1.02[c]	2.53 ± 0.05[c]	1.29 ± 0.03[c]
Triticale	73.11 ± 1.93[a]	3.22 ± 0.08[a]	1.67 ± 0.05[a]
p value	0.001	0.001	0.001
Additives			
Control	65.75 ± 2.01	2.90 ± 0.09	1.48 ± 0.05
Innoculant	63.25 ± 1.95	2.79 ± 0.09	1.43 ± 0.05
Molasses	64.93 ± 3.48	2.86 ± 0.05	1.47 ± 0.03
p value	0.14	0.15	0.20
Plant species × Additives	0.19	0.19	0.19
Forage pea			
Control	63.35 ± 0.75	2.79 ± 0.03	1.41 ± 0.04
Innoculant	65.09 ± 0.73	2.87 ± 0.03	1.47 ± 0.02
Molasses	67.07 ± 0.33	2.94 ± 0.01	1.52 ± 0.01
p value	0.34	0.40	0.24
Hungarian vetch			
Control	64.31 ± 0.65	2.84 ± 0.03	1.46 ± 0.02
Innoculant	60.37 ± 1.82	2.66 ± 0.08	1.36 ± 0.04
Molasses	63.94 ± 1.27	2.82 ± 0.06	1.45 ± 0.03
p value	0.23	0.23	0.25
Rye grass			
Control	57.22 ± 1.14	2.52 ± 0.05	1.28 ± 0.03
Innoculant	54.60 ± 0.73	2.41 ± 0.03	1.22 ± 0.02
Molasses	60.40 ± 2.01	2.66 ± 0.09	1.36 ± 0.05
p value	0.08	0.08	0.09
Triticale			
Control	72.11 ± 0.90	3.21 ± 0.05	1.66 ± 0.02
Innoculant	71.94 ± 3.42	3.20 ± 0.15	1.65 ± 0.08
Molasses	74.29 ± 3.48	3.34 ± 0.15	1.68 ± 0.09
p value	0.29	0.29	0.29

IVDOM: In vitro organic matter digestibility; OM: Organic matter; ME: Metabolic energy; NEL: Net energy for lactation.
[a. b. c.]: Means in a column with different superscripts are different ($p < 0.05$).

higher quality score the addition of silage additives had not significant effect. Also, majority of plants used in the silage preserved their colour and integrity. Similarly, Flieg points were quite high in all silages.

Both DLG silage quality and Flieg scores show that all silages were of very good quality. Dinic et al. [21] have stated that a high-quality silage based on DLG method (class I) with wilted red clover biomass without additives can be achieved. DLG scores of different legumes ranged from class I to class II. Silage additives, especially inoculant significantly improved DLG scores of legumes [22]. On the other hand, Arslan Duru and Aksu Elmalı [23] noted that the sensory analyses of alfalfa silages prepared by using ground wheat, corn and molasses as additives were "satisfying". Similarly, Çetin and Aslan Duru [24] rated DLG scores of forage turnip silages prepared with different

silage additives as satisfying. In the current study, DLG scores of all silages were in class I, which are in agreement with the results of studies previously published [21–24].

The pH values of silages were different among plant types ($p < 0.05$) but were not significantly affected by silage additives ($p > 0.05$). pH is one of the most important indications of high-quality silage and should range from 3.8 to 4.2 [1]. The pH values observed in the current study were close to the upper edge of these values. The sugar content and the buffer capacity of plants precisely determine the suitability of plants for ensiling [5]. The higher buffer capacity of legumes due to high protein and minerals – calcium contents, and small amounts of fermentable carbohydrates limits the application of silage technology for legumes [5]. Therefore, it is difficult to drop silage pH at desirable levels when legumes are ensiled. In the current study, these pH levels are close to ideal levels. The silage pH was closely associated with lactic and acetic acid concentrations in silage. The lactic and acetic acid level of silages made from legumes were higher than those of grass silage ($p < 0.05$) and addition of inoculant improved silage acetic acid level as well ($p < 0.05$). Lack of propionic and butyric acid in silages indicate good preservation of silages. While lactic acid concentrations of silage made from legumes were higher than those reported by Pahlow et al. [22] and Dinic et al. [21], acetic acid concentrations of silages were similar with the findings reported by previous studies [21,22,25,26]. Because legumes used in the current study (vetch and peas) have seeds that are rich in carbohydrate, observing the higher lactic acid concentrations, which more than would normally be expected from legumes, makes sense. Both lactic and acetic acid concentrations of rye grass silage were similar to those reported by Auerbach and Theobald [26]. In all of the silages, the existence of high lactic acid, low acetic acid and lack of propionic and butyric acid levels indicate the presence of homofermentative fermentation, which is an indicator of good preservation. The most significant change in fermentation pattern with silage additives was observed in silage with inoculant, as reflected by very high acetic acid concentrations and the lowest content of lactic acid, which confirms the results of Auerbach et al. [25] and Auerbach and Theobald [26]. This could be due to type of bacteria used in the inoculant. Silage ammonia-N content is an indicator of water-soluble N levels of silages. Since legumes are richer in crude protein compared with grass, silage ammonia-N content of silage was generally higher than those of grass. There is also plant-species effect. Similarly, Pahlow et al. [22] noted the plant-species effect with significantly less protein decomposition in red clover and lotus than in lucerne and galega.

Dry matter levels of silages prepared from different plant species were found between 29.38% and 39.53%. DM levels were in the 30%–40% range, which is accepted as the ideal DM range for silage [1]. Although all the plants involved in the study were planted and harvested at the same time and treated in the same way, it was found that the level of DM belonging to silage made from forage peas was lower than the others. It is thought that this is due to the fact that the vegetation period of the forage peas seems longer than the others. Molasses, one of the silage additives, did not significantly affect the DM level of the silage, despite the tendency to increase the DM level. The effect of plant species on OM levels of silages was significant. It is a known fact that the mineral contents of plants are quite different from each other [27]. The use of molasses as a silage additive to silages reduced the OM level of silages. This is due to the high ash level of molasses [5]. It has been determined that the CP value of silages made from grass was quite low compared to those prepared from legumes. As it is known, legume green feeds contain higher levels of CP than grass [5]. Crude protein levels of all plants included in this study were generally lower than the values reported in the literature [2,25,26,28–31]. The reason for this is that fertilizers have not used in this study. The fact that forage peas contain more CP than Hungarian vetch can be explained by the difference in vegetation. In addition to forage species, factors such as stage of plant maturity, and amount of fertilizer used have been reported to affect protein content of forages [21,27,32]. The silage additives did not affect the CP levels of the silages. NDF and ADF levels of the plants used in the study were found to be slightly lower than those reported by various studies [25,26,28–31]. It has been observed that the NDF and ADF levels of silages prepared from legume plants were lower than those prepared from grass, and the silage additives significantly reduced both NDF and ADF levels. Since molasses has lower NDF and ADF contents compared to plant used in this study also addition of molasses decreased the both NDF and ADF contents of silages. Similar to the results of the current study, it has been noted that legume silages generally had lower NDF content compared to cereal silages [28,33]. The effect of silage additives on NDF and ADF confirms the results of the previous study [6,34].

The in vitro OM digestibility and energy values obtained in the study were found to be similar or higher than the values reported by some previous studies [26,28–30]. These differences among the studies are thought to be due to the stage of maturity of the plants at the time of harvest, the varieties used or the differences in climate. Addition of silage additives did not significantly affect in vitro digestibility. It is generally stated that silage additives increase the digestibility of silages. However, in this study, although there was a numerical increase in some plant species, no significant effects were observed.

5. Conclusion

Based on the results of this experiment, it can be concluded that high quality silage can be prepared from legume forages such as peas and vetch and small cereal grains such as rye and triticale grown without fertilizer and irrigation in central Anatolian arid conditions without any silage additive application, and but silage additive use may improve silage quality.

Conflict of interest

No potential conflict of interest was reported by the authors.

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