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RESEARCH ARTICLE

Silage quality traits of sorghum-sudangrass hybrid and sunn hemp mixtures at different ratios in the Mediterranean climate

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ABSTRACT

This research was conducted to determine some silage quality traits of silage alternatives prepared in different mixture rates of sorghum-sudangrass hybrid [*Sorghum bicolor* (L.) Moench x *Sorghum sudanense* (Piper) Stapf] which is more drought tolerant than maize, and sunn hemp (*Crotalaria juncea* L.) which has a high protein content, under Mediterranean ecological conditions. Different silage alternatives (sorghum-sudangrass hybrid % - sunn hemp %; 100-0, 80-20, 60-40, 50-50, 40-60, 20-80, 0-100, based on fresh matter) were prepared in a randomized design with four replications in both years. Silage weight loss and pH, dry matter, Flieg score, crude protein, crude ash, ADF, NDF, metabolizable energy, dry matter intake, digestible dry matter and relative feed value were determined at the end of 8 weeks ensilage. According to results, good quality silages can be made from all silage alternatives of sorghum-sudangrass hybrid and sunn hemp without affecting the fermentation process. In addition, silages made by adding sunn hemp to sorghum-sudangrass hybrid at different rates have more nutritional value than pure sorghum-sudangrass hybrid silage without sacrificing quality. Ensiling the sorghum-sudangrass hybrid on a fresh matter basis with up to 50% sunn hemp can be recommended for optimum quality. In animal nutrition, it would be best to choose one of the silage alternatives according to the need in the rations.

Keywords: Ensilage; Mixture; Protein; Quality; Sorghum-sudangrass hybrid; Sunn hemp

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is a versalite crop whose grain can be consumed directly as human food, and whole grain and other above-ground parts can be used in many industries, including animal feed, alcohol, fuel, sugar, syrup and paper production (Ratnavathi et al., 2016; Ciampitti et al., 2019). Besides its multifunctionality, sorghum is one of the attractive alternative plants that can replace maize, which is very sensitive to water shortage, salinity, drought and low soil fertility in silage production (Borba et al., 2012; Yucel and Erkan, 2020). On the other hand, the nutritional value of various sorghum cultivars is close to that of maize (Contreras-Govea et al., 2011). Sorghum has also great potential for ensilage when grown as a second crop (Behling Neto et al., 2017). To obtain quality roughage required for the healthy feeding of animals is one of the most important problems of livestock (Demiroglu Topcu and Ozkan, 2019a). Sorghum-sudangrass hybrids obtained by crossing of sorghum and sudangrass [*Sorghum sudanense* (Piper.) Stapf.] have a great potential to close the problems of forage deficit (Kir and Dursun Sahan, 2018).

Forage crops such as corn or sorghum used in silage production have some negative aspects as well as superior features. The most important of these is that the crude protein content of their silages generally varies between 7-9% depending on the fermentation process. The crude protein content of their silages can be increased by some methods. One of these methods is to make silage by growing forage legumes and grasses in different areas and mixing them later (Buxton et al., 2003). The combination of forage grasses with legumes is one of the effective methods for the preparation of high quality silage (Ridwan et al., 2015). Forage legumes such as soybean, pea, alfalfa or others can be ensiled by mixing up to 50% with forage grass in order to increase the quality, especially crude protein (Zavala et al., 2011; Sulas et al., 2012; Zhang et al., 2015; Budakli Carpici, 2016; Xue et al., 2020). Sunn hemp

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(*Crotalaria juncea* L.), which is known to contain 30% protein in its leaves, is an annual, fast-growing, multipurpose alternative legume for the warm season, and it is extensively cultivated in subtropical and tropical regions (Chaudhury et al., 1997; Mosjidis et al., 2013; Demiroglu Topcu and Ozkan, 2019a). In addition, due to its strong taproot system and developed lateral roots, it is more drought-resistant than other summer legume forage crops and grown easily in many types of soil (La Guardia Nave and Corbin, 2018; Wang and Dai, 2018). It was originally cultivated as fiber and green manure crop, and nowadays, it is also used a good fodder with high quality crude protein (Sarkar et al., 2015; Demiroglu Topcu and Ozkan, 2019b).

Sunn hemp can be easily ensiled and used as good roughage in livestock (Coutinho et al., 2015). For this reason, it is recommended as a feeding intervention in the subtropical and tropical regions to support the sustainability of animal farms (Wanapat et al., 2021). Animal feeding is the most imperative factor in success of livestock activities (Jurgens et al., 2012). The nutritional value of feed is associated with its chemical composition and the utilization level of nutrients. Besides the chemical composition, digestibility is a key parameter in the evaluation of quality (Van Soest, 1994). Without sacrificing quality properties such as digestibility, silage alternatives with high protein content should be used in animal nutrition.

Therefore, the objective of this study was to investigate some silage quality traits of silage alternatives prepared in different mixture rates of sorghum-sudangrass hybrid which is more drought tolerant than maize, and sunn hemp which has a high protein content, under Mediterranean ecological conditions.

MATERIALS AND METHODS

Site description

The study was conducted in two consecutive second crop growing seasons at the experimental farm and silage quality laboratory of Field Crops Department, Faculty of Agriculture, Ege University in Izmir/Turkey. The city is located on Latitude 38°27' N and Longitude 27°13' E with an altitude of 26 m above sea level on the Aegean Sea coast in Western Turkey.

Some meteorological data of the location during the plant growth periods and the long-term (30 years) are presented in Table 1. The experimental farm in Izmir is located in the Mediterranean zone of Turkey with temperate-rainy winters and hot-dry summers. Therefore, typically Mediterranean climate was observed during the experimental years. The annual average data for the long term (30 years) of Izmir were 17.9°C at average temperature and 685.1 mm at total precipitation.

The soil of experimental farm was a silty-clay loam (30.6% clay, 36.7% silt, and 32.7% sand) with pH 7.8, 11.3 g kg^{-1} organic matter, 0.75 g kg^{-1} salt, 1.1 g kg^{-1} total nitrogen (N), 40 mg kg^{-1} available phosphorus (P) and 400 mg kg^{-1} available potassium (K). There are no restrictive features for the establishment and growth of sorghum-sudangrass hybrid and sunn hemp crops in the climate and soil characteristics of the experimental farm.

Forages harvesting, experimental design, and ensiling procedures

Sorghum-sudangrass hybrid (SS) cv. Gardavan and sunn hemp (SH) cv. Tillage Sun were used as plant material and were separately grown in the experimental area (Fig 1). The seeds were simultaneously sown at the beginning of summer in 2019 and 2020 under second crop conditions. The plants were grown in rows with 70 cm row spacing (approximately 150.000 plant ha^{-1}) and 40 cm row spacing (50 kg ha^{-1}), respectively. Traditional agriculture practices were carried out during both growing season. Crops were irrigated when required to ensure adequate soil moisture for plant growth. Since there was no significant problem with pests, diseases and weeds, no agricultural chemicals were applied during the growing phase.

The sorghum-sudangrass hybrid was harvested during at the mid-dough stage and sunn hemp was harvested at the beginning of the flowering stage, simultaneously. The harvest process was made by mowing the above-ground parts of the plants from the ground level with a hand sickle. The harvested plant materials were allowed to wilt for a few hours. Then, these materials were chopped to

Table 1: Some climatic data of the experimental area in Izmir city of Turkey

Months	Average Temperature (°C)			Total Precipitation (mm)		
	1st Year	2nd Year	LTA	1st Year	2nd Year	LTA
May	21.6	21.4	20.8	13.3	79.1	29.3
June	27.4	25.1	25.6	23.2	38.3	8.3
July	28.2	29.0	28.0	0.9	0.0	2.0
August	29.5	28.6	27.6	0.0	0.0	2.2
September	24.3	26.8	23.6	33.0	0.0	15.7
October	20.5	21.5	18.8	23.1	48.5	44.3

LTA, long-term average

Fig 1. Images from the study

2 cm with a forage chopper and the chopped samples were homogeneously mixed. In the study, silages alternatives (sorghum-sudangrass hybrid % - sunn hemp %; 100-0, 80-20, 60-40, 50-50, 40-60, 20-80, 0-100) were prepared by mixing on fresh matter basis proportions according to the randomized design in four replications. 500±25 g of silage material prepared for each alternative was filled into special vacuum bags (thickness 110 microns and above). Afterward, the air in bags was taken 99.9% with the vacuum device and the bags were closed (Johnson et al., 2005). The silo process was conducted in the dark and at room temperature for 8 weeks. Then, vacuum bags were opened and silages alternatives were prepared for quality analysis.

Quality analyses and estimations

The silage weight loss was calculated according to Danley et al. (1973). 25 g of each silage sample was weighed per replicate and soaked in 250 ml of distilled water for 1 hour. After the mixture was filtered, silage pH was measured by the HANNA HI 2211 pH/ORP pH meter. The silage samples were dried in the oven for determination of dry matter (DM) content at 65°C for 48 hours. After, they were ground to pass through 1-2 mm sieves and were prepared for chemical analysis. Crude protein and crude ash contents of the silage were carried out as described by AOAC (1990) and the amount of crude protein was calculated by multiplying 6.25 with the content of nitrogen (N). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined with the procedure of Van Soest et al. (1991). All chemical analyses were carried out in duplicate.

Flieg score, which is determined by using the relationship between the dry matter content and pH value of silage, was calculated using equation 1 created by DLG (1987).

$$\text{Flieg score} = 220 + (2 \times \%\,\text{DM} - 15) - 40 \times \text{pH} \quad (1)$$

Considering Flieg score values obtained from equation 1, the silage quality class was evaluated according to the score criteria presented in Table 2.

Metabolizable energy was estimated according to equation 2 (Kirchgessner and Kellner, 1981). Digestible dry matter (DDM), dry matter intake (DMI) and relative feed value (RFV) of the samples were determined by using the equations (3, 4, 5) provided by Morrison (2003).

Table 2: Quality classes of silages according to Flieg score (DLG, 1987)

Calculated Flieg Score	Silage Quality Class
100-81	Very good
80-61	Good
60-41	Satisfactory (medium)
40-21	Low (low value)
20-0	Bad

$$\text{Metabolizable energy (MJ kg}^{-1}\text{ DM)} = 14.70 - 0.150 \times \%\,\text{ADF} \quad (2)$$

$$\text{Digestible dry matter (\%)} = 88.9 - (0.779 \times \%\,\text{ADF}) \quad (3)$$

$$\text{Dry matter intake (\% of body weight)} = 120/\%\,\text{NDF} \quad (4)$$

$$\text{Relative feed value} = (\text{DDM} \times \text{DMI})/1.29 \quad (5)$$

Statistical analysis

Experimental data collected on quality properties of silage alternatives were analyzed by (ANOVA) the Statistical Analysis System (SAS Institute, 1998) according to the randomized design. Probabilities equal to or less than 0.05 were considered significant. If ANOVA indicated differences between treatment means the least significant difference (LSD) test was performed to separate them (Steel et al., 1997).

RESULTS AND DISCUSSION

Weight loss values of the silage alternatives were affected ($p < 0.05$) by interaction (Table 3). In the study, the weight loss values of the silages ranged from 2.60 to 3.15%. The highest average silage loss value (3.15%) was recorded at 100% sunn hemp silages in the second year, whereas the lowest silage loss was at 100% sorghum-sudangrass hybrid silages with 2.60% in the second year again. Weight loss during the ensilage process represents the loss of silage dry matter and a decrease in the feed value. In ideal silage losses as 3-5% could occur due to fermentation or respiration (Buxton et al., 2003). These values agreed with the present results.

ANOVA results showed that dry matter was significantly affected ($p < 0.05$) by silage alternatives and year, but the interaction had no significant effect on dry matter contents (Table 3). The 100% sorghum-sudangrass hybrid silage had the highest average dry matter (33.04%), whereas 100% sunn hemp silages were the lowest (27.67%). Year effect was also significant and the average dry matter of the second year (30.90%) was slightly higher than the first year (29.99%). Dry matter content is a very important property for silage quality. When the dry matter is not at the desired level, the fermentation of silages may be adversely affected. Therefore, the ideal dry matter content of silage materials should be between 25% and 35% (Meyer et al., 1984). All silage alternatives of the study had quite sufficient dry matter.

Silage pH was significantly affected ($p < 0.05$) by silage alternatives, year, and the interaction (Table 3). The highest silage pH (4.48) was obtained from 100% sunn hemp in the first year, whereas the lowest (3.96) was determined from

100% sorghum-sudangrass hybrid in the second year. The average silage pH was significantly higher in the first year (4.28) than in the second year (4.13). Silage pH formed during fermentation is one of the most important traits determining the quality of silage (Kiermeier and Renner, 1963; Buxton et al., 2003). As the sunn hemp ratio at the mixtures increased, silage pH values increased. Wang et al. (2009) reported that pure sunn hemp silage has a high pH value. Increasing dry matter ratios were reported with increasing graminae ratios of the mixtures. Accordingly, increased graminae contents in mixtures resulted in lower pH levels in silages (Lima et al., 2010; Kaplan and Akcura, 2021). Current findings were found similar to these results.

Flieg score values of silage alternatives were affected ($p < 0.05$) by interaction (Table 4). The highest average Flieg score (113.54) was recorded at 100% sorghum-sudangrass hybrid in the second year, whereas the lowest Flieg score (80.16) was at 100% sunn hemp in the first year. The average Flieg scores were significantly higher in the second year (101.60) than in the first year (93.83). As the sunn hemp ratio in the silage alternatives decreased, Flieg score increased. Flieg score values, which provide a practical idea about the chemical properties of silage, showed that all alternatives were included in the "very good" quality class. On the other hand, Flieg score was in an inverse and significant relationship with silage pH (Woolfort, 1984). Current results were in line with these findings.

In terms of crude protein traits, significant differences ($p < 0.05$) were found silage alternatives and years while the interaction was found insignificant (Table 4). The crude protein values of the silage alternatives ranged from 7.55 to 16.94%. The highest average crude protein content (16.72%) was obtained from 100% sunn hemp silages while the lowest (7.62%) was recorded from 100% sorghum-sudangrass hybrid silages. The average crude protein value of the second year (12.38%) was higher than the first year (12.13%). As the legume ratio increased in present silages, crude protein content changed positively. Crude protein contents of the silage alternatives produced from combinations of sorghum-sudangrass hybrid and sunn hemp except for 100% sorghum-sudangrass hybrid were above the crude protein critical level of 8% acceptable for ruminant performance (Norton, 1994). According to NRC (2007), the crude protein content of sweet sorghum silages is insufficient to meet the minimum requirements of ruminants. Present results were in agreement with other studies (Martínez-García et al., 2015; Zhang et al., 2015; Acar et al., 2017; Budakli Carpici, 2017) which legumes also increased crude protein concentrations when in mixture with cereals.

Considering crude ash traits, significant differences ($p < 0.05$) were found in silage alternatives and years while the interaction was found insignificant (Table 4). In the present study, the crude ash values were determined between 6.92-8.26%. The highest crude ash (8.18%) was

Table 3: Some silage quality traits of sorghum-sudangrass hybrid and sunn hemp mixture silage alternatives

Silage Alternatives	Weight Loss (%)			Dry Matter (%)			Silage pH		
	1st Year	2nd Year	Mean	1st Year	2nd Year	Mean	1st Year	2nd Year	Mean
100% SS	2.69	2.60	2.65	32.61	33.47	33.04	4.03	3.96	3.99
80% SS + 20% SH	2.73	2.65	2.69	31.76	32.20	31.98	4.14	3.99	4.07
60% SS + 40% SH	2.77	2.70	2.74	30.41	31.44	30.93	4.23	4.08	4.15
50% SS + 50% SH	2.83	2.75	2.79	30.07	30.90	30.49	4.31	4.11	4.21
40% SS + 60% SH	2.86	2.83	2.85	29.40	30.49	29.95	4.37	4.15	4.26
20% SS + 80% SH	2.94	2.95	2.94	28.53	29.62	29.07	4.40	4.23	4.32
100% SH	3.02	3.15	3.08	27.16	28.18	27.67	4.48	4.39	4.43
Mean	2.83	2.80	2.82	29.99	30.90	30.45	4.28	4.13	4.20
LSD (0.05)	A: 0.04 Y: 0.02 A x Y: 0.06			A: 0.26 Y: 0.14 A x Y: ns			A: 0.04 Y: 0.02 A x Y: 0.05		

SS, sorghum-sudangrass hybrid; SH, sunn hemp; A, silages alternatives; Y, Year; ns, non significant

Table 4: Some silage quality traits of sorghum-sudangrass hybrid and sunn hemp mixture silage alternatives

Silage Alternatives	Flieg Score			Crude Protein (%)			Crude Ash (%)		
	1st Year	2nd Year	Mean	1st Year	2nd Year	Mean	1st Year	2nd Year	Mean
100% SS	109.23	113.54	111.38	7.69	7.55	7.62	8.26	8.09	8.18
80% SS + 20% SH	103.02	109.70	106.36	9.24	9.50	9.37	8.11	7.95	8.03
60% SS + 40% SH	96.61	104.78	100.69	11.02	11.45	11.23	7.80	7.72	7.76
50% SS + 50% SH	92.65	102.40	97.52	12.44	12.64	12.54	7.73	7.63	7.68
40% SS + 60% SH	89.20	99.98	94.59	13.10	13.28	13.19	7.59	7.54	7.56
20% SS + 80% SH	85.96	94.94	90.45	14.94	15.30	15.12	7.24	7.19	7.22
100% SH	80.16	85.87	83.01	16.49	16.94	16.72	7.02	6.92	6.97
Mean	93.83	101.60	97.71	12.13	12.38	12.26	7.68	7.58	7.63
LSD (0.05)	A: 1.51 Y: 0.81 A x Y: 2.13			A: 0.21 Y: 0.11 A x Y: ns			A: 0.06 Y: 0.03 A x Y: ns		

SS, sorghum-sudangrass hybrid; SH, sunn hemp; A, silages alternatives; Y, Year; ns, non significant obtained from 100% sorghum-sudangrass hybrid silages while the lowest value (6.97%) was determined from 100% sunn hemp silages. The average crude ash value of the first year (7.68%) was slightly higher than the second year (7.58%). Crude ash is simply the total mineral content of feed and the normal content of legume-grass forages is near 9.0% (Hoffman, 2005). Madibela et al. (2002) reported crude ash contents of sweet sorghum varieties as between 6.94 and 9.15%. The ash value of sunn hemp varied between 6.45% and 7.58% according to the harvest time (Demiroglu Topcu and Ozkan, 2019b). Current findings were close to these values.

In terms of ADF and NDF values, significant differences ($p < 0.05$) were found silage alternatives and years while the interaction was found insignificant (Table 5). The highest average ADF and NDF values were obtained from 100% sunn hemp silages with 44.56% and 61.40%, respectively. The lowest values were recorded from 100% sorghum-sudangrass hybrid silages with 35.75% and 55.46%, respectively. The average ADF and NDF values of the second year (40.97% and 58.95%, respectively) were similarly higher than the first year (39.05% and 57.80%, respectively). While a high ADF value means lower energy value and digestibility (Rebole et al., 1996), a high NDF value indicates decreased feed intake (Eskandari et al., 2009). Therefore, they are an important measure in forage quality. In a previous study, NDF ratios of silages consisting of mixtures of maize and sorghum-sudangrass hybrid with different legumes varied between 35.55-67.95% (Alaca and Ozaslan Parlak, 2017). The present results were quite consistent with previous studies (Titterton and Maasdorp, 1997; Alaca and Ozaslan Parlak, 2017). On the other hand, stalks contain greater amounts of cellulose and lignin-like cell membrane components than leaves and it is found more in legumes than in cereals. Therefore, increasing ADF and NDF contents were observed with increasing sunn hemp ratios in the mixtures. Some researchers (Contreras-Govea et al., 2009; Kaplan and Akcura, 2021) also reported similar findings regarding increased legume ratios.

ANOVA results showed that the values of metabolizable energy were significantly affected ($p < 0.05$) by silage alternatives and year, but the interaction had no significant effect on metabolizable energy (Table 5). The 100% sorghum-sudangrass hybrid silages had the highest average metabolizable energy (9.34 MJ kg^{-1} DM), whereas 100% sunn hemp silages were the lowest average (8.02 MJ kg^{-1} DM). Year effect was also significant and the average metabolizable energy of the first year (8.84 MJ kg^{-1} DM) was higher than the second year (8.56 MJ kg^{-1} DM). Metabolizable energy has a negative correlation with ADF content and high metabolizable energy is expected at low ADF composition values (Kirchgessner and Kellner, 1981). ADF contents of silages varied between 34.85-45.66% in the present study. Therefore, metabolizable energy values of almost all silage alternatives were above the minimum acceptable level of 8.0 MJ kg^{-1} DM (Ekern and Vik-Mo, 1979) and it was close to that reported for sunn hemp silage (Titterton and Maasdorp, 1997).

According to ANOVA, while significant differences ($p < 0.05$) were found between silage alternatives and years in terms of digestible dry matter, dry matter intake and relative feed value traits, the interaction was found to be significant only in relative feed value (Table 6). The highest average digestible dry matter and dry matter intake values were obtained from 100% sorghum-sudangrass hybrid silages with 61.05% and 2.16%, respectively. The lowest values were recorded from 100% sunn hemp silages with 54.19% and 1.95%, respectively. The average digestible dry matter and dry matter intake values of the first year (58.48% and 2.08%, respectively) were higher than the second year (56.99% and 2.04%, respectively). The best relative feed value was determined from 100% sorghum-sudangrass hybrid silages in the first year with 104.56 while the lowest value was obtained from 100% sunn hemp silages in the second year with 79.88.

Digestible dry matter of silage is negatively correlated with ADF content of silage (Yucel et al., 2018). For this reason,

Table 5: Some silage quality traits of sorghum-sudangrass hybrid and sunn hemp mixture silage alternatives

Silage Alternatives	ADF (%)			NDF (%)			ME (MJ kg^{-1} DM)		
	1st Year	2nd Year	Mean	1st Year	2nd Year	Mean	1st Year	2nd Year	Mean
100% SS	34.85	36.64	35.75	54.94	55.98	55.46	9.47	9.20	9.34
80% SS + 20% SH	36.24	38.00	37.12	56.20	57.01	56.60	9.26	9.00	9.13
60% SS + 40% SH	38.44	39.87	39.16	57.27	58.29	57.78	8.93	8.72	8.83
50% SS + 50% SH	38.90	40.89	39.90	57.63	59.14	58.39	8.86	8.57	8.72
40% SS + 60% SH	39.83	42.24	41.03	58.16	59.50	58.83	8.73	8.36	8.54
20% SS + 80% SH	41.65	43.46	42.56	59.72	60.62	60.17	8.45	8.18	8.32
100% SH	43.45	45.66	44.56	60.68	62.11	61.40	8.18	7.85	8.02
Mean	39.05	40.97	40.01	57.80	58.95	58.38	8.84	8.56	8.70
LSD (0.05)	A: 0.36 Y: 0.19 A x Y: ns			A: 0.57 Y: 0.30 A x Y: ns			A: 0.05 Y: 0.03 A x Y: ns		

SS, sorghum-sudangrass hybrid; SH, sunn hemp; A, silages alternatives; Y, Year; ns, non significant
ADF, acid detergent fiber; NDF, neutral detergent fiber; ME, metabolizable energy; DM, dry matter

Table 6: Some silage quality traits of sorghum-sudangrass hybrid and sunn hemp mixture silage alternatives

Silage Alternatives	DDM (%)			DMI (%)			RFV		
	1st Year	2nd Year	Mean	1st Year	2nd Year	Mean	1st Year	2nd Year	Mean
100% SS	61.75	60.36	61.05	2.18	2.14	2.16	104.56	100.29	102.42
80% SS + 20% SH	60.67	59.30	59.99	2.14	2.10	2.12	100.43	96.76	98.60
60% SS + 40% SH	58.96	57.84	58.40	2.10	2.06	2.08	95.77	92.31	94.04
50% SS + 50% SH	58.59	57.05	57.82	2.08	2.03	2.06	94.58	89.73	92.15
40% SS + 60% SH	57.88	55.99	56.93	2.06	2.02	2.04	92.57	87.55	90.06
20% SS + 80% SH	56.45	55.05	55.75	2.01	1.98	1.99	87.93	84.47	86.20
100% SH	55.05	53.33	54.19	1.98	1.93	1.95	84.39	79.88	82.14
Mean	58.48	56.99	57.73	2.08	2.04	2.06	94.32	90.14	92.23
LSD (0.05)	A: 0.28 Y: 0.15 A x Y: ns			A: 0.01 Y: 0.01 A x Y: ns			A: 0.58 Y: 0.31 A x Y: 0.81		

SS, sorghum-sudangrass hybrid; SH, sunn hemp; A, silages alternatives; Y, Year; ns, non significant
DDM, digestable dry matter; DMI, dry matter intake; RFV, relative feed value

changes in the ADF contents of the present study led to changes in digestible dry matter values. Digestible dry matter ratios of sorghum were reported as between 56.96 and 70.65% (Orrico Junior et al., 2015; Karthikeyan et al., 2017). Present findings were complied with those earlier ones.

On the other hand, the dry matter intake ratio of silage is negatively correlated with NDF content of silage (Horrocks and Valentine, 1999). Therefore, similar to the digestible dry matter trait, the changes in NDF contents led to changes in dry matter intake values. In a previous study, dry matter intake values of sweet sorghum varieties as between 1.67 and 2.20% with an average value of 1.93% (Karthikeyan et al., 2017). Current findings were close to these values.

The nutritive value of forages or silages depends on their dry matter digestibility and voluntary dry matter intake (Rohweder et al., 1978). A relative feed value system was developed using legume forages and intake responses of lactating dairy cows, and higher relative feed value indicates higher forage quality (Jeranyama and Garcia, 2004). It has no units and is used to rank similar forages (Horrocks and Valentine, 1999). The relative feed value is estimated from ADF (the digestibility of the feed) and NDF (how much feed will be consumed) content of forages (Rocateli and Zhang, 2017). Therefore, it also positively correlated with digestible dry matter and dry matter intake contents of silages (Yucel et al., 2018). Acceptable quality levels (Rohweder et al., 1978) of silage alternatives in the present study were quite sufficient for their usability in feeding farm animals.

CONCLUSION

Silage quality is the key to good animal performance. It allows reducing feed costs in winter and increasing profitability during the housing period. According to present results, the addition of sunn hemp to silages increased the crude protein content of silages and all silage alternatives showed superior nutritional properties without affecting the fermentation process in the Mediterranean climate. Although all silage alternatives can be recommended to make quality silage, it is suggested to ensilage sorghum-sudangrass hybrid with up to 50% sunn hemp on a fresh matter basis. The results of this study can make important contributions to animal nutrition in intensive livestock enterprises which protein needs are high.

Authors' contributions

The author designed the study, carried out all experimental work, data analysis and interpretation, and also writing and finalising the manuscript.

Conflict of interest

The author declare no conflict of interest.

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