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Determination of Silage Quality of Some Sorghum Genotypes under Eskişehir Ecological Conditions

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Abstract
A randomized block design was employed to determine the silage quality of some sorghum genotypes grown after wheat harvest. In the study, 10 sorghum lines (104, 12, 301, 302, 304, 32-1, 8, B305 G310, K311) and 12 registered sorghum varieties (Aldarı, Beydarı, E: Sumoc, Erdurmuş, Greengo, Gözde 80, Haybuster, Leoti, Nes, Öğretmenoğlu, Uzun, Rox) were utilized. The analysis focused on dry matter, crude protein, NDF (Neutral Detergent Fiber), ADF (Acid Detergent Fiber) and ADL (Acid Detergent Lignin) content. Significant differences were identified among the lines and varieties in all the measured parameters. The results revealed that the average dry matter, crude protein, NDF, ADF and ADL percentages of the sorghum genotypes were 22.78%, 8.05%, 76.81%, 46.32% and 5.51%, respectively. Based on these findings, it is recommended that the Haybuster variety and line 301 for silage production in Eskişehir and similar ecological regions due to their high dry matter and crude protein content.

Research Article

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1. Introduction

Türkiye is one of the leading countries globally regarding livestock population and has a strategic position in this regard due to its natural ecology. However, it has not yet achieved the desired levels in terms of the productivity, production and quality of animal products. One of the primary reasons for this shortfall is the economic challenge of obtaining feed, which constitutes a significant portion (approximately 60-75%) of production inputs (Acar et al., 2020). Today, one of the most pressing issues in animal production is the need for high-quality roughage. Türkiye faces a 55 million-ton roughage deficit (Acar et al., 2020). While grazing on pastures is one of the most suitable and cost-effective methods to meet the need for high-quality roughage, feeding with silage during the winter months is a critical source of high-quality roughage (Ergün et al., 2016). Silage feed is an essential resource for animal nutrition, providing a substantial portion of ruminant dietary requirements (Sarıçiçek et al., 2002). In agriculturally advanced countries, silage feed is widely used and encouraged.

High-quality silage forms the foundation for producing high-value animal products. Among roughage crops, corn is the most widely grown plant for silage production. Sorghum species and hybrids have the potential to meet the demand for roughage due to their ability to produce high amounts of dry matter per unit area and their richness in water, protein and carbohydrates. These crops are widely used in animal production in many developed countries. Sorghum is more resistant to drought and high temperatures than corn (Getachew et al., 2016; Erkovan and Afacan, 2024) and produces higher yields than corn under limited irrigation conditions (Hadebe et al., 2017). Furthermore, certain sorghum varieties can be planted after corn and have the ability to regrow, allowing for a second harvest. Sorghum silage has a lower production cost than corn silage, as it requires fewer seeds, fertilizers (30% less than corn) and water (Pino and Heinrichs, 2017). Additionally, sorghum produces more biomass in arid, semi-arid and saline regions (Zhang et al., 2016) is resistant to diseases and pests and contains a high digestible nutrient content, with approximately 69-72% starch, 9-14% crude protein, 3% crude fat, 2% crude cellulose and 1.5% crude ash (Kün, 1985). Due to these advantages, sorghum species and hybrids can serve as alternatives to corn (Çiğdem and Uzun, 2006).

Varieties of sorghum species and hybrids are cultivated for silage, green fodder, grazing and grain production, with fresh yields ranging between 3-9 tons da^{-1} for silage production (Erkovan and Afacan, 2024). Therefore, the increasing cultivation of sorghum in Turkey and its resistance to adverse environmental conditions highlight its potential role in addressing the roughage shortage in animal nutrition. In this context, this study was conducted to evaluate the potential of different sorghum lines and varieties for silage production in Eskişehir and similar ecological regions, with varying uses.

2. Materials and Methods

The study was conducted in 2023 following the wheat harvest at the experimental fields of the Faculty of Agriculture, Eskişehir Osmangazi University. Twenty-two sorghum genotypes (8, 12, 32-1, 104, 301, 302, 304, B305, G310, K311, Aldarı, Beydarı, Öğretmenoğlu, Uzun, E: Sumoc, Erdurmuş, Gözde-80, Greengo, Haybuster, Rox, Leoti, Nes) were utilized. The soil in the experimental area was clay-loam, slightly calcareous (14.61%), slightly alkaline (pH 7.68), non-saline (0.07%), low in organic matter (1.62%), rich in potassium (168.80 kg da^{-1}) and had adequate phosphorus content (6.16 kg da^{-1}). Eskişehir has a continental climate, with an average annual precipitation of 291.7 mm. The highest monthly rainfall during the growing season was recorded in June (62.0 mm). The highest average temperatures were recorded in July (21.5 °C) and August (21.4 °C), while the lowest temperature occurred in January (-0.2 °C). Relative humidity in 2023 was 66.4%, higher than the long-term average of 61.7% (Table 1).

The experiment was arranged in a randomized block design with three replications. Each plot measured 5 meters in length and consisted of five rows. After the wheat harvest, the plots were prepared for sowing. Sorghum seeds were manually sown in rows spaced 0.6 meters apart at a seeding rate of 2.5 kg da^{-1} on June 15, 2023 (Açıkgöz, 1995). A base fertilizer of 2 kg of nitrogen and 5 kg of phosphorus per decare was applied. Weed control was performed manually when sorghum plants were approximately 20-25 cm tall. Following weed control, nitrogen fertilizer (ammonium sulfate) was applied at a rate of 15 kg da^{-1}. The plants were irrigated via sprinklers until the soil reached field capacity when necessary. Harvesting was performed manually using a sickle when the plants reached the dough stage, excluding the border rows and 50 cm from the plot edges (first and last rows). The harvested plants were chopped into pieces 0.5-1 cm in length using a mechanical chopper to ensure uniform particle size across all samples. No additives were used, and the chopped samples were placed into silage bags. The bags were vacuum-sealed and tightly closed to prevent air from entering. The experiment was conducted with six replications in a randomized plot design. After an 8-week fermentation period, the silage bags were opened for analysis. A 500 g sample from each bag was dried at 70 °C to constant weight and dry matter content was determined. The samples were then ground to pass through a 2 mm sieve for further analysis of crude protein, NDF, ADF and ADL using FT-NIR (Fourier Transform Near-Infrared Spectroscopy). The data were analyzed using the SAS statistical software and significant means were compared using Scheffe's multiple comparison tests (SAS Institute, 2011).

Table 1. Some climate data of the area where the experiment was conducted between 1928 and 2023

Months	2023 Year			Long-term average		
	Tempurate ºC	**Precipitation mm**	**Relative Humidity %**	**Tempurate ºC**	**Precipitation mm**	**Relative Humidity %**
January	3.5	16.5	77.8	-0.2	40.0	75.2
February	2.5	15.0	70.3	1.4	32.8	71.0
March	7.4	115.7	76.1	5.0	35.3	65.0
April	10.7	41.1	64.8	10.2	38.4	62.4
May	14.5	59.6	71.9	15.0	44.9	59.9
June	19.4	62.0	67.3	18.9	33.6	55.0
July	23.6	0.6	50.6	21.5	13.2	51.8
August	25.9	0.1	49.9	21.4	8.7	52.9
September	19.9	21.2	59.2	17.4	15.9	58.4
October	15.3	24.8	76.4	12.9	28.9	65.2
Total Average	**---**	**356.6**	**---**	**---**	**291.7**	**---**
	14.3	**---**	**66.4**	**12.4**	**---**	**61.7**

3. Results

In this study, conducted to determine the silage quality of some sorghum genotypes grown after wheat harvest, dry matter, crude protein, ADF, NDF and ADL content were examined. Significant differences were observed among the sorghum genotypes in terms of these parameters. The dry matter content of the different sorghum genotypes ranged from 17.33% in the sweet sorghum variety Uzun to 32.03% in the Haybuster variety (Table 2, Figure 1). The average dry matter content was determined to be 22.73% (Table 2, Figure 1). Varieties and lines such as Nes (28.53%), K311 (27.40%), B305 (27.00%) and Greengo (26.30%) stood out in terms of dry matter content (Table 2, Figure 1).

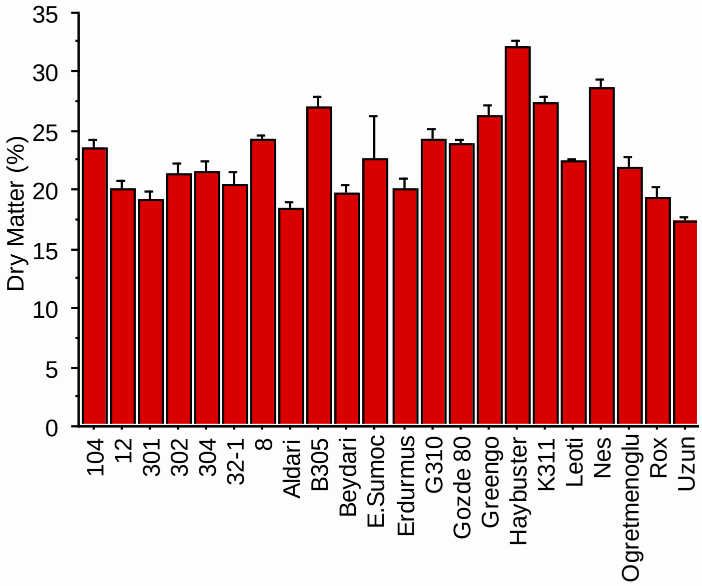

Figure 1. Average dry matter content of sorghum lines and varieties

The crude protein content of some sorghum lines and varieties ranged between 5.07% and 10.47%, with an average crude protein content of 8.05%. The highest crude protein content was obtained from line 301 (10.47%), while the lowest crude protein content was found in the Uzun variety (5.07%) (Table 2, Figure 2). Except for the Uzun, Gözde-80 and Haybuster varieties, all varieties had crude protein content above 6% (Figure 2).

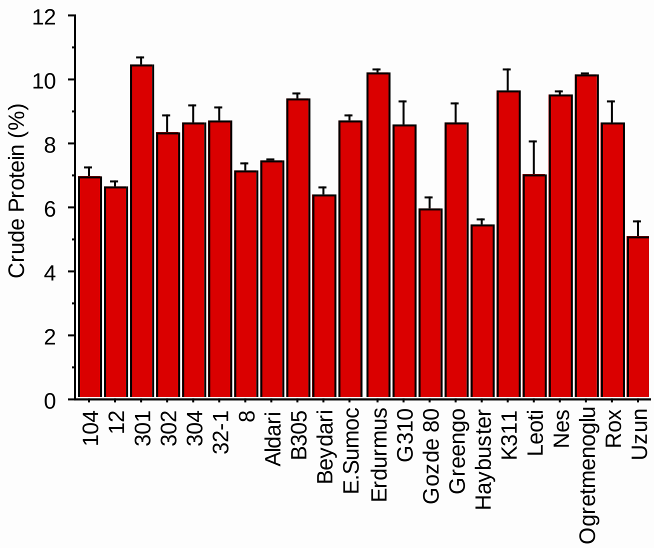

Figure 2. Average crude protein ratio of sorghum lines and varieties

The average NDF value of the sorghum genotypes silaged in Eskişehir ecological conditions was 76.81% (Table 2). It was observed that the NDF content of the Greengo, Nes, Öğretmenoğlu, Aldarı varieties and lines 301, 304, G310 and K311 were above average (Table 2, Figure 3).

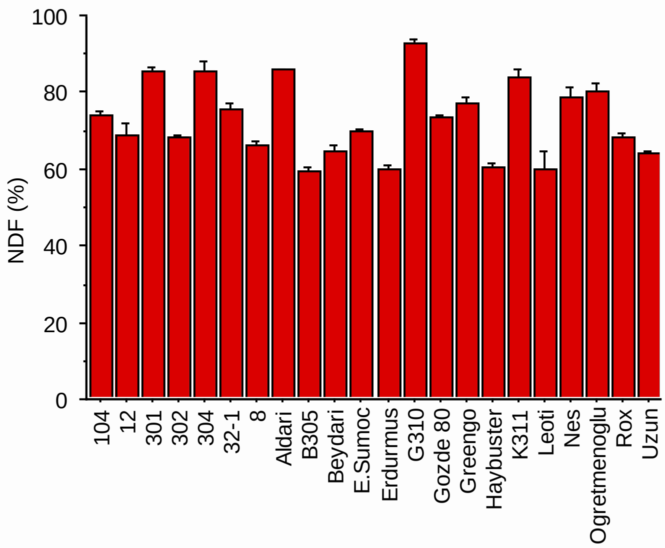

Figure 3. NDF rates (%) of sorghum genotypes silaged in Eskişehir conditions

Table 2. Average dry matter, crude protein, NDF, ADF and ADL ratios of sorghum genotypes

Sorghum varieties/lines	**Dry matter ratio (%)**	**Crude protein (%)**	**NDF (%)**	**ADF (%)**	**ADL (%)**
104	23.43	6.97	73.87	39.77	5.93
12	20.13	6.60	68.60	30.37	4.77
301	19.13	10.47	85.57	54.43	5.43
302	21.30	8.30	68.03	31.73	4.80
304	21.50	8.33	85.67	51.60	6.07
32-1	20.43	8.67	75.63	49.80	6.00
8	24.23	7.13	66.27	42.17	5.63
Aldarı	18.37	7.47	85.77	47.47	5.67
B305	27.00	9.40	59.13	46.83	5.07
Beydarı	19.63	6.40	64.80	51.93	5.53
E: Sumoc	22.53	8.70	69.70	43.43	5.73
Erdurmuş	20.13	10.17	60.03	65.20	5.43
G310	24.27	8.53	92.80	61.27	6.33
Gözde 80	23.87	5.93	73.53	64.63	5.53
Greengo	26.30	8.60	77.10	42.93	5.43
Haybuster	32.03	5.43	60.57	34.67	5.07
K311	27.40	9.60	83.93	53.70	5.77
Leoti	22.33	7.00	59.83	41.00	4.80
Nes	28.53	9.50	78.53	46.010	5.77
Öğretmenoğlu	21.87	10.10	80.43	43.90	4.87
Rox	19.40	8.63	68.03	43.03	5.53
Uzun	17.33	5.07	63.97	33.20	5.73
Average	**22.78**	**8.05**	**76.81**	**46.32**	**5.51**
F Value	**11.74**	**11.33**	**29.68**	**42.42**	**2.52**
P Value	**.0001**	**.0001**	**.0001**	**.0001**	**.0049**

ADF content was the lowest in line 12 (30.37%) and the highest in line G310 (61.27%). Among the sorghum genotypes silaged, the highest ADF value was detected in the sweet sorghum variety Erdurmuş (65.20%) (Table 2, Figure 4).

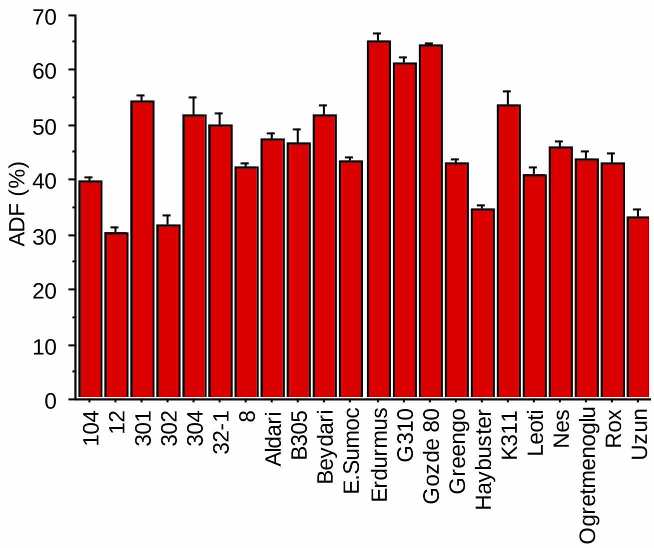

Figure 4. ADF rates (%) of sorghum lines and varieties silaged in Eskişehir conditions

The ADL content of the silages was the lowest in line 12 (4.77%) and the highest in line G310 (6.33%), with an average ADL value of 5.51% (Table 2, Figure 5).

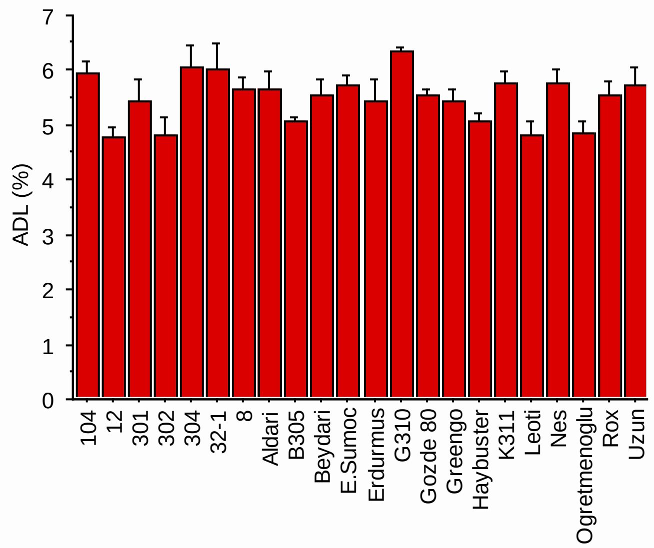

Figure 5. ADL rates of sorghum silages (%)

4. Discussion

The ideal dry matter content in good-quality silage should be between 30-40% (Panyasak and Tumwason, 2015). It has been determined that the significant differences in dry matter content among genotypes are a result of genetic variation (Tanrıkulu et al., 2020; Çetin and Soylu, 2021; Demiroğlu Topçu and Kahya, 2023). In this study, the differences in dry matter content among the sorghum genotypes are attributed to differences in usage characteristics and genetic structure. Since there were no differences in the treatments applied in the study, any observed variation is likely due to genetic differences.

Crude protein content is a critical factor affecting feed quality in roughage and plays an essential role in meeting the nutritional needs of ruminants (Hu et al., 2021; Meen, 2001). The crude protein content in feeds should be at least 6% to meet the nutritional requirements of ruminants (Assefa and Ledin, 2001). As with different plant species (Carr et al., 2004), variations in crude protein content can also occur among genotypes of the same species. The differences in crude protein content among genotypes are thought to be due to their genetic traits (Yücel et al., 2024; Tenikecier and Ateş, 2024). Similar differences were observed in this study.

NDF represents the amount of cellulose, hemicellulose, lignin, cutin and insoluble protein in plant cell walls. NDF content in feed indicates how efficiently animals digest and utilize the feed. When the NDF value is below 40%, animals derive more benefit from the feed (Van Soest, 1994). Like ADF, a lower NDF content is preferred in feed, as a high NDF content makes digestion more difficult and reduces feed intake and nutrient absorption (Yavuz, 2005). NDF content can vary between different plant species and among genotypes of the same species. The variation observed among plants harvested under similar environmental conditions is attributed to genetic factors. Genetic diversity plays an important role in determining NDF content (Lithourgidis et al., 2006; Tulu et al., 2020). Similar results were obtained in this study, as the NDF content varied according to the genetic characteristics of the sorghum genotypes.

ADF consists of cellulose and lignin, which play an important role in determining the cell wall composition of plants (Carlier et al., 2009). Lower ADF content in roughage increases its digestibility and therefore, feeds with low ADF content are considered higher quality (Van Soest, 1994). High ADF content reduces digestibility and energy intake by prolonging the time feed remains in the rumen and making it more difficult to break down (Van Soest, 1994). High-quality feeds have low ADF and NDF content and provide high digestibility (Paterson et al., 1994). The ideal ADF content is considered to be below 31% (Van Soest, 1994). ADF content varies between plant species and genotypes and also changes with growth stages (Tulu et al., 2020, Demiroğlu Topçu et al., 2023). In this study, the differences in ADF content among genotypes are attributed to genetic factors.

ADL is a parameter that measures lignin content in plant cell walls, which plays a crucial role in animal nutrition. Lignin significantly affects the ability of animals to digest feed and therefore, ADL content is critical in animal nutrition. Lower ADL content increases digestibility and nutrient availability, improving animal growth and productivity. In particular, ADL content is an important criterion in the selection of feed for ruminants such as cattle and sheep (Öktem et al., 2021; Tutar, 2024). Genetic differences are expected to result in significant variations in ADL content among genotypes. As there were no differences in the treatments applied in the study, the observed differences are inevitably due to genetic factors.

In conclusion, when examining the quality characteristics of the silages of sorghum lines and varieties grown as a second crop after wheat harvest in areas with no water scarcity, the highest dry matter content was obtained from the Haybuster variety and the highest crude protein content was obtained from line 301. Among the sorghum genotypes, the lowest ADF and ADL content were observed in line 12, while the lowest NDF content was detected in line B305. Based on these results, it has been determined that sorghum genotypes can be cultivated for silage to meet the roughage needs of livestock. Sorghum genotypes with the potential for short growing periods as a second crop in Eskişehir and similar ecological conditions are recommended.

Declaration of Author Contributions

The authors declare that they have contributed equally to the article. All authors declare that they have seen/read and approved the final version of the article ready for publication.

Declaration of Conflicts of Interest

All authors declare that there is no conflict of interest related to this article.

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