DETERMINATION OF THE SILAGE QUALITY CHARACTERISTICS OF DIFFERENT SWITCHGRASS (*PANICUM VIRGATUM* L.) CULTIVARS

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(Received 10th Sep 2019; accepted 14th Nov 2019)

Abstract. This study was carried out to determine the silage quality characteristics of some switchgrass (*Panicum virgatum* L.) cultivars. Kanlow, Shelter, Shawnee, BoMaster, Alamo, Trailblazer, Cave in Rock and Long Island cultivars of switchgrass constituted the plant material of the study. For silage purposes, the plants were harvested 10-15 days after reaching the flowering period. The harvested plants were allowed to ferment for 70 days. According to the results, the silage of switchgrass cultivars was statistically significantly at $p<0.01$ level for both physical and chemical properties. In the study, pH content, the dry matter, lactic acid, butyric acid, acetic acid, crude protein, acid detergent fiber, and neutral detergent fiber ratios of the silage of switchgrass cultivars varied between 3.84-4.86, 39.0-51.0%, 1.78-2.35%, 0.05-0.33%, 0.35-1.55%, 3.76-5.57%, 39.30-41.73%, and 70.96-75.41%, respectively. In terms of the Fleig score, it was determined that the quality of the silage obtained from switchgrass cultivars could be classified as “very good”. According to result, it was determined that BoMaster, Alamo, and Trailblazer cultivars, especially Long Island and Cave in Rock cultivars of switchgrass that came to the forefront in terms of silage quality, could be successfully used in silage production.
Keywords: *switchgrass, physical properties, acetic acid, lactic acid, butyric acid*

Introduction

Switchgrass (*Panicum virgatum* L.) is a perennial warm-season C4 plant, which is one of the grass species specific to North American meadows (McLaughlin and Kszos, 2005; Missaoui et al., 2006; Jiang et al., 2019). It is used as an energy plant in the United States, Canada, and some European countries (Elbersen et al., 2001; Casler and Boe, 2003; Belanger et al., 2012). Furthermore, it is also an important species used for many purposes such as soil and water conservation, grazing and forage (Sanderson et al., 1999; Muir et al., 2001; Vogel et al., 2002; Vogel, 2004; Lee et al., 2007; Sanderson and Burns, 2010; Belanger et al., 2012; Jiang et al., 2019). In the studies carried out, it were reported that high yield and high-quality feed was obtained from some genotypes of switchgrass, and it had the potential to be used as an animal feed (Ameen et al., 2018; Davis et al., 2018; Milenković et al., 2018; Sena et al., 2018).

Few studies were conducted on switchgrass, which is a new plant for Turkey. In this sense, the first basic information about the growing techniques of switchgrass was produced within the scope of the TUBITAK project developed by Soylu et al. (2010). Within the scope of that project, adaptation studies were conducted on switchgrass cultivars as an introductory material in the Central Anatolia Region with an arid and/or semi-arid climate in Turkey, and the cultivars suitable for Turkey were determined. Within the scope of the same study, the necessary information about the growing techniques of high-performance switchgrass cultivars from planting to harvest in Turkey, and their potential to be utilized as a bio-fuel was obtained (Soylu, 2012). As a

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1706_1575515773

result of these studies carried out by Soylu et al. (2010), it was emphasized that the facts that the switchgrass cultivars examined yielded a green biomass in quantities ranging 60-70 tons/ha, that dry matter ratios ranged between 31.84-40.97% during the flowering period, the protein ratio in green biomass increased up to 9-10% in many cultivars, and acid detergent fiber (ADF) and neutral detergent fiber (NDF) values revealed positive results regarding the consumption and digestibility of the feed to be obtained from this plant were the indications that the silage quality of switchgrass plant would also be high, and it was reported that switchgrass plant had a high economic growing potential especially for silage purposes.

The studies carried out around the world mostly focused on the bioenergy value (Brodowska et al., 2018; Kimura et al., 2018), adaptation (Ma et al., 2011), morphological and biological properties (Brunken and Estes, 1975), forage yield (Wolf and Fiske, 1995; Kimura et al., 2018) and biomass yield (Sanderson et al., 1999; Piscioneri et al., 2001; Lemus et al., 2002; Kimura et al., 2018), genetics and genetic variation (Quinn, 1969; Hopkins et al., 1995, 1996; Quinn and Wetherington, 2002) of switchgrass. There are very few studies on the silage and silage quality of switchgrass.

On the other hand, in silage plant production, it is possible to obtain high quality and high yield by the cultivation of varieties suitable for ecologies. In this sense, the selection of variety is also an important cultural practice to achieve a sustainable yield from plant production (Ileri et al., 2018). Undoubtfully, the difference of cultivars, as well as the factors such as climate and soil factors, cultural practices, and harvesting period, significantly affects the silage quality. This study was carried out to determine the silage quality of some switchgrass (*Panicum virgatum* L.) cultivars.

Materials and methods

Silage material and growing conditions

The plant material of the study consisted of Kanlow, Shelter, Shawnee, BoMaster, Alamo, Trailblazer, Cave in Rock, and Long Island cultivars of switchgrass. In the study, the plant materials of the second year (2017) of switchgrass cultivars established on July 10, 2015, under the conditions of Siirt province (*Figure 1*), which is located in the Southeastern Anatolia Region of Turkey with a semi-arid climate, were used for silage purposes.

According to long-term (1960-2017) meteorological data (Anonymous, 2017) of the Siirt province, the current climate in the region is semi-arid. Summers are warmer than winters (the average temperature in July is 30.6 and in January is 2.8°C). The mean annual temperature, rainfall, and evapotranspiration are 16.2ºC, 691.4 mm, and 937.5 mm, respectively. According to the soil climate regime of the Newhall simulation model (Van Wambeke, 2000), it was determined that the study site has a thermic soil temperature regime and xeric (dry xeric in the subgroup) soil moisture regime (*Figure 2*).

Some physical and chemical properties of the soils where the switchgrass is grown are given in *Table 1*. Organic matter content of soil was determined according to Nelson and Sommers (1982) and other parameters were determined according to Anonymous (1992). The soils where switchgrass is grown are clayey textured, salt-free, slightly alkaline and have moderate lime content, less organic matter and available phosphorus (P) coverage, and high available potassium (K) content (*Table 1*).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1706_1575515773

In the study, the field experiment was established according to the randomized block experimental design with 4 replications. In sowing, row spacing was 20 cm, and the number of rows in a parcel was 10. Sowing was performed so that there would be 400 live seeds per square meter. Before sowing, diammonium phosphate (18-46-0%, N-P-K) fertilizer was applied equally to each parcel with the calculation of 100 kg/ha pure P_2O_5 according to the soil analysis results. A drip irrigation system was established immediately after sowing, and irrigation was performed. When plants were 10-15 cm, ammonium nitrate (33% N) fertilizer was given equally to each parcel with the calculation of 60 kg/ha pure nitrogen (N) (*Figure 3*).

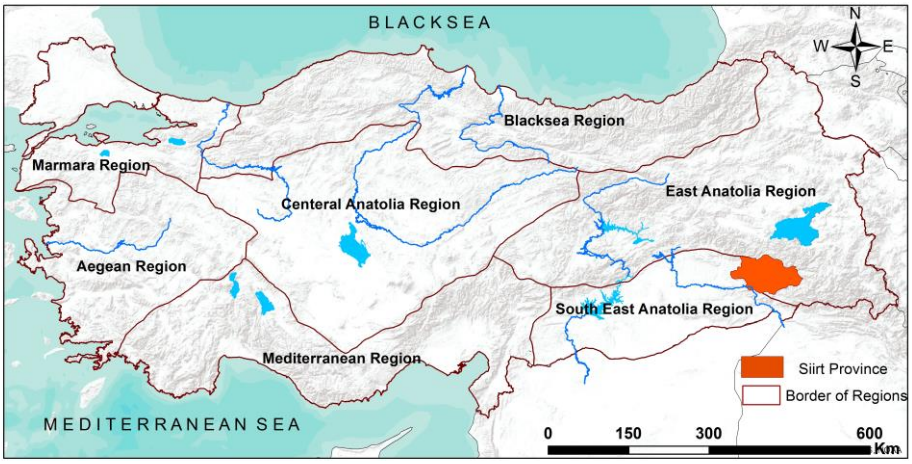

Figure 1. *The location where silaged switchgrass cultivars are grown*

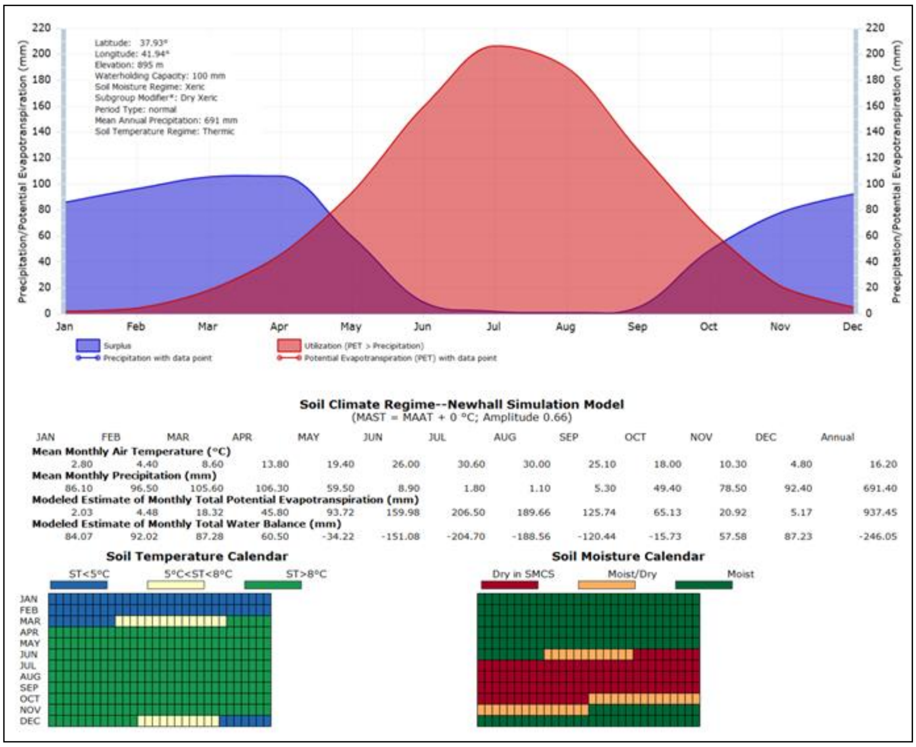

Figure 2. *Soil moisture and temperature regime diagrams according to the Newhall simulation model*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1706_1575515773

Table 1. *Some physical and chemical properties of the soils where switchgrass is grown (0-20 cm)**

Parameters	Value
Clay, %	55.84
Sand, %	36.26
Silt, %	7.90
pH	7.98
Electrical conductivity (EC), mS cm^{-1}	0.363
Calcareous ($CaCO_3$), %	13.0
Organic matter, %	1.31
Available P, kg P_2O_5 ha^{-1}	43
Available K, kg K_2O ha^{-1}	1150

*: The analyzes were carried out in the laboratory of Black Sea Agricultural Research Institute

Figure 3. *Switchgrass experimental site and harvest*

Silage making technique

For silage purposes, switchgrass cultivars were harvested separately for each parcel 10-15 days after reaching the flowering period (Soylu, 2012). The harvested plants were brought to the laboratory environment, and all green plant materials were manually chopped into 0.5-1 cm sizes with a knife. The chopped plant particles were mixed with 0.5% table salt (NaCl) for protection purposes (Kılıç, 1986; Geren et al., 2011). Then, the material of each parcel was filled in 3-liter glass jars by pressing well in accordance with the sequential filling technique (Petterson, 1988), and the lid borders of the jars tightly closed with silicone plastic lids were wrapped with thick packaging tape for 3-4 rounds for airtightness. The silage jars prepared in this way were allowed to ferment for 70 days at room temperature in a dark environment.

Physical and chemical analysis methods of silage samples

After the fermentation process was completed, the matured silage was opened, a 3-4 cm portion was discarded from the cap opening, and then physical and chemical analyses were performed in the remaining silage samples.

In the samples taken to represent the mass in the opened silage jars, physical examinations such as odor, structure, and color were subjectively performed by three subject matter experts. The evaluation of physical analyses was based on the scoring

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1706_1575515773

method developed by Anonymous (1987). The silage quality class according to the physical properties of the silage was determined by the DLG (Deutsche Landwirtschafts-Gesellschaft) score (*Table 2*). The DLG score is the total physical score (0-20 points) obtained from the sum of odor, structure, and color scores (Akyıldız, 1984; Anonymous, 1987; Ergün et al., 2013).

Table 2. *Physical examination key developed by DLG and silage quality class*

Physical examination key	
1. Odor	**Score**
No butter acid odor, slightly sour, fruity and aromatic odor	14
A small amount of butter acid, strong sour odor, and slight escalation	8
Moderate butter acid odor, strong escalation-musty odor	4
Strong butter acid or ammonia odor, very slight sour odor	2
Strong decomposition, ammonia or musty odor	0
2. Structure	
Intact leaves and stems	4
A slightly deteriorated structure of leaves	2
A deteriorated structure of leaves and stems, musty and dirty	1
Rotten Leaf and Stalk	0
3. Color	
Preserved its color at the moment it was silaged (brown in withered silage)	2
Slightly changed color (yellow to brown)	1
Completely changed color (reseda green)	0
Quality class according to the physical properties of silage	
Quality class	**DLG score**
I- Very good	20-18
II- Good	17-14
III- Medium	13-10
IV- Low (low value)	9-5
V- Corrupted (useless)	4-0

Some silage material was taken from each silage jar to represent the jar and mixed homogeneously, and 25 g of the wet silage sample of this mixture was weighed on the precision balance and placed in the mixer. 250 ml of distilled water was added to the sample, and it was mixed for 10 minutes, then filtered through filter paper (Whatman™ No. 1441-125, GE Healthcare Life Sciences, Marlborough, MA, USA), and pH was determined by means of a pH meter in a 200 ml strainer taken into glass beakers (Anonymous, 1993). Lactic acid (LA), acetic acid (AA), and butyric acid (BA) were determined using high-performance liquid chromatography (HPLC) as per the methods of Canale et al. (1984). 300 g of the wet sample was taken from matured silage separately in each silage jar, and it was dried in an oven at 70°C for 48 hours. Dried silage samples were weighed on the precision balance, and their weights were determined, and the dry matter (DM) ratio was determined by proportioning to wet weight (Bulgurlu and Ergül, 1978).

The dried silage samples were ground separately for each jar. The ADF, NDF, and crude protein (CP) ratios in the ground samples were determined by NIRS (Near Infrared Reflectance Spectroscopy) and #IC-0904FE calibration set (Anonymous, 2018) in the laboratory of Ondokuz Mayıs University Faculty of Agriculture Department of Field Crops (Brogna et al., 2009).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1706_1575515773

Quality of silage according to the Fleig score

One of the most common methods used to determine the silage quality practically is the Fleig score (FS), which is determined by using the relationship between the DM content and pH value of silage. FS was calculated using *Equation 1* created by DLG (Anonymous, 1987).

$$FS= [220 + (2 \times \text{silage DM ratio} - 15)] - 40 \times \text{silage pH value} \quad \text{(Eq.1)}$$

Considering the FS values obtained from the above-mentioned equation, the silage quality class was evaluated according to the score criteria presented in *Table 3*.

Table 3. *Quality classes of silo feeds according to FS (Anonymous, 1987)*

Calculated FS	Silage quality class
100-81	I- Very good
80-61	II- Good
60-41	III- Satisfactory (Medium)
40-21	IV- Low (low value)
20-0	V- Bad

Statistical analyses

The data obtained from the study were subjected to the analysis of variance according to the randomized block experimental design. The differences between the groups according to the F-test results were determined by Tukey's multiple comparison test (Açıkgöz and Açıkgöz, 2001).

Results and discussion

Silage dry matter ratio of switchgrass cultivars and some chemical properties of silage

Silage dry matter ratio

The DM ratio has great importance in the full realization of chemical events during silage formation, and this ratio is the most important quality criterion used in the determination of silage quality (Geren, 2001; Çakmak et al., 2013). In the study, the highest DM ratio was found in the Alamo, BoMaster, Kanlow, Trailblazer, and Cave in Rock switchgrass cultivars that statistically constituted the first group. The DM ratios of these cultivars varied between 47.3-51.0%. The lowest DM ratio was found in the silage of Shawnee and Long Island cultivars by 39.0% and 39.7%, respectively. This difference between the cultivars in terms of the silage DM ratio was found to be statistically significant at $p<0.01$ level (*Table 4*). The reason for this difference between the cultivars can be explained by different amounts of DM they can produce by their genetic capacity. Furthermore, it is considered that the difference in the silage DM ratio between the cultivars was also affected by the difference in DM losses, caused by chemical events in the fermentation process, according to cultivars. While Luginbuhl et al. (2000) reported that the silage DM ratio was 27.2% in Kanlow switchgrass cultivar, Cassida et al. (2005) reported that the DM ratio in switchgrass varied between 39.4-45.1%, and Zhao et al. (2017) reported that the DM ratio varied between 24.68-26.43%. It is considered that the fact that the DM ratios determined in our study

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1706_1575515773

were different from those reported in the literature was affected by different genotype, harvest time, and growing conditions.

On the other hand, in the adaptation study carried out by Soylu et al. (2010) with 9 switchgrass cultivars (Alamo, Forestburg, Cave in Rock, Carthage, Shelter, Dacotah, Blackwell, Shawnee, and Kanlow) under irrigated conditions in the Central Anatolia Region of Turkey, they reported that the DM ratios of cultivars varied between 31.84%-40.97% and that the DM ratio of above 30% in switchgrass cultivars was extremely important in terms of use both for silage and directly in animal feeding. Accordingly, although the DM ratio among cultivars varies, a high DM ratio is important for silage quality. Indeed, while Çayıroğlu et al. (2016) reported that the DM content of silage material was an important factor affecting aerobic stability, Filya et al. (2000) reported that the aerobic stability of silage made with the material with a low DM content decreased, and Barnes et al. (1995) and Mohd-Setapar et al. (2012) reported that the DM contents of the material to be silaged for good quality silage and/or successful fermentation should be between 28-42% and 25-40%, respectively. In view of these values reported by the researchers, it was observed that all switchgrass cultivars contained quite sufficient DM.

Table 4. *Values of the DM ratio and some chemical properties of silage obtained from switchgrass cultivars*[*]

Cultivars	DM (%)	LA (%)	BA (%)	AA (%)	pH	CP (%)	ADF (%)	NDF (%)
Kanlow	48.0 a	1.78 b	0.33 a	1.29 ab	4.73 a	4.35 bc	41.20	75.41 a
Shelter	44.7 ab	1.96 ab	0.29 a	1.02 ab	4.72 a	3.76 c	41.73	73.56 abc
Shawnee	39.0 b	1.99 ab	0.21 ab	1.55 a	4.86 a	4.72 abc	39.30	70.96 c
BoMaster	48.7 a	2.22 a	0.08 b	0.45 b	3.94 bcd	4.53 abc	40.33	75.25 a
Alamo	51.0 a	1.94 ab	0.12 b	1.33 ab	4.32 b	4.23 bc	40.77	73.71 ab
Trailblazer	47.7 a	2.01 ab	0.13 b	0.65 ab	4.24 bc	5.33 ab	40.57	71.54 bc
Cave in Rock	47.3 a	2.05 ab	0.08 b	0.62 ab	3.88 cd	5.23 ab	40.72	72.86 abc
Long Island	39.7 b	2.35 a	0.05 b	0.35 b	3.84 d	5.57 a	40.59	73.17 abc
$F_{cultivar}$	9.698**	4.524**	10.365**	4.931**	27.695**	7.210**	0.831	9.054**
CV (%)	5.26	6.98	34.38	38.79	3.13	8.49	3.25	1.24

[*]: The difference between the means indicated by the same letter in the same column is not significant, [**]: p<0.01 is significant within error limits, CV: Coefficient variation

No study was found on the silage characteristics of cultivars in switchgrass plant. Therefore, in view of the silage studies carried out with corn plant which is a physiologically C4 plant such as switchgrass, it was reported that there were significant differences between the cultivars in terms of DM, similarly to the results of our study, and that the DM ratio according to cultivars in corn silage varied between 18.35%-30.72% (Özdüven et al., 2009), 25.30%-31.58% (Güney et al., 2010), 20.3%-28.1% (Seydoşoğlu, 2017), 20.57%-23.35% (Ileri et al., 2018).

Lactic acid (LA) content of silage

The amount and composition of organic acids such as LA formed during silage fermentation determine the quality of fermentation, and LA is one of the main preservative organic acids in the silage (Filya, 2001). According to the results of statistical analysis, it was determined that the LA contents of the silage obtained from switchgrass cultivars showed significant differences (p<0.01). The most distinctive

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1706_1575515773

difference was between Kanlow and all other cultivars. The highest LA ratio was found in the Long Island (2.35%) and BoMaster (2.22%) cultivars that were statistically included in the first group (*Table 4*).

It was reported that the LA ratio should be above 2.00% in high-quality silage feeds (Kılıç, 1986; McDonald et al., 1991; Alçiçek and Özkan, 1997; Weinberg and Ashbell, 2003) and that a high LA ratio was the assurance of a healthy fermentation (Johnson and Harrison, 2001). According to the results of our study (*Table 4*), it was found out that the LA values found in the Long Island, BoMaster, Cave in Rock, and Trailblazer silage of switchgrass cultivars were above the reference value and included in the high-quality silage group. In the silage made with corn and sorghum cultivars, it was reported that the LA ratio varied between 1.58%-8.57% by Reeves et al. (1989), 2.6%-3.1% by Hart (1990), 0.67%-2.35% by Geren and Kavut (2009), and 7.64%-12.33% by Seydoşoğlu (2017) depending on the maturity period.

Butyric acid (BA) content of silage

An important parameter in the determination of silage quality by analytical methods is the BA, which negatively affects silage quality (Geren and Kavut, 2009). In a quality silage feed obtained as a result of a good fermentation, the fact that BA was generally between 0.1-0.7% was considered to be normal although it was undesirable (Woolfort, 1984; Weinberg and Ashbell, 2003). On the other hand, Catchpoole and Henzell (1971) reported that the BA concentration in quality silage was less than 0.2%. When the data of our study were examined, it was observed that the BA content of the silage of switchgrass cultivars varied between 0.05-0.33% and that the BA content of all silaged switchgrass cultivars was within acceptable limits. Nevertheless, the difference between the cultivars in terms of BA was found to be statistically significant at $p<0.01$ level, and the BA ratios of Kanlow (0.33%), Shelter (0.29%), and Shawnee (0.21%) silage were higher than other cultivars (*Table 4*). It can be explained by the limited propagation and activity of LA bacteria during fermentation and/or the degradation of LA into BA, as it was indicated by Bolsen et al. (1996). Indeed, as it is seen in *Table 4*, the low LA values of the cultivars with a high BA ratio confirm this situation.

In the studies carried out with corn silage, the BA ratio was determined to be 0.07% (Phillip and Hidalgo, 1989) and 0.08% (Deswysen et al., 1993). On the contrary, while Geren and Kavut (2009) and Arslan et al. (2017) reported that the BA value was not measured in sorghum and corn silage and sorghum silage, respectively; Hart (1990) reported that the BA value varied between 0.006% and 0.037% in the sorghum silage, and Reeves et al. (1989) reported that the BA value varied between 0.06% and 0.43% in the corn silage. In our study, it is possible to say that the BA values determined in the silage of switchgrass cultivars were compatible with these values in the literature determined in corn and sorghum silage, which are C4 plants like switchgrass.

Acetic acid (AA) content of silage

When the AA ratios of the silage obtained from switchgrass cultivars were examined, the highest AA ratio was found to be 1.55% in Shawnee cultivar, and the difference in terms of AA between Shawnee cultivar and Kanlow, Shelter, Alamo, Trailblazer, and Cave in Rock cultivars was found to be insignificant. The lowest AA content was determined in Long Island (0.35%) and BoMaster (0.45%) cultivars. This difference between the cultivars was statistically significant at $p<0.01$ level (*Table 4*). While Weinberg and Ashbell (2003) reported that the AA ratio should be less than 0.8% in the

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1706_1575515773

silage feed as a result of a good fermentation, McDonald et al. (1991) and Alçiçek and Özkan (1997) reported that the AA ratio should be between 0.3-0.7%. When these values reported in the literature are taken into consideration, it is possible to say that the AA ratios of the silage of BoMaster, Trailblazer, Cave in Rock, and Long Island switchgrass cultivars were below the critical value.

It was reported that the AA ratio varied between 0.6-1.42% in the sorghum silage (Hart, 1990; Arslan and Çakmakçı, 2011; Arslan et al., 2017) and between 0.2-3.71% in the corn silage (Phillip and Hidalgo, 1989; Reeves et al., 1989; Deswysen et al., 1993; Sucu and Filya, 2006). These results obtained from sorghum and corn silage, which are physiologically included in the C4 group such as switchgrass, were similar to the results of our study.

pH of silage

pH formed during silage fermentation is one of the most important parameters determining the quality of fermentation (Kiermeier and Renner, 1963; Filya, 2001). In our study, a statistically significant difference at $p<0.01$ level was found in terms of the pH of silage between switchgrass cultivars. The lowest silage pH value was found to be 3.84 in the Long Island switchgrass cultivar. The highest silage pH value was found in the Shawnee (4.86), Kanlow (4.73), and Shelter (4.72) cultivars that were statistically included in the same group (*Table 4*). The difference in terms of pH between cultivars can be explained by the fact that LA production varies by cultivars. In other words, as it is seen in *Table 4*, the silage pH was found to be low in the cultivars with a high LA ratio. This decrease in pH was due to the accumulation of LA. Indeed, Ohmomo et al. (1995) reported that it was important that pH was less than 4.2 in silage fermentation, which was possible with the efficient production of LA from sugar in a silo.

The way to remove odors, prevent spoilage, and protect nutrients in silage feeds is to make silage protected by good fermentation. Protection is based on high acidity depending on LA formation (Isnandar et al., 2010). Furthermore, low pH may also prevent the growth of parasites and some pathogenic microorganisms (Göhl, 1981). Church (1986) and Ergün et al. (2013) reported that the optimum pH range for the growth of milk acid bacteria growing in the acid medium was 3.8-4.2 and that bacteria causing spoilage and decomposition did not live in the silage with a value in this pH range. Some other researchers (Danley et al., 1973; Comberg, 1974; Kılıç, 1986; Roth, 2001; Açıkgöz et al., 2002; Kılıç, 2006) reported that the pH value of very good silage was between 3.5 and 4.5. It can be said that Long Island, Cave in Rock, BoMaster, Alamo, and Trailblazer from switchgrass cultivars were within the appropriate limits in terms of silage pH. Therefore, a successful fermentation process took place in the silage formation process, especially with respect to these cultivars. While Belanger et al. (2012) reported that pH varied between 4.0-4.3 in the switchgrass silage, Zhao et al. (2017) reported that the pH value was 5.4 in the 30-day silaged switchgrass material.

In the studies carried out on corn and sorghum cultivars that are C4 plant such as switchgrass, it was reported that the silage pH value was different between the cultivars and the pH value ranged between 3.03-5.20 (Hart, 1990; Deswysen et al., 1993; Geren, 2000, 2001; Kavut and Soya, 2012; Canbolat et al., 2016; Seydoşoğlu, 2017; Ileri et al., 2018).

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1706_1575515773

Crude protein (CP) ratio in silage

A statistically significant difference at p<0.01 level was found between switchgrass cultivars in terms of the CP ratio. While the highest CP ratio was found to be 5.57% in the Long Island silage, the difference between the Long Island, Shawnee, BoMaster, Trailblazer, and Cave in Rock cultivars in terms of the CP ratio was found to be statistically insignificant. The lowest silage CP ratio was found in the Shelter cultivar by 3.76% (*Table 4*). The CP ratio emerges a result of the genetic and morphological characteristics of plants (Güney et al., 2010). Therefore, it is possible to say that it is an expected result that there are significant differences between the cultivars with different properties. Indeed, in some studies carried out with the corn plant (Seydoşoğlu, 2017; Ileri et al., 2018), it was also reported that cultivars had a significant effect on the silage CP content.

It was observed that the CP ratio values determined in the silage of switchgrass cultivars were consistent with the results of Sanderson et al. (1999) and Mantino et al. (2017), slightly higher than the data of Cassida et al. (2005), and lower than the values obtained by Anderson et al. (1988), Soylu et al. (2010), Çiçek (2017), and Mohammed and Desta (2017). Milenković et al. (2018) reported that the CP ratio of switchgrass cultivars varied between 5.62% (Alamo) and 8.74% (Kanlov). The difference between the values obtained in our study and the literature in terms of the CP ratio can be explained by different ecologies, cultural processes, and genotypic structures of plants.

In the silage made with the corn plant which is a C4 plant like switchgrass, CP values varied between 5.01%-10.63% (Filya, 2001; Polat et al., 2005; Güney et al., 2010; Çakmak et al., 2013; Rafiuddin et al., 2016).

Silage acid detergent fiber (ADF) and neutral detergent fiber (NDF) ratio

The difference between switchgrass cultivars in terms of the ADF ratio was found to be statistically insignificant. However, the NDF ratio showed a statistically significant difference at the level of p<0.01 between the cultivars. The ADF ratio of silage varied between 39.30-41.73%. The lowest NDF ratio was found in the Shawnee cultivar by 70.96%. The highest NDF ratio was found in the Kanlow (75.41%) and BoMaster (75.25%) cultivars that statistically constituted the first group. Nevertheless, a statistically significant difference in terms of the NDF ratio was between the Shawnee and Trailblazer cultivars and other cultivars (*Table 4*). This difference between the cultivars in terms of NDF can be explained by different temperature, moisture, and fertilizer utilization during the period from sowing-time to harvest.

The ADF and NDF ratios, which are the plant cell wall components, are a good indicator of total digestible nutrients, and the ADF and NDF ratios are desired to be low in roughage (Van Soest, 1994; Gürsoy and Macit, 2014). When the roughage quality standard for farm animals (<31%= top quality, 31-35%= very good, 36-40%= good, 41-42%= medium, 43-45%= bad and >45%= unacceptable for ADF; <40%= top quality, 40-46%= very good, 47-53%= good, 54-60%= medium, 61-65%= bad and >65%= unacceptable for NDF) reported by Rohweder et al. (1978) is considered, it can be said that the silage of switchgrass cultivars was of good and/or medium quality in terms of the ADF ratio and unacceptable in terms of the NDF ratio. The fact that the NDF ratio, which expresses the whole fiber including hemicellulose, cellulose, and fiber in the plant, was high in the silage of switchgrass cultivars is considered to be due to the slowdown of the degradability of cell wall agents such as NDF as a result of the low

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DOI: http://dx.doi.org/10.15666/aeer/1706_1575515773

number of LA bacteria in the silage medium although some cultivars were slightly more than 2% (*Table 4*), as it was also indicated by Filya (2001).

In the studies conducted for different purposes with switchgrass cultivars, it was reported that the ADF and NDF ratios varied between 21.3%-66.9% and 57.6%-86.5%, respectively (Madakadze et al., 1999; Sanderson et al., 1999; Soylu et al., 2010; Mantino et al., 2017; Mohammed and Desta, 2017).

Fleig score (FS)

One of the most important criteria used in the determination of the quality of silage feed is the FS, which is calculated based on the regression equation between DM and pH of the silage (Woolfort, 1984; Kılıç, 1986; Geren, 2001). In terms of the FS, the difference between the silage of the switchgrass cultivars examined in the study was found to be statistically significant at p<0.01 level. Although the highest FS was determined in the BoMaster (144.7 points) cultivar, the difference between the Alamo, Trailblazer, Cave in Rock, and Long Island cultivars was found to be statistically insignificant. The lowest FS was found in the Shawnee cultivar by 88.6 (*Table 5*).

Table 5. *Fleig scores of the silage obtained from switchgrass cultivars**

Cultivars	FS
Kanlow	111.9 b
Shelter	105.5 bc
Shawnee	88.6 c
BoMaster	144.7 a
Alamo	134.2 a
Trailblazer	130.9 a
Cave in Rock	144.3 a
Long Island	130.6 a
$F_{cultivar}$	30.658^{**}
CV (%)	5.00

*: The difference between the means indicated by the same letter is not significant, **: p<0.01 is significant within error limits, CV: Coefficient variation

In the study, when the FS of the silage of switchgrass cultivars ranging from 88.6-144.7 were evaluated according to *Table 3*, the quality of silage obtained from switchgrass cultivars was found to be “very good”. When the FS calculated by considering the DM and pH contents of silo feeds is compared with the studies carried out in corn (Geren, 2000, 2001; Demirel et al., 2001; Kavut and Soya, 2012), it can be said that similar results have been achieved.

When the desired pH and DM ratio is ensured in the silo feed, the FS is also high. In our study, it was observed that the FS of all switchgrass cultivars other than the Shawnee cultivar was above 100 (*Table 5*). Similar results were also achieved in corn (150.5 points) and sorghum (123.3 points) silage by Öten et al. (2016) and in corn (104.2 points) silage by Seydoşoğlu (2017).

Physical properties of the silage of switchgrass cultivars

The scores of the physical properties (odor, structure, and color) of the silage obtained from switchgrass cultivars, the DLG score, and the silage quality class according to physical properties are presented in *Table 6*.

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DOI: http://dx.doi.org/10.15666/aeer/1706_1575515773

While the difference between the cultivars in terms of odor and structure was found to be statistically significant at p<0.01 level, the difference between the cultivars in terms of color was found to be insignificant. The Long Island cultivar had the highest score in terms of all three physical properties. Nevertheless, the difference between the Long Island cultivar and the Cave in Rock cultivar in terms of odor and the difference between the Cave in Rock, Alamo, BoMaster, and Shelter cultivars in terms of the structure were found to be statistically insignificant (*Table 6*). In the silage made with switchgrass, the fact that the physical appearance was largely preserved, especially in terms of the above-mentioned cultivars producing high scores, indicates that successful silage can be achieved with switchgrass plant. On the other hand, silage quality also varies depending on the fermentation process (Geren, 2001). Therefore, as it was also indicated by Comberg (1974) and Akyıldız (1984), the silage feed of an ideal quality may have a pleasant acidic, slightly sour and aromatic odor resulting from the odor of the products produced by LA bacteria. Furthermore, it was reported that the physical structure of the feed (Geren, 2001) and the color of the silage (Woolfort, 1984) could be largely preserved if the silage was made well.

Table 6. *Mean scores of the physical properties of the silage obtained from switchgrass cultivars, and the quality class[*]*

Cultivars	Odor	Structure	Color	DLG score	Quality class
Kanlow	8.0 e	2.0 b	1.3	11.3 d	Medium
Shelter	8.7 de	3.3 ab	1.3	13.3 cd	Medium
Shawnee	9.3 cde	2.0 b	1.3	12.7 d	Medium
BoMaster	11.3 bc	3.3 ab	1.3	16.0 bc	Good
Alamo	10.7 bcd	4.0 a	1.7	16.3 b	Good
Trailblazer	10.3 bcd	2.0 b	1.0	13.3 cd	Medium
Cave in Rock	12.0 ab	4.0 a	1.7	17.7 ab	Very good
Long Island	13.7 a	4.0 a	2.0	19.7 a	Very good
$F_{cultivar}$	18.58[**]	7.40[**]	1.06	24.78[**]	
CV (%)	7.09	12.85	6.08	6.55	

[*]: The difference between the means indicated by the same letter in the same column is not significant, [**]: p<0.01 is significant within error limits, CV: Coefficient variation

When the DLG scores were considered, the highest value was determined in the silage of the Long Island cultivar by 19.7 points, followed by the Cave in Rock cultivar by 17.7 points. The lowest DLG score was found in the Kanlow (11.3 points) and Shawnee (12.7) cultivars. This difference between the cultivars in terms of DLG was found to be statistically significant at p<0.01 level. According to the classification of the DLG score obtained by adding the odor, structure, and color scores of the silage (Anonymous, 1987) in the evaluation of the physical properties of silage feed, it was observed that "good" quality silage was obtained from the BoMaster and Alamo cultivars and "very good" quality silage was obtained from the Long Island and Cave in Rock cultivars (*Table 6*).

The harvest time (10-15 days after the beginning of flowering) was effective in obtaining high-quality silage from switchgrass cultivars in terms of physical properties. In the silage study carried out with corn and sorghum plants in a different flowering period (Rafiuddin et al., 2016), it was reported that the color, odor, structure, and total physical score values of the silage increased from early flowering to the full flowering period (as the developmental stage progresses), and the silage quality class became

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DOI: http://dx.doi.org/10.15666/aeer/1706_1575515773

"very good" from a physical aspect. The improvement in the physical properties of silage as the harvest period progressed was also indicated by Khan et al. (2011) and Khan et al. (2012). Moreover, it is considered that the high score in physical properties was affected by low pH, high DM, and high LA values, as it was also indicated by Rafiuddin et al. (2016).

With respect to the switchgrass plant, there was no study on the physical characteristics of silage. However, when compared to the properties of silage made with plants such as corn, sorghum, sorghum x sudangrass hybrid which are physiologically C4 plants such as switchgrass plant, it was observed that the results similar to the results of our study were achieved. In the silage studies carried out with these C4 plants (Geren, 2000; Güney et al., 2010; Öten et al., 2016; Rafiuddin et al., 2016; Seydoşoğlu, 2017), it was reported that the physical score of silage odor varied between 8-14, the silage structure varied between 2-4 points, and the silage color varied between 1-2, and good and/or very good quality silage was obtained according to the DLG score, as in the switchgrass cultivars in the results of our study. Furthermore, our results indicating that cultivars had no significant effects on silage color were found to be consistent with the results obtained by Geren (2000), Güney et al. (2010), Kavut and Soya (2012), and Seydoşoğlu (2017).

Conclusions

According to the study results, it was determined that the Long Island and Cave in Rock cultivars came to the forefront in terms of silage quality and that the BoMaster, Alamo, and Trailblazer cultivars could also be used successfully in silage production. In this study carried out with switchgrass which is used as an alternative plant for the production of bioethanol and forage plants in the world but is a new plant for Turkey, it was concluded that promising results were achieved in terms of silage quality and it could be an alternative source of roughage for livestock businesses. Since switchgrass is a perennial plant with 10 to 15 years lifespan, it would be a longterm resource for silage production.

Acknowledgements. This study was produced from the first author's master's thesis accepted by the Graduate School of Natural and Applied Science of Siirt University. The study was supported by the Scientific Research Projects Coordinatorship of Siirt University with the project code 2017-SİÜFEB-85.

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