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Original article

Evaluation of Sweet Sorghum Biomass as an Alternative Livestock Feed

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Abstract

In case of using sorghum biomass as a source of feed, quality attributes of different forms of the biomass should be known. This study was conducted to determine quality attributes of sweet sorghum (*Sorghum bicolor var. saccharatum (L.) Mohlenbr*.) biomass in different forms. Six different sweet sorghum varieties (M81-E, Ramada, Roma, Topper 76, UNL Hybrid and No 91) were used in different forms. Quality attributes of sweet sorghum herbage before silage (SSH), whole plant silage (WPS) and sap-extracted bagasse silage (SES) were determined. Harvests were performed at milk-dough stage of the plants.While green herbage had greater crude protein ratios, whole plant silages had greater values for the other quality attributes. The sap-extracted bagasse silage had a mean RFV of over 111 indicating a high quality feed. As compared to other varieties, Topper 76 and Ramada varieties had greater values for quality attributes of sweet sorghums.

Keywords: Sweet Sorghum, Silage, Biomass, Quality, Feed.

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INTRODUCTION

As compared to the other feed crops, sweet sorghum has less fertilizer demands and soil preference. Sweet sorghum is quite resistant to draughts and high temperatures (Mastrorilli et al., 1999; Gnansounou et al., 2005; Tesso et al., 2005), more tolerant to floods and salinity (Almodares et al., 2008). Sorghum plants have also quite high energy contents (Negro et al., 1999). Although the water demand of sorghum is lower than those of maize and sugar cane, it has greater potential of biomass than many other C4 plants (Gnansounou et al., 2005). Sweet sorghum is a short-day plant and majority of sorghum varieties require very high temperatures and achieve the best growth and development under these conditions (Reise and Almodares, 2008). Sweet sorghum stalks are ensiled and thus generate a quality feed source for ruminants (Jafarina et al., 2005). According to Kumari et al. (2013), sweet sorghum bagasse, which is an agricultural byproduct, may constitute a good source of silage without any additives and reliably be used in animal diets. Naeini et al. (2014) reported that addition of substances such as urea and molasses into sorghum silage may improve the quality of the silage even further. Many new sorghum varieties have been developed for silage purposes in recent years. They provide greater biomass yield per unit area and they have almost equivalent quality attributes to maize silage (Yucel et al., 2018). Production of summer C4 plants like sorghum with high yield potential per unit-area should be increased to provide quality roughage source for livestock. Number of studies about the potential use of sweet sorghum as a feed source for ruminants in Turkey is quite limited. Thus, information about potential uses of sweet sorghum plants is not available.

This study was conducted to determine the forage quality of six sorghum genotypes grown under the ecological conditions of the Mediterranean Region of Turkey. Whole plants (leaf-stem-panicle) and sap-extracted plants (bagasse) were ensiled and silage quality attributes were also determined in this study.

Materials and Methods

Materials

The material included M81-E, Ramada, Roma and Topper 76 varieties,and UNL-hybrid (26297 X M81 E) of sweet sorghum obtained from the University of Nebraska (USA) in addition to the populations of no91 with USDA-Taiwan origins.

Method

Field experiments were conducted over the experimental fields of Eastern Mediterranean Agricultural Research Institute (Dogankent-Adana/TURKEY) (36° 51' 35" N and 35° 20' 43" E) in 2016 under second crop conditions insplit-plots experimental design with 4 replications. Sowing was performed on 13th of June, 2016 following the harvest of wheat. Before sowing, 50 kg/ha of nitrogen and phosphorus were applied as base fertilizer. All varieties were manually sown at 70 cm row spacing and 15 cm on-row plant spacing. Each plot had 4 rows of 5 m long. When the plants reached to 40-50 cm heights, 50 kg/ha of pure nitrogen was applied as top-dressing fertilizer. Harvesting was carried out between the milk and dough stage of the plants. A total of 15 plants were randomly selected from each plot: 5 plants for herbage, 5 plants for whole plant silage and 5 plants for sap-extracted plant silage.

Three different treatments were conducted to determine the quality attributes of sweet sorghum varieties:

1. Quality values of the herbage material (pre-ensilage): 5 plants harvested from the field were cut into pieces of 15-20 cm, they were put into paper bags, dried in an oven at 65 °Cuntil a constant weight for about 7-10 days. They were ground to pass 1-2 mm sieves.
2. Quality values of whole plant (leaf-stem-panicle) silage: 5 plants harvested from the field were chopped into 3-5 cm pieces in a chipper-chopper machine. Chopped samples were then used to make whole plant silage.
3. Quality values of sap-extracted (squeezed-bagasse) silage: Stalks of 5 plants were squeezed by a specially designed device to extract the plant sap, then resultant bagasse material was chopped into 3-5 cm pieces with a grinding machine. Chopped samples were used to make sap-extracted plant silage (Yucel et al., 2017).

About 1-kg green samples were taken from chopped silage materials, green samples were put into special plastic bags (110 microns of thickness or thicker), 99.9% of the oxygen inside the bags was removed by a Crompack vacuum device, and the bags were sealed automatically to finalize the silage process. Ensiled materialwas labeled and kept at room temperature (17-25 °C) for 60 days. For all treatments, silage samples were dried, weighed and ground to pass 1-2 mm sieves. The Kjeldahl method was used to determine the nitrogen (N) contents of the samples. The crude protein ratio was determined by the formula Nx6.25 (AOAC 1990). The % NDF and ADF contents which constituted the cell membrane components of the feeds were determined by the methods described by Van Soest et al. (1991) in an ANKOM fiber analysis device (Fiber Analyzer). Digestible dry matter (DDM) ratio, dry matter intake (DMI) andrelative feed value (RFV) were calculated by the formulae reported by Schroeder (1994). Accordingly, DDM=88.9-(0.779x%ADF); DMI=120/%NDF; RFV =(%DDM X %DMI)/1.29. Net energy-lactation (NEL-Mcal/kg) was calculated by the formula:NE =1.892-(0.0141*ADF) (Anonymous, 2018).

JUMP statistical software was used for statistical analyses. Significant means were compared with the aid of LSD test at $P<0.05$ level.

Figure 1. a) b c

a) SSH:Sweet sorghum herbage b) SES: Sap-extracted plant silage c) WPS: Whole plant silage

Results and Discussion

Crude Protein Ratio (%)

There were significant differences in crude protein ratios of both the varieties and the treatments (Table 1).The crude protein ratios of the treatments and varieties varied between 2.53 - 5.99%.The greatest crude protein ratio of the varieties (5.08%) was obtained from Ramada variety (Table 1). The greatest crude protein ratio of the treatments (4.88%) was obtained from sweet sorghum herbage and it was respectively followed by whole plant silage (4.06%) and sap-extracted plant (bagasse) silage (3.65%) treatments. The quality values of green herbage and whole plant silagewere higher than those of sap-extracted plant silage since whole plants contained stalks, leaves and panicles, and panicle contained grains. As the grains in the panicles of the ensiled plants were in dough stage, they provided quite high protein values. CP contents of sorghum grains were reported as between 7 - 15% (FAO 1995; Beta et al., 1995). CP ratios of sorghum herbage were reported as between 4.10-8.01% (Rodrigues et al., 2006; Junior et al., 2015; Durul, 2016), and the crude protein ratios of silage sorghum were reported as between 5.6-11.71% (Mahmood et al., 2013 a,b; Karadağ and Özkurt, 2014; Neto et al., 2017). It was reported in previous studies that CP ratios of sap-extracted sweet sorghum silage varied between 4.1 - 7.26% (Kumari et al., 2013; Trulea et al., 2013; Naeini et al., 2014; Rocha et al., 2018) and the CP ratio of silage made out of the bagasse of sweet sorghum that was squeezed with its leaf was 7.48% (Vidya et al., 2016).

Crude Ash (CA, %)

There were significant differences in crude ash contents of the verities and the treatments. Crude ash contents of the treatments and varieties varied between 4.20 - 7.38%.The greatest crude ash content was obtained from whole plant silage and it was followed by the other treatments (Table1). Crude ash contents of sweet sorghum varieties were reported as between 6.15-13.08% (Chakravarthi et al., 2017); they had a crude ash quantity of 79.3 g in 1 kg of DM (Cattani et al. 2017); CA content of herbage before silage was 3.35% and CA content of sorghum silage was 3.54%, while the CA content of sorghum bagasse before silage was 2.52%, the CA content of bagasse silage was 2.55% (Trulea et al. 2013); the crude ash contents of the green material of sorghum and the bagasse of sorghum varied as between 59 - 60 g per 1 kg of DM, and the crude ash values of the ensiled sorghum and bagasse were found respectively as 57 and 70 g per 1 kg of DM (Naeini et al., 2014).

Table 1. Mean Crude Protein and Crude Ash Ratios of Sweet Sorghum Biomass Based on Different Treatment

Cultivars	**Crude Protein Ratio (%)**				**Ash Content (%)**			
	SSH*	**WPS**	**SES**	**Mean**	**SSH***	**WPS**	**SES**	**Mean**
M81-E	4.56	3.36	2.53	**3.50 C+**	5.42	6.56	6.18	**6.05**
Ramada	5.99	5.01	4.25	**5.08 A**	6.27	6.25	6.28	**6.27**
Roma	5.13	4.46	4.29	**4.63 B**	6.13	7.38	6.57	**6.69**
Topper 76	4.14	3.77	3.47	**3.79 C**	5.64	7.21	4.20	**5.66**
UNL Hybrid	5.04	4.21	4.04	**4.43 B**	6.35	6.60	5.05	**6.00**
No91	4.42	3.55	3.24	**3.74 C**	5.20	5.67	5.14	**5.34**
Mean	**4.88 A**	**4.06 B**	**3.65 C[1]**		**5.84 B**	**6.60 A**	**5.57 B[1]**	
CV (%)	9.48				19.48			

***) SSH:** Sweet sorghum herbage **b) WPS:** Whole plant silage **c) SES:** Sap-extracted plant silage

+) There is no statistically significant difference between the mean values that are represented by the same letter on the same column according to the LSD test at P≤0.05

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Acid Detergent Fiber (ADF, %)

There were significant differences in acid detergent fiber ratios of the treatments, varieties and treatment x variety interactions (Table 2). The ADF valuesof different variety-treatment combinations varied between 25.00-39.57%. The silage made out of the whole plant had lower ADF values. It may be due to the silages made out of the whole plant contained both the leaves and panicles. Moreover, leaves were found to contain lower levels of cell-membrane materials as compared to stalks. It was reported that cell-membrane components such as cellulose and lignin were found at higher rates in the stalks as compared to the leaves (Aman, 1993) and these components negatively correlated with digestion (Hatfield, 1993). Among the varieties, Topper 76 had the lowest ADF content. The ADF content of sweet sorghum silages were reported as between 27.9-42.0% (Mahmood et al., 2013; Durul, 2016). It was determined that the ADF content of silage made out of the bagasse of squeezed sweet sorghum variedbetween 19.16-46.82% (Ávila et al., 2013; Kumari et al., 2013; Rocha et al., 2018), and the ADF content of silage made out of the bagasse of sweet sorghum that is squeezed with its leaves was 46.75% (Vidya et al., 2016). Naeini et al. (2014) reported the ADF values of the green materials of maize, sorghum and sorghum bagasse respectively as 263, 213 and 258 g per 1 kg of DM and ADF values of silage made out of these materials respectively as 272, 254 and 246 g per 1 kg of DM.It was reported that sorghum and sorghum bagasse without any additives had lower NDF and ADF values than maize (Naeini et al., 2014).

Neutral Detergent Fiber (NDF, %)

Neutral detergent fiber ratios of the treatments, varieties and treatment x variety interactions are provided in Table 2. The NDF values of different treatment-variety combinations varied between 42.58-60.70%. The silage made out of bagasse had lower NDF values. Since the silages made out of bagassedid not contain leaves and panicles, some quality parameters may be expected to be low. The Topper 76 variety had the lowest NDF value. The mean NDF values of sweet sorghum varieties were reported as between 32.6-54.9 % (Gomes et al., 2006; Machado et al., 2012; Durul, 2016; Neto et al., 2017). Karadağ and Özkurt (2014) reported NDF ratios of silage sorghum varieties as between 61.23-63.00%. The NDF ratios of silage made out of the bagasse of squeezed sweet sorghum was reported as between 39.23 - 75.4% (Ávila et al., 2013; Kumari et al., 2013; Rocha et al., 2018), and the NDF content of silage made out of the bagasse of sweet sorghum that was squeezed with its leaves was 71.81% (Vidya et al., 2016). Naeini et al. (2014) reported the NDF values of the green materials of maize, sorghum and sorghum bagasse respectively as 526, 447 and 491 g per 1 kg of DM.

Table 2. The Mean ADF and NDF Values in Different Varieties of Sorghum and Different Treatment

Cultivars	**Acid Detergent Fiber (%)**				**Neutral Detergent Fiber (%)**			
	SSH*	**WPS**	**SES**	**Mean**	**SSH***	**WPS**	**SES**	**Mean**
M81-E	30.35 cde[2]	29.18 c-f	39.57 a	**33.05 A[+]**	47.64 c-g	46.89 d-h	57.59 a[2]	**50.71 A[+]**
Ramada	29.29 cde	25.00 g	30.35 cde	**28.45CD**	48.10 b-f	43.29 gh	48.56 b-f	**46.65BC**
Roma	27.88 d-g	26.25 fg	35.48 b	**29.87 BC**	45.63 e-h	42.83 h	52.40 b	**46.95 BC**
Topper 76	25.11 g	26.19 fg	30.73 cd	**27.34 D**	43.39 gh	46.22 d-h	44.02 fgh	**44.54 C**
UNL H.	32.83 bc	25.76 fg	36.05 ab	**31.55 AB**	50.79 bcd	42.58 h	52.13 bc	**48.50 AB**
No91	30.81 cd	26.69 efg	39.50 a	**32.34 A**	48.86 b-e	44.05 fgh	60.70 a	**51.20 A**
Mean	**29.50 B**	**26.51 C**	**35.28 A[1]**		**47.40 B**	**44.31 C**	**52.56 A[1]**	
CV (%)	8.54				6.86			

***) SSH:** Sweet sorghum herbage, **WPS:** Whole plant silage, **SES:** Sap-extracted plant silage

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2) There is no statistically significant difference between different cultivars-treatment combination that are represented by the same letter according to the LSD test at P≤0.05.

Dry Matter Intake (DMI, %)

There were significant differences in dry matter intake ratios of the treatments, varieties and treatment x variety interactions (Table 3). The DMI ratios ofdifferent variety-treatment combinations varied between 2.39-2.70% . The DMI ratio of silage made out of the whole plant was significantly greater than those of the other treatments. The Topper 76 variety had the greatest dry matter intake ratio. Lower DMI ratios of sap-extracted bagasse silages were attributed to high NDF values of these silages made out of only the stalks without the leaves and panicles (grains). It is known that there was a negative correlation between NDF and DMI. Karthikeyan et al. (2017) reported dry matter intake ratios of sorghum varieties as between 1.67-2.20 % with an average value of 1.93 %.

Table 3. The Mean DMI Ratio and DDMR Values in Different Varieties of Sorghum and Different Treatment

Cultivars	Dry Matter Intake (%)				Digestable Dry Matter Ratio (%)			
	SSH*	WPS	SES	Mean	SSH*	WPS	SES	Mean
M81-E	2.52 c-f[2]	2.56 b-e	2.09 g-h	**2.39 C[+]**	65.23 cde	66.17 b-e	58.08 g[2]	**63.16 D[+]**
Ramada	2.50 def	2.80 a	2.48 def	**2.59 AB**	65.54 cde	69.43 a	62.26 cde	**66.74 AB**
Roma	2.64 a-d	2.81 a	2.30 fg	**2.58 AB**	67.18 a-d	68.45 ab	61.26 f	**65.63 BC**
Topper 76	2.77 ab	2.61 a-e	2.74 abc	**2.70 A**	69.34 a	68.50 ab	64.96 de	**67.60 A**
UNL H.	2.39 ef	2.83 a	2.31 fg	**2.51 BC**	63.33 ef	68.83 ab	60.82 fg	**64.32 CD**
No91	2.46 def	2.73 abc	1.99 h	**2.39 C**	64.90 de	68.10 abc	58.13 g	**63.71 D**
Mean	**2.55 B**	**2.72 A**	**2.32 C[1]**		**65.92 B**	**68.25 A**	**61.42 C[1]**	
CV (%)	6.40				3.11			

***) SSH:** Sweet sorghum herbage, **WPS:** Whole plant silage, **SES:** Sap-extracted plant silage

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Digestible Dry Matter (DDM, %)

There were significant differences in digestible dry matter ratios of the treatments, varieties and treatment x variety interactions (Table 3). The DDM ratios of different variety-treatment combinations varied between 58.08-69.43%. The DDM ratio of silage made out of the whole plant was greater than the other treatments. The Topper 76 variety had the lowest DDM ratio. Increasing sugar content of sorghum stalks increases digestibility and feed quality (Poehlman, 1994; Blümmel et al., 2009). The digestible dry matter ratios of sorghum silages were reported as between 57.02-66.30% (Junior et al., 2015; Karthikeyan et al., 2017).

Relative Feed Value

There were significant differences in relative feed values of the treatments, varieties and treatment x variety interactions (Table 4). The RFV of the varieties varied between 81.5- 146.9. The greatest value was obtained from Topper 76 variety and the lowest value was obtained from M81-Evariety. The values of the other genotypes were in between them. The RFV of alfalfa is assumed to be 100 when the plants were harvested at 100% flowering stage. Durul (2016) reported RFV of sweet sorghum silages as between 104-126.

Table 4. The Mean RFV and NEL Values in Different Varieties of Sorghum and Different Treatment

Cultivars	**Relative Feed Value**				**Net Energy Lactation (%)**			
	SSH*	**WPS**	**SES**	**Mean**	**SSH***	**WPS**	**SES**	**Mean**
M81-E	127.4 cd[2]	131.5 bcd	94.4 f	**117.8 C[+]**	1.849 a	1.852a	1.334 d	**1.678B[+]**
Ramada	127.3 cd	150.7 a	125.5 cd	**134.5 AB**	1.850 a	1.856 a	1.464 b	**1.723 A**
Roma	137.3 abc	148.9 a	109.6 ef	**131.9 B**	1.853 a	1.855 a	1.392 c	**1.700AB**
Topper 76	148.8 a	138.5 abc	137.9 abc	**141.7 A**	1.857 a	1.854 a	1.459 b	**1.723 A**
UNL Hybrid	117.8 de	151.4 a	108.8 ef	**126.0 BC**	1.846 a	1.854 a	1.384 c	**1.695 B**
No91	123.7 cde	144.4 ab	90.2 g	**119.4 C**	1.849 a	1.855 a	1.335 d	**1.679 B**
Mean	**130.4 B**	**144.2 A**	**111.1 C[1]**		**1.850 A**	**1.854 A**	**1.395 B[1]**	
CV (%)	8.63				1.79			

***) SSH:** Sweet sorghum herbage, **WPS:** Whole plant silage, **SES:** Sap-extracted plant silage

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Net Energy - Lactation (Mcal/kg)

There were significant differences in net energy values of the treatments, varieties and treatment x variety interactions (Table 4). Net energy values of the varieties varied between 1.273 - 1.473 Mcal kg^{-1} with the greatest value from Topper 76 variety and lowest value from no91 variety. It was stated that the energy content of sweet sorghum was high due to its high water-soluble carbohydrate contents (Kaiser et al., 2004). Cattani et al. (2017) reported NE contents of sorghum silages asbetween 1.82-0.92 Mcal per kg of DM.

Conclusion

Quality attributes of sorghum biomass in different forms (as fresh herbage, whole plant silage, sap-extracted bagasse silage) were analyzed in this study. While green herbage had greater crude protein ratios, whole plant silages had greater values for the other quality attributes. RFV was calculated by taking 100% flowering stage of alfalfa into consideration. Accordingly, the sap-extracted bagasse silage had a mean RFV of over 111, the values of Topper 76 and Ramada varieties were even higher, respectively as 137.9 and 125.5, and these values were also higher than those of several other feed crops. In terms of the varieties, Topper 76 and Ramada showed higher values of quality.

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