Assessment of Biochemical Forage Quality of Sweet Sorghum [Sorghum bicolor (L.) Moench ssp. saccharatum]

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Authors’ contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In this study, it was aimed to determine some forage quality characteristics of sweet sorghum genotypes in semi-arid climatic conditions. The experiment was set up in randomized complete block design with 4 replicates. Research was carried out in 2016 and 2017 under Harran Plain second crop conditions, Sanliurfa, Turkey. In the study 21 genotypes of sweet sorghum were used. Crude protein content, crude ash, acid detergent fiber (ADF), neutral detergent fiber (NDF), dry matter digestibility, dry matter consumption, were determined in the study. Significant differences were found between the genotypes for tested characteristics (P≤0.01). According to average of two years, crude protein content ranged from 4.20% (Tracy) to 5.90% (USDA S.Africa), crude ash from 4.44% (Theis) to 6.90% (Topper 76), acid detergent fiber (ADF) from 27.84% (Nebraska sugar) to 36.30% (USDA-Zaire). The highest NDF value was obtained from USDA-Zaire genotype (56.49%) whereas the lowest values were seen at N98 genotype (43.11%). Dry matter digestibility values were between 60.62% (USDA-Zaire) and 67.21% (Nebraska sugar), dry matter consumption between 2.14% and 2.85%. The highest relative feed value was obtained from N98 genotype (148.95) whereas the lowest values were seen at USDA-Zaire genotype (101.00). Net energy values ranged from 1.38 Mcal kg⁻¹ (USDA-Zaire) to 1.50 Mcal kg⁻¹ (Nebraska sugar). Considering the properties examined in terms of feed quality, it was seen that the crude protein content and net
energy value was low. But ADF, NDF, digestible dry matter, dry matter consumption and relative feed values were within acceptable levels. Nebraska sugar, Topper 76, N98, Roma, M81E, Tracy and Corina genotypes were found as the best for forage quality in sweet sorghum. It was determined that sweet sorghum can be used as a forage source.

Keywords: Sweet sorghum; crude protein content; ADF; NDF; dry matter digestibility; net energy.

1. INTRODUCTION

Sweet sorghum is seen as one of the most important plant in the world, which has many uses and has a promising future with its low production cost. Sweet sorghum thrives better under drier and warmer conditions than many other crops and is grown primarily for forage, silage, and syrup production.

All vegetative parts of sweet sorghum are used in the industry. Sweet sorghum is any of the many varieties of the sorghum grass whose stalks have a high sugar content. Sugary plant juice in the stem of sweet sorghum is used in ethanol production, its stem in energy production and plastic production, and grain in human food, animal feed and ethanol production. Its pulp and green leaves are an excellent feed, organic fertilizer, and cellulosic raw material in industry [1-3]. The importance of sweet sorghum in the world is increasing day by day due to its many uses areas.

Sweet sorghum is more tolerant of dryness and high temperature [4]. It is a plant that can be grown successfully in semi-arid regions compared to other species due to its lower transpiration coefficient (310 liters per 1 kg of DM). Although the water demand of sorghum is less than corn and sugar cane, it has higher biomass potential than other C4 plants [5].

Sweet sorghum needs less fertilizer than the economically important plant. It tolerates soil salinity [6]. Sweet sorghum can grow easily in any soil from the heaviest clay soil to sandy soil, where the pH varies between 5.5 and 8.5 [7]. Sorghum species are tolerant to abiotic stress conditions.

Sorghum plant is used in different ranges of forage such as pasture, green fodder, hay and silage [8]. Its biomass yield is higher than many plants. Thanks to the sweet juice in sweet sorghum stems, it has a high energy potential and provides an increase in meat and milk in animals consuming biomass.

Amer et al. [9] in a study evaluating the performance of cattle fed with sweet sorghum, reported that daily milk production increased. Rodrigues et al. [10] reported that the crude protein content in different feed sorghum varieties ranged from 4.85% to 7.78% and was 6.73% on average.

Junior et al. [11] emphasized that sorghum forage crude protein content was 4.10-4.98, NDF ratio was 43.63-48.32. They stated that the ADF rate varied between 24.01-27.69% and the digestibility rate varied between 57.02-61.35%.

Mosali et al. [12] stated that biomass yield in sweet sorghum varied between 6.05 and 9.82 t/da. They stated that the crude protein content of the M81E variety was 3.9%, the ADF value was 39.2%, the NDF rate was 66.3%, and the total digestible nitrogen content was 58.4%. In the Topper variety, they stated that the crude protein content was 4.7%, the ADF rate was 37.5%, the NDF rate was 62.2% and the total digestible nitrogen content was 59.6%.

Kumari et al. [13] investigated some quality values in sweet sorghum material; They found that crude protein content varied 6.02-7.26%, total ash content 5.62-6.76%, NDF ratio 75.4 and 73.54%, ADF ratio 45.9-46.82% and ADL ratio between 8.79-8.95%.

Khota et al. [14] found the values of crude protein content, NDF, ADF and ADL as 4.59%, 69.46%, 43.5% and 4.74%, respectively. ADF concentration is reported to vary between 34.6% and 40.3% [8] and between 31.2% and 37.4% [15].

The objectives of the study are to determine some forage quality characteristics of sweet sorghum genotypes in semi-arid climatic conditions.

2. MATERIALS AND METHODS

This study was conducted in 2016 and 2017 second crop conditions, Sanliurfa, Turkey. The experimental field is located in Harran Plain where the climate varies from arid to semi-arid. Table 1 provides the climatic data belong to 2016 and 2017 years obtained from Sanliurfa City Meteorological Station. As can be seen from
Table 1 that the weather is hot and dry in the months of June, July and August where maximum temperatures were all above 40°C while the relative humidity was below 50%.

The soil of the research field was slightly alkaline, high in lime and very low in salt contents. Organic matter was low. Some physical and chemical properties of research area soil were given in Table 2.

Twenty-one sweet sorghum genotypes (*Sorghum bicolor* (L.) Moench ssp. *saccharatum*) were used as crop material. Land was ploughed and cultivated then prepared for planting with a single pass of a disk-harrow. The experiment was laid out in a randomized block design with four replications. Each plot area was 14 m² (5 m x 2.8 m) and consisted of four rows of 5 m in length. The plants were grown 70 cm apart between the rows with 15 cm spacing in each row.

The seeds were sown in second part of June at a 30-40 mm depth. At sowing, 50 kg ha⁻¹ of pure N, P and K, as a 15-15-15 composed fertilizer, was applied to each plot; this was followed by 50 kg ha⁻¹ of pure N as urea when the plants reached 30-40 cm in height. Irrigation water was first applied to all the plots using a sprinkler irrigation system. After the emergence of plants, plots were irrigated equally by the furrow irrigation system.

All tested characteristics were measured from randomized selected 10 plants in the middle of each plot. Sweet sorghum plant samples were dried at 65°C. Crude ash contents were determined by burning in an ash furnace at 550°C for 4 hours. After the nitrogen (N) content of the plant samples was determined by the Kjeldahl method [18], the crude protein content was calculated with the formula Nx6.25. The determination of NDF and ADF, one of the cell wall structural elements, was determined by using ANKOM 200 Fiber Analyzer [19] according to Van Soest et al. [20].

Dry matter digestibility (%) was calculated using the ADF value given below formula [21].

\[
\text{DM digestibility} = 88.9 - (0.779 \times \% \text{ADF})
\]

\[
\text{Dry matter consumption} = \frac{\text{ADF value}}{0.779}
\]

### Table 1. Monthly some climatic data during 2016 and 2017 sweet sorghum growth period in Sanliurfa

| Climatic parameters | 2016 | 2017 |
|---------------------|------|------|
|                      | May  | June | July | August | September | October | November | December |
| Av. Temp. (°C)      | 22.6 | 27.1 | 30.6 | 29.2   | 26.9      | 20.8    | 14.0     | 7.0      |
| Max. Temp. (°C)     | 35.5 | 40.5 | 41.8 | 42.2   | 36.2      | 31.0    | 22.4     | 18.0     |
| Min. Temp (°C)      | 9.30 | 13.1 | 15.4 | 16.2   | 14.0      | 9.2     | 1.7      | -0.8     |
| Av. Humidity (%)    | 45.0 | 42.1 | 40.5 | 49.8   | 48.1      | 60.0    | 56.8     | 55.6     |
| Rainfall (kg/m²)    | 16.4 | -    | -    | -      | 1.0       | 15.8    | 26.4     | 63.8     |

### Table 2. Some physical and chemical properties of research soil in 2016 and 2017

| Deep (cm) | 2016 | 2017 |
|-----------|------|------|
|           | pH   | EC 1:2.5 | N% | OC% | P mg/kg | CaCO₃% | Sand% | Silt% | Clay% | Texture |
| 0-15      | 7.68 | 0.34     | 0.08 | 0.40 | 0.45    | 46.6   | 29    | 27    | 44    | C       |
| 15-30     | 7.65 | 0.30     | 0.06 | 0.34 | 0.39    | 44.5   | 28    | 27    | 45    | C       |
|           | pH   | EC 1:2.5 | N% | OC% | P mg/kg | CaCO₃% | Sand% | Silt% | Clay% | Texture |
| 0-15      | 7.70 | 0.37     | 0.07 | 0.50 | 0.50    | 47.0   | 30    | 26    | 44    | C       |
| 15-30     | 7.74 | 0.36     | 0.05 | 0.40 | 0.41    | 45.5   | 29    | 26    | 45    | C       |

†Data collected from the Sanliurfa Meteorological Station [16,17]
120% NDF [22]. Relative feed value was calculated by Van Dyke and Anderson [23]. Relative feed value = % Dry matter digestibility x % Dry matter consumption / 1.29.

An analysis-of-variance (One-Way ANOVA) was performed using Jump statistical package program to evaluate statistically differences between results. Means of the data obtained from research were compared using Duncan test at P≤0.05.

3. RESULTS AND DISCUSSION

3.1 Crude Protein Content

The difference between the sorghum genotypes was found to be statistically significant in terms of crude protein content (P≤0.01) at the variance analyses. As seen from Table 3 that crude protein contents were ranged from 3.25% (Smith and Theis) to 6.82% (Gulseker). According to average of two years, the highest crude protein content obtained from USDA-S Africa (5.90%) genotype whereas the lowest crude protein content was seen at Tracy (4.20%) genotype.

Some researchers reported different crude protein content values. Rodrigues et al. [10] reported that the crude protein content in different feed sorghum varieties ranged from 4.85% to 7.78% and was 6.73% on average. Junior et al. [11] emphasized that sorghum forage crude protein content was 4.10-4.98. Mosali et al. [12] stated that crude protein content of the M81E variety was 3.9% and 4.7%, in the Topper variety. Kumari et al. [13] found that crude protein content varied 6.02-7.26%. Khota et al. [14] found the values of crude protein content as 4.59%.

3.2 Crude Ash

There were statistically significant differences among tested sweet sorghum genotypes for crude ash (P≤0.05). The highest crude ash yield value was obtained from Topper 76 genotype (7.78%) in 2017 whereas the lowest values were seen at Smith genotype (3.87%) in 2016. According to average of two years crude ash values varied from 4.44% (Theis) to 6.90% (Topper 76). Crude ash value was higher at Topper-76, N98, Rio, Ramada, Nebraska sugar, USDA-Taiwan, USDA-Zaire and Gulseker genotypes (Table 3). Similar finding reported that crude ash was between 5.62 and 6.76% [13].

3.3 Acid Detergent Fiber (ADF)

In performed variance analyses, Acid Detergent Fiber (ADF) value was found significant (P≤0.01). ADF values were varied from 24.75% (N98) in 2016 to 39.12% (USDA-Zaire) in 2017. According to two average years, the lowest ADF value was obtained from Nebraska sugar genotype (27.84%) whereas the highest values were seen at USDA-Zaire genotype (36.30%). UNL-Hybrid-3, P1579753, USDA-Taiwan, Gulseker, Grassi, Rio, Williams and Ramada genotypes gave higher ADF values than others (Table 4).

Similar results were obtained by some researchers. Junior et al. [11] emphasized that sorghum forage ADF value varied between 24.01 and 27.69%. Mosali et al. [12] stated that ADF value was 39.2%. ADF value in sweet sorghum material was reported as 45.9-46.82% by Kumari et al. [13]. Khota et al. [14] found the values of ADF 43.5%. ADF value is reported to vary between 34.6% and 40.3% [8] and between 31.2% and 37.4% [15].

ADF expresses the amount of cellulose, lignin and insoluble protein in the structure of the plant cell wall. As the rate of ADF increases in a feed, the rate of digestion decreases [20,24]. It is desirable that the ADF value of the cell wall elements in the feed is low [24]. In the best quality feed, the ADF value should be lower than 31%. Most of the ADF values of tested genotypes were lower than 33%.

3.4 Neutral Detergent Fiber (NDF)

As seen from Table 4 that Neutral Detergent Fiber (NDF) value was significant (P≤0.01). NDF values were ranged from 37.90% (N98) in 2016 to 60.58% (USDA-Zaire) in 2017. According to two average years, the highest NDF value was obtained from USDA-Zaire genotype (56.49%) whereas the lowest values were seen at N98 genotype (43.11%).

Junior et al. [11] emphasized lower NDF values than our findings as 43.63%-48.32%. Some researchers stated higher NDF values than ours as 75.4% -73.54% [13]. Research results was in accord with some previous studies. Similar results were obtained by some researchers. Mosali et al. [12] stated that NDF value was 62.2-66.3%. Khota et al. [14] found the values of NDF as 69.46%.
Table 3. Crude protein content and crude ash values of sweet sorghum genotypes grown in 1996 and 1997 under semi-arid conditions

| Genotype   | Crude Protein Content** (%) | Crude Ash* (%) |
|------------|-----------------------------|----------------|
|            | 2016 | 2017 | Average | 2016 | 2017 | Average |
| Corina     | 4.24 a-g | 6.73 a-g | 5.48 ab | 5.44 ab | 5.89 ab | 5.66 ab |
| Cowley     | 3.62 d-g | 5.13 a-g | 4.37 ab | 6.01 ab | 5.70 ab | 5.86 ab |
| Grassi     | 3.58 efg | 6.15 a-e | 4.87 ab | 5.23 ab | 6.66 ab | 5.94 a-b |
| M81-E      | 3.73 c-g | 6.01 a-f | 4.87 ab | 6.01 ab | 6.02 ab | 6.01 ab |
| N98        | 3.97 b-g | 6.18 a-e | 5.07 ab | 7.37 ab | 6.26 ab | 6.82 ab |
| Nebraska sugar | 4.28 a-g | 5.79 a-g | 5.04 ab | 6.56 ab | 5.92 ab | 6.24 a |
| P1579753   | 3.45 fg | 6.55 ab | 5.00 ab | 5.67 ab | 6.50 ab | 6.08 ab |
| Ramada     | 4.40 a-g | 6.68 a | 5.55 ab | 6.50 ab | 6.92 ab | 6.26 ab |
| Rio        | 4.03 b-g | 5.57 a-g | 4.80 ab | 6.63 ab | 7.24 ab | 6.43 ab |
| Roma       | 4.45 a-g | 5.96 a-g | 5.20 ab | 5.69 ab | 6.30 ab | 5.99 ab |
| Smith      | 3.25 g | 5.25 a-g | 4.25 ab | 3.87 b | 6.48 ab | 5.17 ab |
| Theis      | 3.25 g | 5.37 a-g | 4.31 ab | 4.59 ab | 4.28 ab | 4.44 b |
| Topper 76  | 3.72 c-g | 6.18 a-e | 4.95 ab | 6.02 ab | 7.78 a | 6.90 a |
| Tracy      | 3.48 fg | 4.92 a-g | 4.20 b | 4.94 ab | 5.06 a | 5.00 b |
| UNL-hybrid-3 | 3.57 efg | 5.46 a-g | 4.52 ab | 5.38 ab | 5.70 ab | 5.54 ab |
| Williams   | 3.76 c-g | 6.31 abc | 5.03 ab | 5.03 ab | 5.52 ab | 5.27 ab |
| Wray       | 4.52 a-g | 5.99 a-f | 5.25 ab | 5.99 ab | 6.21 ab | 6.10 ab |
| USDA Taiwan | 3.65 d-g | 6.36 abc | 5.00 ab | 6.64 ab | 6.99 ab | 6.82 ab |
| USDA S.Africa | 5.58 a-g | 6.23 a-d | 5.90 a | 5.87 ab | 5.09 ab | 5.48 ab |
| USDA Zaire | 4.90 a-g | 6.14 a-e | 5.52 ab | 6.52 ab | 6.11 ab | 6.32 ab |
| Gulseker   | 4.34 a-g | 6.82 a | 5.58 ab | 6.04 ab | 6.46 ab | 6.25 ab |
| Average    | 3.99 g | 5.37 a-g | 4.31 ab | 4.59 ab | 4.28 ab | 4.44 b |

LSD 1.70 2.64 2.21 3.80

†There is no statistical difference among values annotated with the same letter according to Duncan test at P≤0.05, *, **: denotes P≤0.05 and P≤0.01, respectively

Table 4. Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) values of sweet sorghum genotypes grown in 1996 and 1997 under semi-arid conditions

| Genotype   | Acid Detergent Fiber ADF** (%) | Neutral Detergent Fiber NDF** (%) |
|------------|-------------------------------|-----------------------------------|
|            | 2016 | 2017 | Average | 2016 | 2017 | Average |
| Corina     | 29.78 b-f | 30.83 a-f | 30.31 b-e | 43.25 cg | 45.81 b-g | 44.43 c |
| Cowley     | 27.92 c-f | 30.90 a-f | 29.41 b-e | 44.19 b-g | 47.63 a-g | 45.91 c |
| Grassi     | 30.92 a-f | 33.92 a-e | 32.42 a-e | 47.79 a-g | 52.13 a-f | 49.96 abc |
| M81-E      | 30.25 b-f | 30.78 a-f | 30.52 b-e | 45.80 b-g | 51.41 a-f | 48.61 abc |
| N98        | 24.75 f | 32.08 a-f | 28.41 de | 37.90 g | 48.32 a-g | 43.11 c |
| Nebraska sugar | 26.75 ef | 28.93 b-f | 27.84 e | 42.09 ef | 49.77 a-g | 45.93 c |
| P1579753   | 35.33 a-d | 33.30 a-e | 34.32 ab | 54.64 a-e | 56.02 abc | 55.33 ab |
| Ramada     | 30.66 b-f | 32.58 a-f | 31.62 a-e | 47.14 b-g | 49.26 a-g | 49.20 abc |
| Rio        | 27.07 def | 36.20 abc | 31.64 a-e | 43.02 d-g | 55.83 a-d | 49.42 abc |
| Roma       | 26.97 def | 30.54 b-f | 28.76 cde | 42.37 ef | 48.81 a-g | 45.59 c |
| Smith      | 28.49 b-f | 32.70 a-f | 30.60 b-e | 43.00 dg | 53.76 a-e | 48.38 abc |
| Theis      | 29.20 b-f | 32.49 a-f | 30.85 b-e | 47.15 b-g | 52.01 a-f | 49.58 abc |
| Topper 76  | 27.96 c-f | 32.47 a-f | 30.22 b-e | 43.78 b-g | 51.53 a-f | 47.66 bc |
| Tracy      | 26.76 ef | 31.41 a-f | 29.09 b-e | 40.63 fg | 50.26 a-g | 45.45 c |
| UNL-hybrid-3 | 34.09 a-e | 33.73 a-e | 33.91 abc | 48.78 a-g | 53.09 a-f | 50.94 abc |
| Williams   | 26.39 ef | 36.87 ab | 31.63 a-e | 40.36 fg | 56.22 ab | 48.29 abc |
| Wray       | 26.69 ef | 33.34 a-e | 30.02 b-e | 40.39 fg | 51.95 a-f | 46.17 c |
| USDA-Taiwan | 33.35 a-e | 33.29 a-e | 33.32 a-d | 49.27 a-g | 53.29 a-f | 51.28 abc |
| USDA S.Africa | 30.46 b-f | 29.69 b-f | 30.08 b-e | 48.05 a-g | 47.73 a-g | 47.89 bc |
| USDA Zaire | 33.49 a-e | 39.12 a | 36.30 a | 52.41 a-f | 60.58 a | 56.49 a |
| Gulseker   | 31.09 a-f | 33.84 a-e | 32.47 a-e | 48.57 a-g | 48.43 a-g | 48.51 abc |
| Average    | 29.45 g | 32.81 | 31.13 | 45.27 | 51.60 | 48.43 |

LSD 5.41 8.41 8.33 12.95

†There is no statistical difference among values annotated with the same letter according to Duncan test at P≤0.05, **: denotes P≤0.01
NDF refers to the amount of hemicellulose, cellulose, lignin, cutin and insoluble protein found in the plant cell wall structure. The NDF ratio is often used as an indicator of the development or maturity of the plant. As the rate of NDF in feed decreases, the animal's feed intake increases \[20,24\]. NDF value is required to be lower than 40% in the best quality feed. NDF values of some genotypes like M81E, N98, Nebraska sugar, Topper 76, Tracy, Corina, Cowley and Wray genotypes gave lower NDF values than others.

3.5 Dry Matter Digestibility

Differences among tested sweet sorghum genotypes for dry matter digestibility was significant (Ps0.01). Dry matter digestibility values ranged between 58.43% (USDA-Zaire) in 2017 and 69.62% (N98) in 2016. According to two years average, the highest dry matter digestibility value was obtained from Nebraska sugar genotype (67.21%) whereas the lowest values were seen at USDA-Zaire genotype (60.62%).

Similar results were obtained by some researchers. Junior et al. \[11\] emphasized that sorghum forage dry matter digestibility varied between 57.02-61.35%. Mosali et al. \[12\] stated that the total digestible was 58.4%-59.6%. Digestibility is an important quality criterion in roughages. For a quality roughage it is desirable that its digestibility is as high as possible. Because the high digestible dry matter ratio in roughages not only enables animals to consume the feed easily, but also increases the rate of conversion into animal products such as meat and milk. The best quality feed should have a dry matter digestibility value higher than 65%. Dry matter digestibility values were found higher at Cowley, N98, Roma, Tracy, M81E, Nebraska sugar and Wray genotypes and Dry matter digestibility values was seen over than 65% in these genotypes.

3.6 Dry Matter Consumption

At the variance analyses, differences between genotypes for dry matter consumption was significant (Ps0.01). Dry matter consumption was the highest in N98 genotype as 2.86% whereas the lowest dry matter consumption value was seen at USDA-Zaire genotype as 2.30% in the years of average. In the best quality feed, the dry matter consumption value is desired to be higher than 3%. N98, Corina, Roma, Cowley, Nebraska sugar, Topper 76, Tracy and Wray genotypes

| Genotype             | Dry matter digestibility** (%) | Dry matter consumption** (%) |
|----------------------|-------------------------------|-------------------------------|
|                      | 2016  | 2017  | Average | 2016  | 2017  | Average |
| Corina               | 65.70 a-e | 64.88 a-f | 65.29 a-d | 2.78 a-d | 2.65 a-d | 2.72 ab |
| Cowley               | 67.15 a-d | 64.83 a-f | 65.99 a-d | 2.72 a-d | 2.53 a-e | 2.63 ab |
| Grassi               | 64.82 b-f | 62.48 a-f | 63.65 a-e | 2.53 a-e | 2.30 cde | 2.42 bc |
| M81-E                | 65.33 a-e | 64.92 a-f | 65.13 a-d | 2.62 a-e | 2.34 b-e | 2.48 abc |
| N98                  | 69.62 a-f | 63.91 a-f | 66.77 ab  | 3.19 a  | 2.52 b-e | 2.85 a  |
| Nebraska sugar       | 68.06 ab | 66.37 a-e | 67.21 a   | 2.86 abc | 2.44 b-e | 2.65 ab |
| P1579753             | 61.37 cf | 62.96 b-f | 62.17 de  | 2.21 cde | 2.15 de  | 2.18 c  |
| Ramada               | 65.02 a-e | 63.52 a-f | 64.27 a-e | 2.56 a-e | 2.46 b-e | 2.51 abc |
| Rio                  | 67.81 abc | 60.70 def | 64.26 a-e | 2.79 a-d | 2.18 de  | 2.49 abc |
| Roma                 | 67.89 abc | 65.11 a-e | 66.50 abc | 2.84 abc | 2.48 b-e | 2.66 ab |
| Smith                | 66.70 a-e | 63.43 a-f | 65.06 a-d | 2.84 abc | 2.24 cde | 2.54 abc |
| Theis                | 66.15 a-e | 63.59 a-f | 64.87 a-d | 2.54 a-e | 2.32 b-e | 2.43 abc |
| Topper 76            | 67.12 a-d | 63.60 a-f | 65.36 e-d | 2.77 a-d | 2.33 b-e | 2.55 abc |
| Tracy                | 68.05 ab | 64.43 a-f | 66.24 a-d | 2.96 ab  | 2.40 b-e | 2.68 ab |
| UNL-hybrid-3         | 62.34 b-f | 62.62 a-f | 62.48 cde | 2.48 be  | 2.27 cde | 2.37 bc |
| Williams             | 68.34 ab | 60.18 e-f | 64.26 a-e | 2.97 ab  | 2.14 de  | 2.56 abc |
| Wray                 | 68.11 ab | 62.92 b-f | 65.52 a-d | 2.97 ab  | 2.33 b-e | 2.65 ab |
| USDA-Taiwan          | 62.92 b-f | 62.97 b-f | 62.94 b-e | 2.44 be  | 2.27 cde | 2.36 bc |
| USDA S.Africa        | 65.17 a-e | 65.77 a-e | 65.47 a-d | 2.55 a-e | 2.53 a-e | 2.54 abc |
| USDA Zaire           | 62.81 b-f | 58.43 f   | 60.62 e   | 2.30 cde | 1.99 e   | 2.14 c  |
| Gulseker             | 64.68 b-f | 62.54 a-f | 63.61 a-e | 2.47 be  | 2.53 b-e | 2.50 abc |
| Average              | 65.96   | 63.34     | 64.65     | 2.69     | 2.35     | 2.52     |

LSD 4.21 6.55 0.42 0.66

*There is no statistical difference among values annotated with the same letter according to Duncan test at Ps0.05, **: denotes Ps0.01*
Table 6. Relative feed value and net energy values of sweet sorghum genotypes grown in 1996 and 1997 under semi-arid conditions

| Genotype         | Relative feed value** (%) | Net energy** (Mcal kg⁻¹) |
|------------------|---------------------------|--------------------------|
|                  | 2016          | 2017          | Average | 2016          | 2017          | Average |
| Corina           | 141.48 a-f   | 134.24 a-f   | 137.86 ab | 1.47 a-e   | 1.46 a-f   | 1.46 a-d |
| Cowley           | 141.70 a-f   | 127.36 b-g   | 134.53 ab | 1.50 a-d   | 1.46 a-f   | 1.46 a-d |
| Grassi           | 127.27 b-g   | 111.55 c-g   | 119.40 bcd | 1.46 a-f   | 1.41 b-f   | 1.43 a-e |
| M81-E            | 132.81 a-g   | 118.13 b-g   | 125.47 a-d | 1.47 a-e   | 1.46 a-f   | 1.46 a-d |
| N98              | 172.43 a†    | 125.47 b-g   | 148.95 a   | 1.54 a     | 1.44 a-f   | 1.49 ab  |
| Nebraska sugar   | 151.17 abc   | 125.98 b-g   | 138.58 ab  | 1.51 ab    | 1.48 a-e   | 1.50 a   |
| P.1579753        | 105.85 d-g   | 105.15 d-g   | 105.50 cd  | 1.39 c-f   | 1.42 b-f   | 1.41 de  |
| Ramada           | 129.20 a-g   | 121.33 b-g   | 125.26 a-d | 1.46 a-e   | 1.43 a-f   | 1.45 a-e |
| Rio              | 146.99 a-e   | 103.06 efg   | 125.03 a-d | 1.51 abc   | 1.38 def   | 1.45 a-e |
| Roma             | 149.89 abc   | 125.84 b-g   | 137.87 ab  | 1.51abc    | 1.46 a-e   | 1.49 abc |
| Smith            | 147.37 a-d   | 110.53 c-g   | 128.95 a-d | 1.49 a-e   | 1.43 a-f   | 1.46 a-d |
| Theis            | 130.56 a-g   | 114.31 b-g   | 122.43 a-d | 1.48 a-e   | 1.43 a-f   | 1.46 a-d |
| Topper 76        | 144.26 a-e   | 114.92 b-g   | 129.59 abc | 1.50 a-d   | 1.43 a-f   | 1.46 a-d |
| Tracy            | 156.65 ab    | 120.57 b-g   | 138.61 ab  | 1.51 ab    | 1.45 a-f   | 1.48 a-d |
| UNL-hybrid-3     | 120.42 b-g   | 110.16 c-g   | 115.29 bcd | 1.41 b-f   | 1.42 b-f   | 1.41 cde |
| Williams         | 157.56 ab    | 99.82 f-g    | 128.69 a-d | 1.52 ab    | 1.37 ef    | 1.45 a-e |
| Wray             | 157.11 ab    | 113.87 b-g   | 135.49 ab  | 1.52 ab    | 1.42 b-f   | 1.47 a-d |
| USDA-Taiwan      | 119.11 b-g   | 111.36 c-g   | 115.25 bcd | 1.42 b-f   | 1.42 b-f   | 1.42 b-e |
| USDA-S.Africa    | 129.72 a-g   | 129.34 b-g   | 129.53 abc | 1.46 a-e   | 1.47 a-e   | 1.47 a-d |
| USDA-Zaire       | 111.97 c-g   | 90.04 g      | 101.00 d   | 1.42 b-f   | 1.34 f     | 1.38 e   |
| Gulseker         | 124.14 b-g   | 123.52 b-g   | 123.83 a-d | 1.45 a-f   | 1.41 b-f   | 1.43 a-e |
| Average          | 137.98       | 116.03       | 127.01     | 1.48       | 1.43       | 1.45 |

LSD 28.29 43.99 0.08 0.19

† There is no statistical difference among values annotated with the same letter according to Duncan test at P≤0.05, ** : denotes P≤0.01

3.7 Relative Feed Value

Differences among tested sweet sorghum genotypes for relative feed value was significant (P≤0.01). Relative feed values ranged between 90.04 (USDA-Zaire) in 2017 and 172.43 (N98) in 2016. According to two years average, the highest relative feed value was obtained from N98 genotype (148.95) whereas the lowest values were seen at USDA-Zaire genotype (101.00). Relative feed value values were found higher at N98, Roma, Tracy, Nebraska sugar and Corina genotypes.

The best quality if the relative feed value is above 150, if 125-150 is 1st quality, 103-124 is 2nd quality, 87-102 is 3rd quality, 75-86 is 4th quality and 75 is accepted as the 5th quality [25,26]. As seen from Table 6 that some genotypes such as N98, Roma, Tracy, Nebraska sugar and Corina gave higher relative feed value. Most of Relative feed values of tested genotypes was over 125 at the average of two years.

3.8 Net Energy

There were statistically significant differences among tested sweet sorghum genotypes for net energy (P≤0.01). The highest net energy value was obtained from N98 genotype as 1.54 (Mcal kg⁻¹) in 2016 whereas the lowest values were seen at USDA-Zaire genotype (1.34 Mcal kg⁻¹) in 2017. According to average of two years net energy values varied from 1.38 Mcal kg⁻¹ (USDA-Zaire) to 1.50 Mcal kg⁻¹ (Nebraska sugar). Net energy value was higher at N98, Roma, Nebraska sugar, Tracy, Wray and Cowley sweet sorghum genotypes (Table 6).

4. CONCLUSION

Different sweet sorghum genotypes have been biochemically compared for forage value. Some of them have been found to be better than others. According to mean of two research years; the highest crude protein content was obtained as 5.90% (USDA S.Africa), crude ash as 6.90% (Topper 76) and acid detergent fiber (ADF) as 36.30% (USDA-Zaire). NDF values ranged from 43.11% (N98) to 56.49% (USDA-Zaire). Dry matter digestibility values were between 60.62% (USDA-Zaire) and 67.21% (Nebraska sugar), dry
matter consumption between 2.14% and 2.85%. The highest relative feed value was obtained from N98 genotype (148.95) whereas the lowest values were seen at USDA-Zaire genotype (101.00). Net energy values varied from 1.38 Mcal kg\(^{-1}\) (USDA-Zaire) to 1.46 Mcal kg\(^{-1}\) (M81-E).

Considering examined properties in terms of feed quality, it was seen that the crude protein content and net energy values of sweet sorghum genotypes were low. But ADF, NDF, digestible dry matter, dry matter consumption and relative feed values were within acceptable levels for forage quality. Some sweet sorghum genotypes such as Nebraska sugar, Topper 76, N98, Roma, M81E, Tracy and Corina were found as the best for forage quality in sweet sorghum. Research results showed that sweet sorghum has a forage value, and it can be used as a forage source for animal feeding.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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