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Feed Quality of Sweet Sorghum Grains

Seyithan Seydoşoğlu[1,*], Nizamettin Turan[1], Kağan Kökten[2], Selim Özdemir[3]

[1] Siirt University, Faculty of Agriculture, Department of Field Crops, Siirt, Türkiye

[2] Sivas University of Science and Technology, Faculty of Agricultural Sciences and Technology, Department of Field Crops, Sivas, Türkiye

[3] Bingol University, Vocational School of Food, Agriculture and Livestock, Department of Crop and Animal Production, Bingol, Türkiye

HIGHLIGHTS

- Considering global climate change, sorghum has become an increasingly important crop in terms of tolerance to drought, high temperatures and salinity.
- While sorghum herbage constitutes the roughage source of ruminant animals in many countries of the world, its grain is included in both human nutrition and concentrated feed rations of animals.
- In this study, we tried to determine the nutritional properties of grains of some sweet sorghum varieties.

Abstract

Sweet sorghum crop produces grains at its ear-head which can be utilised as food and feed, produces stalks for the production of syrup, bio-ethanol, bio-diesel, bagasse and green foliage for use as organic fertiliser and excellent animal fodder. Approximately 4000 sweet sorghum cultivars are spread over the globe, providing a broad and varied genetic foundation for the development of highly productive, region-specific cultivars. A study was conducted to assess the grains of selected 10 different sweet sorghum varieties for the feed quality characters. For this aim, ADF, NDF, ADL, DMD, DMI, TDN, RFV, DE and ME values of sweet sorghum grains were determined. As a result of the study, crude ash, CP, ADF, NDF, ADL, DMD, DMI, RFV, TDN, DE and ME values were determined as 0.19-3.74%; 9.03-11.05%; 10.0-24.6%; 24.3-38.0%; 1.07-9.13%; 69.69-81.09%; 3.16-4.94%; 170.5-309.5%; 63.85-74.84%; 3.25-3.74 MJ/kg and 9.85-11.78 Mcal/kg, respectively. Variety "Smith" stands out with its ADF, NDF and ADL characteristics. Gülşeker, USDA-Taiwan and Erdurmuş varieties were significant in terms of CP. Ulusoy variety stands out with DMI, TDN, RFV, DE and ME.

Keywords: Sweet sorghum; *Sorghum bicolor*; grain quality.

1. Introduction

Warm-season tropical grass *Sorghum bicolor* [L.] Moench is the most well adapted species of cereal grass that survive in arid climates. Sorghum uses more water efficiently and grows longer, denser, and longer roots to sustain a physiological activity that is similar to that of plants with enough moisture in the soil. Sweet

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Corresponding Author E-mail: seyithanseydosoglu@siirt.edu.tr
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sorghum (*Sorghum bicolor* [L.] Moench) yields less grain than other sorghums, but the stem of this plant has a significant amount of easily fermentable sugars. In comparison to maize, sweet sorghums yield 23% more fermentable carbohydrates, require 37% less nitrogen fertiliser, use 17% less irrigation water, and may produce more ethanol in a dry year. Approximately 4000 sweet sorghum cultivars are spread over the globe, providing a broad and varied genetic foundation for the development of highly productive, region-specific cultivars (Rutto et al. 2013). Sorghum is a significant grain crop that is fed to cattle, humans, and ethanol plants to produce biofuel. Sorghum's ability to withstand high temperatures, droughts, and salt will probably make it increasingly significant in the context of global climate change. Sorghum is an intriguing feed option for salty soils in arid and semi-arid locations due to its resistance to salt and drought (Fahmy et al. 2010). In addition to grain as food for human and feed for non-ruminant and ruminant livestock, sorghum stover is an important source of roughage for ruminants in many developing countries of the world (Singh et al. 2017).

Similar to grain sorghum, sweet sorghum has stalks that are high in sugar. It is a crop with many uses that can be grown in tandem to produce grains from its ear-head for use as food and feed, sugary juice from its stalks for the production of syrup, bio-ethanol, and bio-diesel, and bagasse and green foliage for use as organic fertiliser, paper manufacturing, and excellent animal fodder (Ray and Behera 2011). According to Almodares and Hadi (2009), sweet sorghum yields 3-7 tonnes of grain and 54-69 tonnes of stalk per hectare.

Some of the many positive traits of sweet sorghum include resilience to salinity, drought, and waterlodging, as well as a high biomass output. Sweet sorghum is a C_4 crop that has a good photosynthetic efficiency as well. Therefore, the advancement of sweet sorghum will be crucial to the growth of animal husbandry, agricultural output, and energy sources. Sweet sorghum's primary nonstructural carbohydrate in the grain is starch, whereas the primary carbohydrate in the stalk-which is the predominant form carried within the plant-is sucrose. The best seeds for producing starch are white or pale yellow. The main sugars found in sweet sorghum grains include maltose, sucrose, raffinose, glucose, and fructose. Studies on sweet sorghum grain plus stem have demonstrated higher yields of fermentable carbohydrates compared to other fuel crops (Murray et al. 2008b). Furthermore, high fructose syrup and animal feed can be made from the grain (Ebadi et al. 1997). Sorghum grain is a vital cereal to grow in tropical and subtropical regions. There might be less demand for imported maize if its cultivation is expanded and used in the diets of animals and poultry (Azarfa et al. 1998).

To ascertain the nutritional value of sorghum, 36 sorghum grain (SG) cultivars and one type of maize were grown at the same location in the study carried out by Ebadi et al. (1997). The nutritional makeup of the grains was examined. The SG's ash, crude protein (CP), phosphorous (P), and acid detergent fibre (ADF) contents were 1.72±0.54, 11.6±1.18, 0.34±0.03, and 8.35±3.93, respectively, according to the results of proximate analyses. SG's ether extract (EE) was lower than that of imported and Iranian corns. The quantities of CP (10.7%), EE (5.9%), and CF (3.3%) in Iranian maize were higher than those in imported maize (7.8, 4.2, and 2.25). The levels of tannin in the high and low SG cultivars were 0.998% and 0.021%, respectively. The increase in tannin levels resulted in a decrease in the apparent and true metabolizable energy (AME and TME) of SG. Significant variations were seen in the levels of TMEn (3853, 3771, and 3213 Kcal/kg) between the low, medium, and high tannin sorghum (LTS, MTS, and HTS) cultivars. Nonetheless, the maize showed greater TME levels (3853, 3771, and 3213 VS. 3947 Kcal/kg) than the SG. Of all the cereals, LTS had the highest AME (3453 Kcal/kg), while MTS (3458 Kcal/kg) and the two maize grains (3406 Kcal/kg) did not differ significantly from one another.

The objective of this study was to assess the grains of selected sweet sorghum varieties for the feed quality characters.

2. Materials and Methods

The Seeds of sweet sorghum (*Sorghum bicolor* [L.] Moench) varieties (Ulusoy, Sorge, Gülşeker, USDA-Tayvan, Smith, Cowley, Tracy, Uzun, MSI-E, Erdurmuş) were obtained from XXX University, Faculty of Agriculture, Department of Field Crops (XXX, Turkiye).

Seeds of the sweet sorghum varieties were ground in a mill and passed through 1 mm for chemical analysis. Crude ash ratio of sweet sorghum grain samples was determined by burning at 550 °C for 8 hours. Crude protein analyses were performed by the methods specified in AOAC (1990). The ADF, NDF and ADL constituting the cell wall were performed by the method specified in Van Soest (1963) and Van Soest and Wine (1967). Relative feed value (RFV), dry matter digestibility (DDM) and dry matter intake (DMI) of sweet sorghum grains were calculated according to the following formulas (Rohweder et al. 1978).

DMD % = 88.9 - (0.779 x ADF %);

DMI % of BW = 120 / NDF %;

RFV = (DDM % x DMI %) /1.29

The TDN and ME values of the seeds of sweet sorghum cultivars were determined according to the method specified by Moore and Undersander (2002), and the DE value was determined by Fonnesbeck et al. (1984) according to the method specified.

The data obtained from the features examined in the study were analyzed in the Jump-Pro13 statistical package program according to the randomized block trial design, and the differences between the averages were compared according to the LSD (0.05) test. Scatterplot biplot and scatterplot matrix graphics were generated to determine the relationship between features were obtained from the Genstat 12th (Genstat 2009; VSN international 2021) program, and the correlation table was obtained from the Jump-Pro13 package program. Interpretations of the graphs were made according to Yan and Tinker (2006).

3. Results and discussion

Crude ash, crude protein, ADF, NDF, ADL, DMD, DMI and TDN ratios and RFV, DE and ME values determined in the seeds of some sweet sorghum cultivars were found to be statistically significant at the 1% level (Table 1).

Table 1. Means of the examined characteristics

Varieties	CA (%)	CP (%)	ADF (%)	NDF (%)	ADL (%)	DMD (%)	DMI (%)	RFV	TDN (%)	DE (MJ/kg)	ME (Mcal/kg)
Ulusoy	2.07 d	9.72 d	10.8 ef	25.9 de	1.96 c	80.44 ab	4.94 a	288.6 bc	74.21 ab	3.71 ab	11.78 a
Sorge	1.55 e	9.03 f	10.0 f	24.8 ef	1.23 e	81.09 a	4.83 ab	303.9 ab	74.84 a	3.74 a	11.78 a
Gülşeker	1.56 e	11.05 a	10.4 ef	24.3 f	1.56 d	80.77 ab	4.63 bc	309.5 a	74.54 ab	3.73 ab	11.73 ab
USDA-Tayvan	2.24 c	10.67 b	12.0 de	27.5 cd	1.16 e	79.53 bc	3.16 g	269.1 cd	73.34 bc	3.67 bc	11.67 ab
Smith	2.46 b	9.72 d	24.6 a	38.0 a	9.13 a	69.69 f	4.29 e	170.5 f	63.85 f	3.25 f	11.52 bc
Cowley	0.19 g	9.74 d	10.0 f	26.3 de	1.43 d	81.08 a	4.36 de	286.8 bc	74.84 a	3.74 a	11.52 bc
Tracy	1.63 e	10.03 c	13.7 c	31.6 b	2.67 b	78.21 d	3.71 f	230.0 e	72.06 d	3.62 d	11.32 cd
Uzun	0.88 f	9.46 e	15.5 b	32.3 b	1.44 d	76.80 e	4.27 e	220.9 e	70.71 e	3.56 e	11.30 d
MSI-E	0.97 f	10.05 c	13.5 cd	28.1 c	2.06 c	78.36 cd	3.79 f	259.4 d	72.21 cd	3.62 cd	11.06 e
Erdurmuş	3.74 a	10.57 b	12.0 de	25.9 de	1.07 e	79.55 bc	4.56 cd	264.9 d	73.36 bc	3.67 bc	9.85 f
Mean	**1.73**	**10.01**	**13.2**	**28.7**	**2.37**	**78.55**	**4.25**	**260.3**	**72.40**	**3.63**	**11.35**
LSD (0.05)	**0.081****	**0.086****	**0.777****	**0.783****	**0.082****	**0.605****	**0.124****	**9.678****	**0.584****	**0.025****	**0.102****
CV (%)	**5.232**	**1.050**	**7.153**	**3.308**	**4.219**	**0.942**	**3.529**	**4.551**	**0.980**	**0.826**	**1.057**

**; significant at the P≤0.01 level. There is no statistical difference between the averages shown with the same letter.

The crude ash and crude protein ratios of the seeds of sweet sorghum cultivars varied between 0.19-3.74% and 9.03-11.05%, respectively. Crude ash and crude protein ratios of sweet sorghum seeds showed great differences between varieties; While the highest crude ash and crude protein ratios were obtained in Erdurmuş and Gülşeker cultivars, respectively, the lowest crude ash and crude protein rates were found in Cowley and Sorge cultivars. In the researches on the raw ash and crude protein contents of sorghum; the crude ash and crude protein ratios were obtained as 1.4-1.6% and 12.1-14.1%, respectively, in sorghum hybrid grains (Isa 2009), as 5.9-9.1% and 18.6-25.2%, respectively, in different sorghum varieties forage (Zhapayev et al. 2015), as 4.8% and 5.1%, respectively, in Ceres-81 sweet sorghum variety (Macedo et al., 2017), as 1.03-2.94% and 10.90-

14.97%, respectively, in sorghum grain (Ebadi et al. 2019), as 1.57% and 11.58%, respectively, in Kisra sorghum cultivar (Mustafa et al. 2021).

ADF, NDF and ADL ratios of the seeds of sweet sorghum cultivars varied between 10.0-24.6%, 24.3-38.0% and 1.07-9.13%, respectively. ADF, NDF and ADL ratios of sweet sorghum seeds differed between cultivars. While the highest ADF, NDF and ADL ratios were obtained from Smith variety; the lowest ADF rate was found in Sorge and Cowley cultivars in the same group, the lowest NDF rate was found in Gülşeker cultivars, and the lowest ADL rate was found in Sorge, USDA-Taiwan and Erdurmuş cultivars, which are in the same group statistically. In the study examining the effects of plant growth regulators on the nutritional values of sweet sorghum, it was reported that the NDF ratios of Cerse-81 sweet sorghum variety ranged from 42.7-73.2 g/kg DM (Macedo 2017). On the other hand, crude fiber ratios were obtained as 2.0-2.7% in sorghum hybrid grain (Issa 2009), as 2.0-2.7% in sorghum grain (Vila-Real et al., 2017), as 1.98-8.99% in different varieties of sorghum kernels (Ebadi et al. 2019), and as 1.68% in Kisra sorghum variety (Mustafa et al. 2021).

DMD and DMI ratios and RFV values of sweet sorghum seeds differed statistically by 1% between cultivars and varied between 69.69-81.09%, 3.16-4.94% and 170.5-309.5%, respectively. While the highest DMD rates were obtained from Sorge, Cowley, Gülşeker and Ulusoy cultivars, which are statistically in the same group, the highest DMI rates were obtained from Ulusoy and Sorge cultivars, and the highest RFV values were obtained from Gülşeker and Sorge cultivars. The lowest DMD rate and RFV value were determined from Smith cultivar, and the lowest DMI rate was determined from USDA-Taiwan cultivar. In the study examining the effects of plant growth regulators on the nutritional values of sweet sorghum, it was reported that the IVD value ranged between 554.0-689.9 g/kg DM (Macedo 2017). On the other hand, it has been reported that the apparent dry matter digestibility and the true dry matter digestibility values in different varieties of sorghum kernels vary between 44.62-76.96% and 64.74-97.52%, respectively (Ebadi et al. 2019).

TDN ratio, DE and ME values of sweet sorghum seeds differed statistically at the level of 1% between cultivars. TDN ratios and DE and ME values of seeds of sweet sorghum cultivars varied between 63.85-74.84%, 3.25-3.74 MJ/kg and 9.85-11.78 Mcal/kg, respectively. While the highest TDN ratios and DE values were obtained from Sorge, Cowley, Gülşeker and Ulusoy cultivars, which are in the same group, the highest ME values were obtained from Ulusoy and Sorge cultivars. The lowest TDN rate and DE value were determined from Smith cultivar, and the lowest ME value from Erdurmuş cultivar. While it has been reported that the available energy content of sorghum grain varies between 9.73-16.08 MJ/kg DM (Black 2001), the apparent metabolisable energy value of different varieties of sorghum kernels has been reported to vary between 2616-3680 g/100 g (Ebadi et al. 2019). On the other hand, it has been reported that ME and apparent metabolisable energy values in sorghum hybrid grain ranged between 3.29-3.59 Mcal/kg and 13.88-14.46 MJ/kg, respectively (Issa 2009).

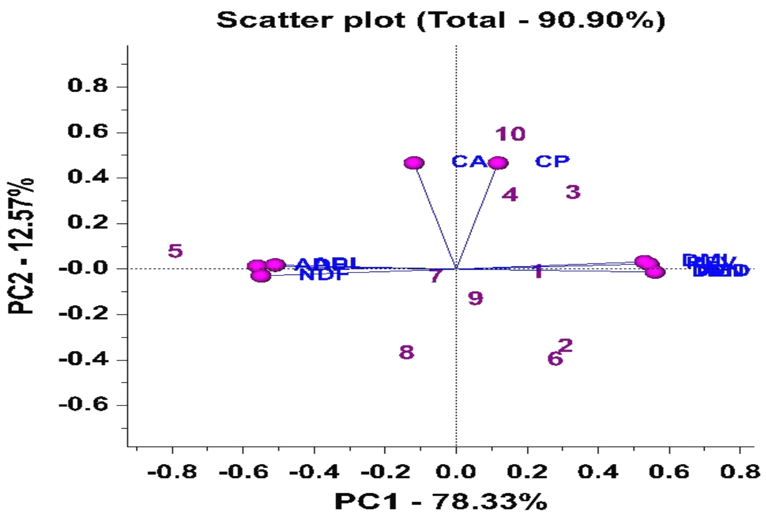

Fig. 1. Vector representation of the relationship between the features examined in terms of average data

With the aid of scatterplot biplot graphics, the relationship between the variations and the characters investigated in the research was visually portrayed. In these graphs, PC-1 represents the productivity of the varieties and PC-2 represents the stability of the varieties (Yan et al., 2000). For this reason, it is desired that an ideal variety should have a high PC-1 value in terms of these characters and a PC-2 value close to zero (Farshadfar et al. 2013). In the research, the total variation between varieties and features was 90.90%, and 78.33% of this rate was PC-1, while 12.57% was PC-2. In this graphic obtained visually with vectors, the narrowing of the angle view between the vectors (DMD, TDN, DMI, RFV, DE and ME, ADL, ADF and NDF) indicates that the relationship between the features is positive and high, and the widening of the angle (ADF and CP, ADF and CA, ADL and CP, ADL and CA, NDF and CP, NDF and CA, CP and NDF) indicates that the relationship is weak, and the angle is greater than 90 0C (as in DMI and CP) indicating a negative relationship. The weak relationship between these characteristics is the cause of the distances of the vectors expressing the features and these vectors from the coordinate plane's centre point (Abate et al. 2015). The ordinate plane can be used to display the inverse relationship between the CA, ADF, NDF, and ADL ratios and other features.

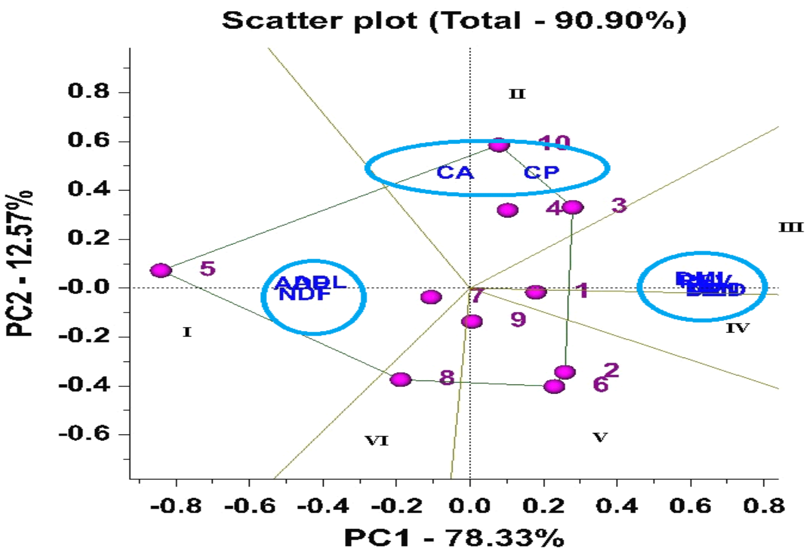

Fig. 2. Illustration of the relationship between the examined features in terms of average data by sectors, polygons and mega environments

The most optimal variety in terms of the characters in each sector are those found at its centre, as seen in Figure 2's sector chart, which uses straight lines to split the graph into parts from the centre to the graphic corners on the x-axis of the coordinate plane. In our research, there are 6 sectors, and in the first sector, variety number 5 (Smith) stands out with its ADF, NDF and ADL characteristics, and in the second sector, varieties number 3 (Gülşeker), 4 (USDA-Taiwan) and 10 (Erdurmuş) were significant with CA and in terms of CP, variety 1 (Ulusoy) in the fourth sector came to the fore in terms of DMI, TDN, RFV, DE and ME. Other varieties did not stand out in terms of any feature. There is a positive relationship between features within the same sector. In addition, it can be said that the varieties in the same sector are close to each other in terms of the characteristics in question, while the varieties in different sectors are far from each other. In the graph, it can be seen that in addition to 6 different sectors, there are 3 separate mega environments. The first mega environment consists of ADF, NDF and ADL, the second mega environment is CA and CP, and the third mega environment is DMI, RFV, TDN, DE and ME. Varieties numbered 2 (Sorge), 6 (Cowley) and 8 (Uzun), located at the corners of the polygon, do not stand out in terms of any feature. In the same sector, however, varieties 3 (Gülşeker), 10 (Erdurmuş), and 5 (Smith) made up the most ideal variety in terms of traits. While Kökten et al. (2017) reported a total variation of 80%, our analysis observed a total variation of 83.75%.

Table 2. Pairwise correlation analysis result of the relationship between features

	CA	CP	ADF	NDF	ADL	DMD	DMI	RFV	TDN	DE
CP	0.3745	1.0000								
ADF	0.2107	-0.1777	1.0000							
NDF	0.1585	-0.2285	0.9496**	1.0000						
ADL	0.2028	-0.1757	0.9211**	0.8124**	1.0000					
DMD	-0.2107	0.1777	-1.0000	-0.9496**	-0.9211**	1.0000				
DMI	-0.1491	0.2185	-0.9067**	-0.9905**	-0.7357*	0.9067	1.0000			
RFV	-0.1633	0.2083	-0.9346**	-0.9957**	-0.7738**	0.9346**	0.9973**	1.0000		
TDN	-0.2107	0.1777	-1.0000**	-0.9496**	-0.9211**	1.0000**	0.9067**	0.9346**	1.0000	
DE	-0.2107	0.1777	-1.0000**	-0.9496**	-0.9211**	1.0000**	0.9067**	0.9346**	1.0000**	1.0000
ME	-0.2107	0.1777	-1.0000**	-0.9496**	-0.9211**	1.0000**	0.9067**	0.9346**	1.0000**	1.0000**

*: Significant at P≤0.05 level, **: Significant at P≤0.01 level.

The scatterplot matrix shows how the characteristics used in the study relate to one another. If the scatter plot matrix representing the relationship between any two features appears as a cloud of dust on the regression curve, it can be said that the relationship between the two features is weak or there is no relationship between them. However, if the distribution is regular and clustered on the regression curve, it can be said that the relationship between the two features is strong (Karaman 2022; Ipekesen et al. 2023). In our research, it was determined that there was a linear and strong relationship between DMD and TDN, DE and ME, between TDN and DE and ME, and between DE and ME, and that the distribution was regular on the regression line and the correlation coefficients (r) were equal to 1. In addition, it was determined that the distribution on the regression line expressing the relationship between CA and CP and other features was in the form of a dust cloud and not regular, and the correlation coefficients were low and mostly negative (Table 2; Figure 3).

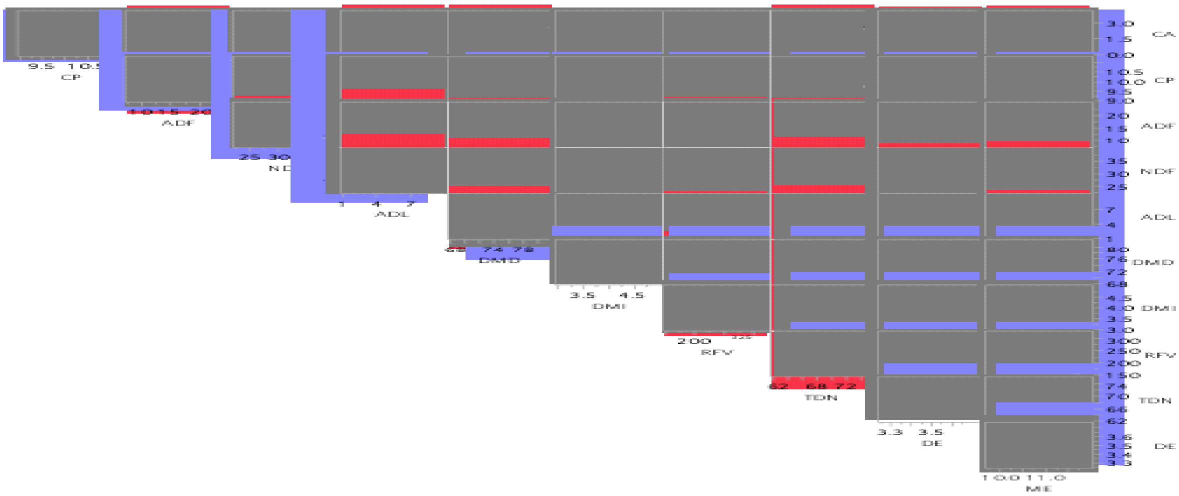

Figure 3. Representation of the correlation between features with scatterplot matrix

4. Conclusions

This Crude ash, CP, ADF, NDF, ADL, DMD, DMI, RFV, TDN, DE and ME values were determined as 0.19-3.74%; 9.03-11.05%; 10.0-24.6%; 24.3-38.0%; 1.07-9.13%; 69.69-81.09%; 3.16-4.94%; 170.5-309.5%; 63.85-74.84%; 3.25-3.74 MJ/kg and 9.85-11.78 Mcal/kg, respectively. Variety Smith stands out with its ADF, NDF and ADL characteristics. Gülşeker, USDA-Taiwan and Erdurmuş were significant in terms of CP. Ulusoy stands out with DMI, TDN, RFV, DE and ME.

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