Archiva Zootechnica 25:1, 5-23, 2022
DOI: 10.2478/azibna-2022-0001

Nutritional potentialities of sweet sorghum plant parts in ruminant production system

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ABSTRACT

The study evaluated the nutritive potentials of 8 cultivars of sweet sorghum and their suitability as ruminant feedstuff. The sorghum cultivars were grown and harvested, each cultivar divided into 2 portions (whole plants and leaves), thereafter ensiled with the view of assessing their nutritive potentials vis-à-vis eco-friendliness for improved/sustained ruminant production. Nutrients and anti-nutrient compositions were assessed. Organic matter digestibility (OMD), methane gas production (CH_4), short chain fatty acids (SCFA) and metabolizable energy (ME) were evaluated using *in vitro* gas production technique. Data generated were subjected to appropriate statistical analysis. From the results, parameters assessed were significantly (P<0.05) improved among the treatments. Ensiling significantly improved the nutritive qualities with respect to the cultivars. The assayed phytochemicals were at tolerable levels and would not hinder nutrients absorption, if fed to ruminants. Further, the *in vitro* degradability study revealed that whole plant of Samsorg-14 sweet sorghum cultivar and its silage have the best nutritive qualities (CP (7.66%; 9.16%), OMD (37.20%; 37.74%), SCFA (0.32; 0.36 umol/200MgDM), ME (4.91; 4.99 MJ/kgDM), respectively. Hence, Samsorg-14 sweet sorghum cultivar was the best of all the cultivars and could serve as protein/energy source in ruminants' diet vis-à-vis its methanogenesis, which invariably could contribute to greenhouse gas emission.

Keywords: methane, nutrients, small ruminants, sorghum cultivars, tropics

INTRODUCTION

Sorghum bicolor (L) Moench is widely grown in the semi-arid and arid savannah regions of Nigeria. Maunder (2002) reported that sorghum is a traditional crop of Africa. It benefits from an ability to tolerate drought, soil toxicities and temperature extremes effectively than other cereals. In terms of the nutritive value, cost and availability, sorghum grain is the next alternative to maize in poultry feed (Subramanian and Metta, 2000) and easily accepted by virtually all classes of livestock. Several varieties of sorghum have been developed and introduced in Nigeria (LAR, 1999). Varieties of sorghum, climatic and soil conditions, fertilizer types are listed among the factors responsible for the variations in chemical composition of sorghum (Etuk, 2008). The success of animal performance is measured by its growth, the ability to produce younger ones and its feed conversion to muscle (Aderemi and Nworgu, 2007). However, inadequate nutrition, the seasonal fluctuation of fodder in quality and quantity has made small ruminant production timeless and unprofitable venture. Ahamefule *et al*. (2001) reported that during the dry season, the natural pastures and crop residues available for animals after crop harvest are usually fibrous and devoid of most essential nutrients which are required for improved microbial fermentation and improved performance of host animal. This manifest in loss of weight, reduced reproduction capacity and increased mortality rate. Furthermore, with the ever increasing population of Nigeria, there has been an increase in demand for animal protein which has caused a considerable increase in demand for animal protein. Also, due to the growing interest in many tropical countries to provide lasting solution to global warming and food security, alongside with the indiscriminate harsh weather that poses threat to forage crops in Nigeria, the need to exploit nutritive potential of sorghum fodder and stover will be a welcome development. Finally, the availability of the forage/fodder for livestock is scarce during offseason in Nigeria, as such, planting of sweet sorghum which is drought resistant should be encouraged, while the nutritive potentials of the cultivars should be exploited beyond its present use.

MATERIALS AND METHODS

Experimental materials and planting operations

Eight different cultivars of sweet Sorghum (*Sorghum bicolour (L) Moench*) were sourced from Institute of Agricultural Research, Zaria, Kaduna State, Nigeria. They are; CSR-01, CSR-02, Samsorg-14, Samsorg-16, Samsorg-17, Samsorg 44, NJJ- 01, and Macia-3. After the land preparation, the sorghum was planted in three replicates, 2 rows per plot, 24 replicate. Thinning and fertilizers (NPK 15: 15:15 and Urea) application were done both at the 4th and 8th week. Avicides and local control method of birds were put in place to deter birds which are a major pest of sorghum. The sorghum cultivars were harvested at late flowering stage, they were cut at about 5 cm above ground level, each cultivar was divided into 2 portions; whole plants and leaves.

Silage preparation

The cultivars were weighed and bagged separately in air-tight nylon bags immediately after harvesting. The bagged plants (2kg each of each cultivar) were then kept in air-tight plastic drums covered with sands to ensure suitable condition for effective anaerobic fermentation. All the silage bags were kept under room temperature. The silage bags were opened at the 4th week, thereafter, physical and chemical parameters of the ensiled cultivars were determined. The whole plants, leaves, and ensiled cultivars were air-dried for two weeks after which they are ground into 2mm particle size using hammer mill and packed into plastic bags for chemical composition determination.

Laboratory analysis

Chemical compositions of the whole plants, leaves and ensiled whole plants were determined according to AOAC (2002) method. The fibre fraction: Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL) were determined according to the procedures of Van Soest *et al*. (1991).

Anti-nutritional factors like tannin, oxalate, saponin, alkaloid, phytate were determined. Tannin was determined using the standard procedures according to the methods of Makkar and Goodchild (1996). Alkaloid was obtained by Harbone (1973) method, saponin was assayed by the test described by Obadoni and Ochuko (2001).

In vitro degradability study

This trial was carried out using in vitro gas production technique. Rumen liquor was collected from West African Dwarf rams after two weeks of feeding 40% concentrate (40% com, 10% wheat offal, 10% palm kernel cake, 20% groundnut cake, 5% Soybean meal, 10% dried brewer's grain, 1% common salt, 3.75% oyster shell and 0.25% fish meal) and 60% *Panicum maximum* at 5% body weight. The rumen liquor was collected through suction pipe (before feeding) into the thermo-flask that has been pre-warmed to a temperature of 39^0C. Incubation procedure was carried out according to Menke and Steingass (1988) using 120ml calibrated transparent plastic syringes with fitted silicon tube. 200mg of the sample was measured and carefully dropped into 50ml calibrated transparent plastic syringes and 30ml each of the inoculums containing cheese cloth strained rumen liquor and buffer (g/litre) solution of 9.8 $NaHCO_3$ + 2.77 Na_2HPO_4 + 0.57KCl + 0.47 NaCl + 2.16 $MgSO_3.7H_2O$ +16 $CaCl_2.2H_20$ (1:4 v/v) under continuous flushing with CO_2 (to minimize changes in microbial populations and to avoid oxygen contamination) was added using another 50 ml plastic calibrated syringe. The syringes were closed and pushed upwards by the piston in order to completely eliminate air in the inoculums. The silicon tube fitted to the syringe was then tightened by a plastic clip so as to prevent escape of gas. Incubation was carried out at 39 ± 1^0C and the volume of gas production was measured at 0, 3, 6, 9, 12, and 24 hours. At the end of 24th hour of termination, 4ml of NaOH (10M) was introduced to eliminate the methane production according to Fievez *et al*. (2005). Metabolizable energy (ME), organic matter digestibility (OMD) and short chain fatty acids (SCFA) were estimated according to the methods of Menke and Steingass (1988). The average volume of gas produced from the blanks was deducted from the volume of gas produced per sample. The gas production characteristics were estimated using the equation Y= a + b (1-ec) as described by Orskov and McDonald (1979). Where Y = volume of gas produced time t, c = intercept (gas produced from the insoluble fraction (b), t = incubation time. ME (MJ/kg DM) = 2.20 +0.136GV + 0.057CP + 0.0029CF; OMD (%) = 14.88 + 889GV + 0.45 CP + 0.651 XA according to Babayemi and Bankole (2006) SCFA = 0.0239v - 0.0601 according to Getachew et al. (1999). Where GV, CP, CF and XA are total gas volume, crude protein, crude fibre and ash, respectively.

Experimental design and statistical analysis

The experimental layout was a completely randomized design and data generated were subjected to analysis of variance using SPSS (2011) version 23.0 and where significant differences are found the means separation was done using the same package with probability level set at 0.05.

RESULTS

Chemical composition of the sorghum cultivar whole plant

The chemical composition of the sorghum cultivar (whole plant) is shown in Table 1. The values were significantly (P<0.05) influenced by the treatments. The recorded values of dry matter ranged from 83.69% (CSR-02) to 87.05% (Samsorg-14). The crude protein values ranged from 6.48% to 7.66%, Samsorg-14 had the highest value. Samsorg-14 had the least crude fibre (30.95%) while NJJ-01 had the highest value 34.51%CF. The recorded values of ether extract ranged from 1.54% (NJJ-01) to 1.98% (MA3). The neutral detergent fibre (NDF) values are observed values ranged from 63.57% (Samsorg-17 and Samsorg-44) to 68.33% (NJJ-01).

Table 1. Nutrient composition of sweet sorghum whole plant

Parameters (%)	**CSR-01**	**CSR-02**	**S14**	**S16**	**S17**	**S44**	**NJJ-01**	**MA3**	**SEM**	**P-value**
Dry matter	85.02^{c}	83.69^{d}	87.05^{a}	86.46^{b}	86.49^{b}	86.14^{b}	86.87^{b}	86.60^{b}	0.30	0.02
Crude protein	7.17^{b}	7.46^{a}	7.66^{a}	7.33^{a}	6.75^{c}	7.51^{a}	7.22^{ab}	6.93^{b}	0.13	0.01
Crude fibre	32.45^{b}	31.87^{c}	30.95^{d}	34.14^{ab}	32.25^{b}	32.02^{b}	34.51^{a}	33.74^{ab}	0.19	0.01
Ether extract	1.67^{c}	1.87^{b}	1.89^{b}	1.86^{b}	1.68^{c}	1.81^{b}	1.54^{d}	1.98^{a}	0.04	0.00
Ash	8.16^{a}	7.56^{b}	7.13^{b}	7.27^{b}	6.52^{c}	6.51^{c}	7.40^{ab}	7.08^{b}	0.08	0.01
NDF	65.60^{b}	64.65^{c}	67.61^{b}	65.68^{c}	63.57^{d}	63.57^{d}	68.33^{a}	67.43^{b}	0.27	0.04
ADL	7.59^{c}	7.63^{c}	8.63^{ab}	8.45^{b}	8.99^{a}	9.00^{a}	8.55^{ab}	8.42^{b}	0.17	0.03
ADF	34.45^{c}	33.50^{c}	37.15^{ab}	40.29^{a}	36.83^{b}	36.74^{b}	37.81^{ab}	39.80^{a}	0.29	0.01

abcd = means within the same row with different superscripts are not significantly (p<0.05) different. NFE - Nitrogen free extract, NDF - Neutral Detergent fibre, ADL - Acid detergent lignin, ADF - Acid detergent fibre, S14 - Samsorg-14, S16 - Samsorg-16, S17 - Samsorg-17, MA3 – Macia-3. n = 3

Meanwhile, S-17 and S-44 had both statistical and numerical similar values (63.57%). Acid detergent lignin of CSR-01 cultivar of whole plant (sorghum) had the least value (7.59%) while Samsorg-44 had the highest value (9.00%). The observed values for acid detergent fibre ranged from 33.50% (CSR-02) to 40.29% (Samsorg-16).

Chemical composition of sorghum cultivar leaves

The chemical composition of the sweet sorghum leaves were shown in Table 2. The values were significantly (P<0.05) influenced by the treatments. The dry matter values ranged from 82.75% to 89.82%, leaves of Samsorg-16 had the highest value while leaves of sweet sorghum CSR-01 cultivar had the least value (82.75%). The recorded values of crude protein ranged from 7.49% (Samsorg-16) to 8.45% (Samsorg-17). The crude fibre ranged from 31.29% to 33.50%, leaves of Samsorg-16 had the highest value while leaves from CSR-02 had the least value (31.29%). Ether extract of ranged from 1.70% (NJJ-01) to 2.06% (CSR-02.) However, Samsorg-14, Samsorg-17 and Samsorg-44 had statistically and numerically similar values (2.02%). The ash contents of the whole leaves ranged from 6.75% to 10.20%, leaves from Samsorg-14 had the highest value while NJJ-01 had the least value (6.75%). The neutral detergent fibre (NDF) values ranged from 47.56% (CSR-02) to 52.13% (Macia-3). The observed values of acid detergent fibre (ADF) ranged from 36.71% to 39.11%, Samsorg- 17 had the least value while leaves from Samsorg-16 had the highest value. The acid detergent lignin (ADL) values ranged from 6.16% to 8.17%, with least value in leave of Samsorg-14 and highest value in leaves of Samsorg-16.

Table 2. Nutrient composition of sweet sorghum whole leaves

Parameters (%)	CSR-01	CSR-02	S14	S16	S17	S44	NJJ-01	MA3	SEM	P-value
Dry matter	82.75^{e}	88.80^{ab}	87.87^{b}	89.82^{a}	86.49^{c}	84.62^{d}	89.35^{a}	88.74^{ab}	0.24	0.002
Crude protein	8.25^{ab}	8.01^{b}	7.88^{c}	7.49^{d}	8.45^{a}	8.25^{ab}	7.62^{cd}	8.18^{b}	0.10	0.001
Crude fibre	32.25^{b}	31.29^{c}	32.63^{b}	33.50^{a}	31.98^{c}	31.78^{c}	32.60^{b}	32.46^{b}	0.37	0.01
Ether extract	1.80^{b}	2.06^{a}	2.02^{a}	1.77^{b}	2.02^{a}	2.02^{a}	1.70^{c}	2.04^{a}	0.02	0.01
Ash	8.77^{c}	9.59^{b}	10.20^{a}	8.88^{c}	8.64^{c}	9.68^{b}	6.75^{d}	8.80^{c}	0.14	0.02
NDF	48.51^{c}	47.56^{d}	48.46^{c}	50.56^{b}	51.95^{a}	50.00^{b}	50.44^{b}	52.13^{a}	0.11	0.04
ADF	36.80^{c}	36.90^{c}	37.20^{b}	39.11^{a}	36.71^{c}	37.96^{b}	37.99^{b}	38.83^{ab}	0.24	0.03
ADL	7.50^{b}	7.88^{ab}	6.16^{c}	8.17^{a}	6.50^{c}	6.67^{c}	7.51^{b}	6.63^{c}	0.10	0.03

abcd = means within the same row with different superscripts are not significantly (p<0.05) different. NFE - Nitrogen free extract, NDF - Neutral Detergent fibre, ADL - Acid detergent lignin, ADF - Acid detergent fibre, S14 - Samsorg-14, S16 - Samsorg-16, S17 - Samsorg-17, MA3 – Macia-3, n = 3

Chemical composition of ensiled sweet sorghum whole plant

The chemical composition of the silage of the different cultivars of the sorghum assessed in this present study is presented in Table 3. The composition of the silage was significantly (P<0.05) influenced by the treatments. The recorded values of dry matter ranged from 85.84% (Macia-03) to 88.22% (Samsorg-16). The crude protein ranged from 8.25% to 9.16 %, Samsorg 14 had the highest value (9.16%) while Samsorg-17 had the least crude protein (8.25%). The crude fibre content of NJJ-01 had the least recorded value (28.29%) while ensiled CSR-01 whole plant had the highest crude fibre (30.20%). The recorded values of ether extract ranged from 1.74% to 2.14%, NJJ-01 had the least while CSR-02 had the highest value (2.14%). The neutral detergent fibre (NDF) observed value ranged from 45.19% (Samsorg-14) to 55.73% (Samsorg-16). The observed values of acid detergent fibre (ADF) ranged from 28.60% to 32.28%, CSR-02 cultivar had the least value while NJJ-01 had the highest. The acid detergent lignin (ADL) ranged from 6.39% to 7.78% with least value in NJJ-01 cultivar and highest value in Samsorg-44.

Table 3. Nutrient composition of ensiled sweet sorghum whole plant

Parameters (%)	CSR-01	CSR-02	S14	S16	S17	S44	NJJ-01	MA3	SEM	P-value
Dry matter	86.04^{d}	86.84^{c}	88.20^{a}	88.22^{a}	87.20^{b}	86.30^{c}	87.26^{b}	85.84^{d}	0.21	0.01
Crude protein	8.25^{c}	8.96^{ab}	9.16^{a}	8.83^{b}	8.25^{c}	9.01^{a}	8.72^{b}	8.43^{c}	0.81	0.04
Crude fibre	30.20^{a}	29.47^{ab}	29.69^{ab}	28.99^{c}	28.55^{c}	30.24^{a}	28.29^{c}	30.16^{a}	0.15	0.01
Ether extract	2.00^{ab}	2.14^{a}	2.02^{ab}	1.78^{b}	1.79^{b}	1.80^{b}	1.74^{c}	2.13^{a}	0.11	0.02
Ash	7.05^{e}	8.19^{a}	8.09^{ab}	7.82^{b}	7.24^{c}	7.87^{b}	7.71^{bc}	7.15^{d}	0.06	0.01
NDF	48.23^{d}	47.88^{e}	45.19^{f}	55.73^{a}	48.62^{d}	49.87^{c}	52.61^{b}	49.63^{c}	0.31	0.03
ADF	29.84^{c}	28.60^{c}	30.17^{b}	31.49^{ab}	28.78^{c}	29.81^{bc}	32.28^{a}	30.64^{b}	0.29	0.02
ADL	6.52^{c}	6.42^{c}	7.61^{a}	6.63^{c}	7.40^{b}	7.78^{a}	6.39^{c}	6.62^{c}	0.15	0.01

abcd = means within the same row with different superscripts are not significantly (p<0.05) different. NDF - Neutral Detergent fibre, ADL - Acid detergent lignin, ADF - Acid detergent fibre, S14 - Samsorg-14, S16 - Samsorg-16, S17 - Samsorg-17, MA3 – Macia-3, n = 3

Anti-nutrients composition of sweet sorghum whole plant

The observed anti-nutrient contents of selected cultivars of whole sorghum plant were presented in Table 4. All parameters observed were significantly (P<0.05) influenced by the treatment. Values obtained for oxalate were from 1.09 mg/g to 1.99 mg/g with NJJ-01 and CSR-01 having the highest and the least values, respectively. Saponin concentration in Samsorg-17 was the least recorded value (1.25%) while the highest was recorded for NJJ-01 (2.44%). Phytate content ranged from 8.24 mg/g in Samsorg-44 to 10.73 mg/g in NJJ-01. Alkaloid content recorded was from 2.65% in NJJ-01 to 3.88% in Samsorg-14. Tannin was least in Samsorg-17 (2.14%) and highest in Samsorg-16 (2.98%).

Table 4. Anti-nutrient composition of sweet sorghum whole plant

Parameters (%)	CSR-01	CSR-02	S14	S16	S17	S44	NJJ-01	MA3	SEM	P-value
Oxalate(mg/g)	1.09^{e}	1.84^{bc}	1.82^{bc}	1.45^{d}	1.88^{b}	1.82^{bc}	1.99^{a}	1.64^{c}	0.02	0.01
Saponin	1.46^{d}	1.38^{e}	1.87^{b}	1.46^{d}	1.25^{f}	1.70^{c}	2.44^{a}	1.34^{e}	0.04	0.01
Phytate(mg/g)	10.25^{ab}	10.72^{a}	10.73^{a}	9.91^{b}	8.84^{c}	8.24^{c}	10.73^{a}	9.68^{b}	1.03	0.04
Alkaloid	3.13^{ab}	2.67^{c}	3.88^{a}	3.14^{ab}	3.05^{b}	2.76^{c}	2.65^{d}	2.86^{bc}	0.03	0.02
Tannin	2.84^{a}	2.97^{a}	2.65^{b}	2.98^{a}	2.14^{c}	2.76^{b}	2.95^{a}	2.23^{c}	0.03	0.01

abcde = means within the same row with different superscripts are not significantly (p<0.05) different. NDF - Neutral Detergent fibre, ADL - Acid detergent lignin, ADF - Acid detergent fibre, S14 - Samsorg-14, S16 - Samsorg-16, S17 - Samsorg-17, MA3 – Macia-3, n = 3.

Anti-nutrients composition of sweet sorghum leaves

The anti-nutrient composition of selected cultivars of sorghum leaves were presented in Table 5. Values obtained were statistically (P<0.05) influenced by the treatment. Oxalate content ranged from 1.60 mg/g (Samsorg-16) to 2.78 mg/g (NJJ-01). Values for saponin was least in Macia-3 (2.15%) and highest (2.85%) in Samsorg-17. Phytate content ranged from 11.54 mg/g (NJJ-01) to 13.19 mg/g (Samsorg-14). Alkaloid content ranged from 2.06 % in (Samsorg-17) to 3.52% in (Samsorg-14). Tannin content was observed to be least in Macia-3 (2.05%) and highest in Samsorg-16 at (3.16%).

Table 5. Anti-nutrient composition of sweet sorghum leaves

Parameters (%)	CSR-01	CSR-02	S-14	S-16	S-17	S-44	NJJ-01	MA-3	SEM	P-value
Oxalate(mg/g)	1.85^{d}	1.90^{d}	2.13^{c}	1.60^{e}	1.90^{d}	2.52^{b}	2.78^{a}	2.00^{c}	0.08	0.01
Saponin	2.16^{d}	2.45^{c}	2.67^{b}	2.65^{b}	2.85^{a}	2.42^{c}	2.65^{b}	2.15^{d}	0.02	0.01
Phytate(mg/g)	12.37^{b}	12.38^{b}	13.19^{a}	12.38^{b}	12.42^{c}	12.32^{c}	11.54^{d}	12.38^{b}	0.02	0.01
Alkaloid	2.94^{c}	2.45^{d}	3.52^{a}	3.24^{b}	2.06^{e}	2.86^{c}	3.15^{b}	2.80^{c}	0.05	0.02
Tannin	2.96^{b}	2.90^{b}	2.27^{d}	3.16^{a}	2.96^{b}	2.07^{e}	2.82^{c}	2.05^{e}	0.02	0.01

abcde = means within the same row with different superscripts are not significantly (p<0.05) different. S14 - Samsorg-14, S16 - Samsorg-16, S17 - Samsorg-17, MA3 – Macia-3, n = 3.

Anti-nutrients composition of sweet sorghum ensiled whole plant

The anti-nutritional factors of sorghum silage were presented in Table 6. The oxalate content ranged from 0.45 mg/g (Samsorg-14) to 2.79 mg/g (Samsorg-44). Saponin ranged from 1.96% in Samsorg-16 (lowest value) to 2.86% in CSR-01 (highest value).

Table 6. Anti-nutrient composition of sweet sorghum ensiled whole plant

Parameters (%)	CSR-01	CSR-02	S14	S16	S17	S44	NJJ-01	MA3	SEM	P-value
Oxalate (mg/g)	1.83^{e}	2.05^{d}	0.45^{f}	2.16^{c}	1.73^{e}	2.79^{a}	2.36^{b}	2.18^{c}	0.20	0.03
Saponin	2.86^{a}	2.71^{b}	2.53^{bc}	1.96^{e}	2.46^{c}	2.46^{c}	2.05^{d}	2.76^{b}	0.02	0.01
Phytate (mg/g)	12.38^{b}	12.38^{b}	8.25^{c}	12.37^{b}	8.26^{c}	16.23^{a}	12.36^{b}	12.36^{b}	0.02	0.01
Alkaloid	2.41^{d}	2.36^{d}	2.84^{b}	2.94^{a}	2.73^{c}	2.67^{c}	2.22^{e}	2.40^{d}	0.04	0.02
Tannin	2.66^{c}	2.94^{a}	2.23^{e}	2.56^{d}	2.52^{d}	2.79^{b}	2.65^{c}	2.64^{c}	0.02	0.01

abcde = means within the same row with different superscripts are not significantly (p<0.05) different. S14 - Samsorg-14, S16 - Samsorg-16, S17 - Samsorg-17, MA3 – Macia-3, n = 3.

The phytate concentration was least in Samsorg-14 (8.25 mg/g) and highest in Samsorg-44 (16.23 mg/g). CSR-01 and CSR-02 are numerically and statistically (P>0.05) similar (12.38 mg/g). The values of alkaloid ranged from 2.22% in (NJJ-01) to 2.94% in (Samsorg-16). Tannin content ranged from 2.23% in Samsorg-14 to 2.94% in CSR-02.

In vitro gas production of sweet sorghum ensiled whole plant

The in vitro gas production for selected cultivars of sorghum silage is presented in Figure 1. The gas production after 3 hours of incubation ranged from 2.33ml (NJJ-01) to 5.00ml (Samsorg-16). At the 6th hour of incubation, the gas production observed ranged from 2.33ml to 6.00ml, NJJ-01 had the least value while CSR-01 had the highest value. CSR-01 at the 9th hour of incubation had the highest value of gas produced at 7.00ml while NJJ-01 had the least value of gas produced at 2.67ml. At the 12th hour of incubation CSR-02 had the highest value of gas produced at 9.67 ml while NJJ-01 had the least value of gas produced at 3.00ml. Value recorded for NJJ-01 was the least (4.33ml) at the 15th hour of incubation while (9.67ml) was the highest and was recorded for CSR-02. At the 18th hour of incubation the gas production recorded were statistically and numerically similar (10.33ml) for Samsorg-14. The value ranged from 11.30ml (CSR-01) to 4.33ml (NJJ-01). The gas production after 21 hours of incubation was highest for Samsorg-14 (14.00ml) and the least observed was 4.67ml for (NJJ-01). The 24th hour of incubation, gas produced ranged from 5.33ml for (NJJ-01) to 16.00ml for (Samsorg-14). The methane production observed after termination at the 24th hour of incubation period ranged from 2.33ml in (Samsorg-44) to 9.00ml in (NJJ-01).

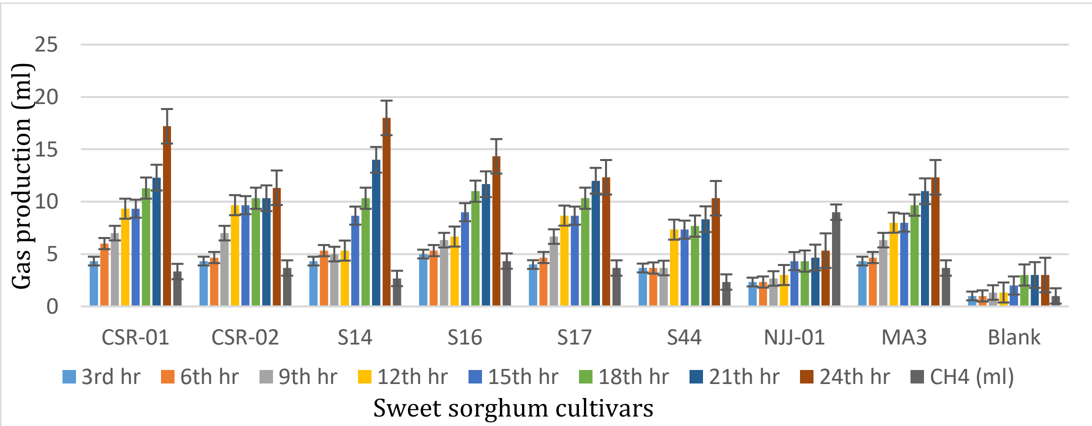

Figure 1: *In vitro* gas production of sweet sorghum ensiled whole plant

In vitro gas production of sweet sorghum whole plant

The in vitro gas production for selected cultivars of sorghum whole plants is presented in Figure 2. The gas production after the 3rd hour of incubation ranged from 2.67ml (Samsorg-14) to 5.00ml (CSR-02). However, CSR-01, Macia-03, Samsorg-16, and Samsorg-17 are statistically and numerically similar. At the 6th hour of incubation, the gas production observed ranged from 3.33ml to 5.67ml, Samsorg-14 had the least value while Samsorg-44 has the highest value. NJJ-01 at the 9th hour of incubation had the highest value of gas produced at 6.00ml while Samsorg-14 had the least value of gas produced at 3.33ml. At the 12 hour of incubation NJJ-01 had the highest value of gas produced at (7.67ml). The gas production after 21 hours of incubation was highest for CSR-01 (14.00ml) and the least observed was (9.67 ml) for Samsorg-14 and NJJ-01. The 24th hour of incubation gas produced ranged from 9.33ml (MA-3) to 17.00ml for (CSR-01). The methane production observed after termination at the 24th hour of incubation period ranged from 2.33ml in (Samsorg -14) to 8.00ml in MA-3.

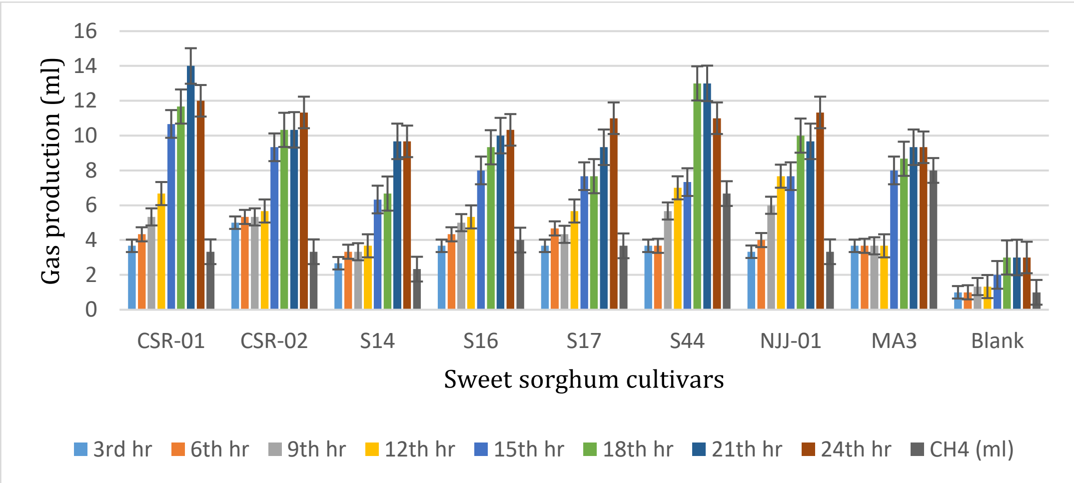

Figure 2: *In vitro* gas production of sweet sorghum whole plant

In vitro characteristics of sweet sorghum ensiled whole plant

The *in vitro* characteristics of sweet sorghum ensiled whole plant are shown in Table 7. The organic matter digestibility ranged from 27.44% (NJJ-01) to 37.20% (Samsorg-14). Short chain fatty acids content ranged from 0.17 to 0.32 umol/200mgDM, with NJJ-01 having the least values and Samsorg-14 having the highest value. This trend goes for the metabolisable energy. The obtained values ranged from 3.29 MJ/KgDM (NJJ-01) to 4.91 MJ/KgDM

(Samsorg-14). But CSR-01 had the highest in vitro dry matter disappearance (0.20%) while Samsorg-17 had the least value (0.01%).

Table 7. *In vitro* characteristics of ensiled sweet sorghum whole plant

Incubation time (hr)	CSR-01	CSR-02	S14	S16	S17	S44	NJJ-01	MA3	SEM	P-value
OMD (%)	36.01^{b}	33.48^{c}	37.20^{a}	35.24^{b}	33.61^{c}	31.95^{d}	27.44^{e}	34.11^{c}	3.10	0.02
SCFA(umol/200mgDM)	0.26^{a}	0.21^{a}	0.32^{a}	0.28^{c}	0.24^{a}	0.19^{ab}	0.17^{b}	0.22^{a}	0.08	0.01
ME (MJ/kgDM)	4.62^{ab}	4.29^{ab}	4.91^{a}	4.66^{ab}	4.41^{ab}	4.17^{ab}	3.29^{c}	4.44^{ab}	0.45	0.02
IVDMD (%)	0.20	0.12	0.17	0.10	0.01	0.07	0.20	0.15	0.08	0.02

abcde = means within the same row with different superscripts are not significantly (p<0.05) different. S14 - Samsorg-14, S16 - Samsorg-16, S17 - Samsorg-17, MA3 – Macia-3, OMD – Organic matter digestibility, SCFA – Short Chain Fatty Acid, ME – Metabolizable energy, IVDMD – In vitro dry matter digestibility, n = 3.

In vitro characteristics of sweet sorghum whole plant

The *in vitro* characteristics of the sorghum whole plant are shown in Table 8. All the parameters observed were significantly (P<0.05) influenced. CSR-01 had the least recorded value for organic matter digestibility (30.86%), short chain fatty acid (0.16umol/200mgDM), and metabolisable energy (3.96MJ/kgDM) while Samsorg-14 had the highest recorded values 37.74%OMD, 0.36 umol/200mgDM SCFA and 4.99 MJ/kgDM ME, respectively. The in vitro dry matter disappearance ranged from 0.07% (CSR-02) to 0.13% (Samsorg-17 and NJJ-01).

Table 8. *In vitro* characteristics of sweet sorghum whole plant

Incubation time (hr)	CSR-01	CSR-02	S14	S16	S17	S44	NJJ-01	MA3	SEM	P-value
OMD (%)	30.86^{c}	32.36^{b}	37.74^{a}	32.13^{b}	36.05^{ab}	35.86^{ab}	33.03^{b}	31.87^{bc}	4.03	0.02
SCFA	0.16^{c}	0.19^{b}	0.36^{a}	0.19^{bc}	0.19^{bc}	0.28^{b}	0.21^{b}	0.17^{c}	0.09	0.01
ME(MJ/kgDM)	3.96^{b}	4.07^{b}	4.99^{a}	4.08^{b}	4.04^{b}	4.34^{ab}	4.60^{ab}	4.01^{ab}	0.64	0.02
IVDMD (%)	0.08	0.07	0.10	0.10	0.13	0.12	0.13	0.09	0.00	0.02

abcde = means within the same row with different superscripts are not significantly (p<0.05) different. S14 - Samsorg-14, S16 - Samsorg-16, S17 - Samsorg-17, MA3 – Macia-3, OMD – Organic matter digestibility, SCFA – Short Chain Fatty Acid, ME – Metabolizable energy, IVDMD – In vitro dry matter digestibility, n = 3.

DISCUSSION

Dry matter values of sweet sorghum cultivar for whole plant were higher compared to values (77.00-80.70%) reported by Calabro *et al*. (2010) for sorghum silage. The reported high DM in this present study might be attributed to the fibre content of the sorghum whole plant which could be influenced by the age and time of harvest (late flowering stage). However, this could encourage chewing and rumination by ruminant animals. More so, the observed high dietary fibre may require ensiling technology to enhance the nutritive quality. The crude protein contents of the sorghum cultivars of whole plant corroborate the value (5.90%CP) reported by Harinarayana *et al*. (2003) for sorghum whole plants. The CP contents were relatively below the critical 8%CP required by ruminants for optimum microbial activities in the rumen (Norton, 2003), and as such, supplement such as legumes (either fresh or processed) and/or concentrates diets should be combined to be fed, as to meet the nutrients (protein) requirement of small ruminants, especially for production ration. The crude fibre contents of the sorghum cultivars whole plant might be attributed to its time of harvest which probably influences the ligno-cellulosic of the sorghum cultivars under study. This, implies that the feeding of sorghum whole plant will supply the bulk of feed needed for small ruminant, but it will supply low energy as the whole plants combines the stem, stalks and leaves.

Neutral detergent fibre (NDF) is one of the factors that influences voluntary intake by ruminant animals as it fills the gut for effective regurgitation. The acid detergent fibre which is a measure of the more indigestible portion of cell wall and reflects degree of lignification. Higher values indicate more mature, lower quality forages while neutral detergent fibre was 50% lower in many of the cultivars - an indicator that the leaves will supply higher energy compared to the whole plant (Robert, 2017). Thus, the rate at which cell wall are lignified will affect intake and acceptance by small ruminants, which will influence the ability of rumen microbes to breakdown cellulose and utilize nutrient efficiently (Ranhjan 1993, Khampa, Wanapat, 2006, Faniyi *et al*., 2019). Consequently, the reported ADL contents would not hinder cellulose utilization.

Silage as a treatment (processing) improved the nutritive value of the cultivars. The reported high DM might be attributed to the age of the forages, season of harvest and thus would prevent microbial deterioration if preserved. Further, this would encourage rumination and efficient utilization by ruminants. The crude protein contents of the sweet sorghum silage were within range of the critical 8% crude protein required by ruminant for optimum microbial activities in the rumen (Norton, 2003). But it is noteworthy that Samsorg-14 had best CP content. The crude fibre reported in this study might be attributed to high lignification of the sorghum cultivars and the time of harvest. The fibre fractions increased as crude protein decreases and this might be because of lignification and time of harvest of the sorghum for silage. This increased fibre fraction will improve voluntary DM intake as well as impact digestibility which are dependent on cell wall constituents such as NDF, ADF, Lignin (Bakshi and Wadhwa, 2004). Like NDF, ADF is a good indicator of fodder quality, lower values in the ensiled whole plants suggest lower-quality fodder (Robert, 2017). This suggest that Samsorg-14 can be fed to ruminant in tropics during the dry season to reduce the weight loss that occurs during this period and serve as aa maintenance diet of the animals.

Anti-nutritional factors are sometimes known to depress palatability and feed intake, decrease rumen ammonia which results in the reduction of nutrient utilization and absorption by animal. The phytate content of the whole plant were above the level of (5-7%) suggested for ruminants by Kankuka *et al.* (2005) and Soetan (2008). The raised levels of phytate in CSR-01, Samsorg-14 and NJJ-01 are capable of binding with the protein and minerals like calcium, iron, magnesium and zinc to form phytic acid and thus, making it not properly available for absorption by animals, if fed. Although, the tannin concentrations in all the sweet sorghum cultivars were lower than the threshold level of 4% opined by Onwuka (1992) that could be tolerated by small ruminants without exhibiting deleterious effect or hampering the proper functioning of the rumen microbes. Oxalate contents of the cultivars were lower compared to 2.80% and 4.10% reported by Adepoju (2012) and Fadiyimu et al*.* (2011) for selected browse plant. This inferred that consumption of sorghum whole plant is beneficial to the animal. However, Samsorg-16 with the least recorded value of oxalate should be fed to the ruminants as its feeding will reduce the binding of minerals like calcium and magnesium which has been reported to contend with their metabolism (Adeniyi *et al*., 2009). Oxalate might react with protein to form complexes (oxalic acid) which have an inhibitory effect on peptic digestion. Saponin contents might not likely influence the nutritional requirement /potential of small ruminant to any extent. The high alkaloid content might affect intake and bind minerals which would have been available for normal functioning of the animals (Kumar, 2011).

Oxalates may limit calcium availability and result in negative correlation between digestibility and lignin content (Kumar, 2011). But from Table 5, values of oxalate for sweet sorghum leaves were lower compared to (4.31%) reported by Fadiyimu *et al*. (2011) for various forages. This low oxalate content will ensure its consumption by ruminants and will not result in loss of minerals like calcium, magnesium and phosphorus. Feeding of forages/leaves without adequate treatment against saponin may cause hypo-cholesterol by binding itself to cholesterol, making it unavailable for absorption. This can also cause haemolysis of red blood cell and has been shown to be toxic to rats (Soetan and Oyewole, 2009), which might have the same effect in small ruminants as well. Further, saponin have been blamed for the incidence of bloat in ruminants consuming fresh alfalfa (Kumar, 2011). Forage containing saponin have been shown to be a defaunating agent (Tefreredgene, 2001) and capable of reducing methane production in small ruminants (Babayemi *et al*., 2004). On the contrary, the obtained saponin values from this study were higher compared to those present in some selected browse plant as reported by Di Marco *et al*. (2009) and Ogunbusoye and Babayemi (2010).

Higher concentration of phytate in ruminant diet may result in low utilization of mineral element by forming compound with anions and proteins (Akinmutimi *et al*., 2009), it might also reduce protein and starch digestibility. High phytate intake has been discovered to reduce vitamin D utilization (Kankuka *et al*., 2005). However, phytate concentration were within the threshold level and corroborates the report by Njidda (2010). Alkaloid content of Sorghum leaves were lower in range than what was observed by Bailey *et al.* (1999) for Sorghum ergot but less than 20mg/100g, which have been associated with intestinal upset and neurological disorder in rats (Aletor, 1993) which might have the same effect in small ruminants. High content of alkaloid in the selected sorghum silage cultivars means its consumption without treatment will cause gastrointestinal and neurological disorder (Alelor, 1993; Kumar, 2011). Tannin contents were below 5% acceptability level for small ruminants reported by Salem *et al.* (2005). The consumption of Samsorg -14 by small ruminants should be encouraged as it has the least recorded values for tannin content. However, tannin value of 4.13% in *Acacia albida* promotes digestibility in grazing ruminants (Akinmutimi *et al.,* 2009). High tannin contents depress cellulase activity by binding fibre, thus affecting biodegradability (digestibility). Feeding sorghum leaves to small ruminants without further treatment could result in the formation of complex protein and impair rumen microbes functioning, depresses feed intake and wool growth in sheep (D'Mello, 2000).

Ensiling significantly reduced the anti-nutritional factors, such that it would encourage intake by small ruminants. It would also enhance palatability, well degraded in rumen and consequently be well utilized for growth by small ruminants (Kumar, 2011). The lower methane gas production of sweet sorghum may be attributed to decreased fibre which might increase the rate of fibre digestibility of sweet sorghum cultivar under study. Also, the presence of secondary metabolites which according to Babayemi *et al*. (2004a) could also affect the potency of rumen liquor for incubation. The presence of other phytochemicals such as phenol might be responsible for the low methane gas production (Faniyi *et al*., 2021). The methane production is lower compared to values of Babayemi (2005) for dry season forages but similar to values obtained by Ardiansyah *et al*. (2016) for sorghum silage. The low methane production implies that feeding of sorghum cultivars will reduce methanogenesis in small ruminant. This will translate into reduced energy loss (Babayemi, 2009). The gas production is a function and mirror of degradable carbohydrates and therefore the amount of gas produced depends on the nature of the carbohydrates. Sommart *et al*. (2000) suggested that gas volume is a good parameter from which to predict digestibility, fermentation end-product and microbial protein synthesis of the substrate by numen microbes in the *in vitro* system.

Furthermore, *in vitro* dry matter and organic matter digestibility were shown to have high correlation with gas volume (Sommart *et al*. 2000; Nitipot and Sommart, 2003). Gas volume has also shown to have a close relationship with feed intake (Blummel and Becker, 1997) and growth rate (Blummel and Orskov, 1993). Akinfemi *et al*. (2010) suggested that gas production from protein fermentation is relatively small as compared to carbohydrate fermentation while the contribution of fat to gas production is negligible. Menke and Steingass (1988) reported a strong connection between ME values measured *in vivo* and predicted from 24th in vitro gas production and chemical composition of feed. Kamalak *et al*. (2005) and Abdulrazak *et al*. (2000) reported that gas production and estimated parameters are negatively correlated with NDF and ADF. Methane production has negative effect on the animals as it is an energy loss to the animal and can also result in bloat when it accumulates in the rumen. Menke *et al*. (1979) suggested that gas volume at 24 hours after incubation is in direct proportion with metabolizable energy in feedstuffs.

From Figure 1, the observed low gas production could be attributed to the high cell wall content. Akinfemi *et al*. (2010) reported that the lignification of cell wall limits the function of rumen microbial flora/polysaccharide. This is an indication of lower energy loss to ruminants. Methane gas produced were within range of values (4.28 - 6.02ml) reported by Costa *et al*. (2016) for sorghum silage but lower to values obtained (10.87 - 11.93ml) reported by Ardiansynah *et al*. (2016) for sorghum silage. The variation might be attributed to the different species, soil composition on which it is grown, stage and time of harvest which are capable of altering the nutritive compositions and presence of high anti-nutritional factors like tannin. Gas volume reflected the differences in the degradability of the structural and insoluble fraction of the whole plant, mainly NDF (Blummel and Becker, 1997). The gas produced was closely related to the production of SCFA which was based on carbohydrate fermentation (Sallam *et al*., 2007). The level of SCFA is an indicator of energy availability to the animal, this means due to the activity of anti-nutritional components, the whole plant will supply lesser energy. Metabolizable energy present in sweet sorghum whole plant cultivars might have been influenced by the presence of secondary metabolites, which is capable of not making the nutrients available to the animals if fed except they are being utilized as a by-pass protein.

CONCLUSION

Findings of this study indicate that sweet sorghum foliage and their silage have the nutritive potentials as ruminant feed, particularly the Samsorg-14 cultivar was best improved by the ensiling technology. More so, the in vitro degradability study predicts that foliage has potentials as ruminants' feedstuff. However, in vivo trials should be carried out to substantiate the feeding value of sweet sorghum.

ACKNOWLEDGEMENTS

The authors acknowledge the Institute of Agricultural Research, Zaria, Kaduna State, Nigeria for the provision of the various cultivars of sweet sorghum. The department of Crop, Soil and Pest Management of the University is *appreciated for their support in the agronomic practices and also to the Departmental Technologists for the assistance rendered in the course of the laboratory analyses.*

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