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Carbohydrate and protein fractions, nutritive value and energetic efficiency in different sorghum accessions

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Abstract
Under sorghum breeding programme, 19 accessions (IC-355466 to IC-355484) along with 2 national checks (CSV 15 and SSG59-3) grown under identical agronomic conditions and harvested at 50 % flowering stage, were screened for their crude protein (CP), fiber contents, carbohydrate fractions, protein fractions, methane production and palatability attributes. Accessions mean CP and ether extract contents were 7.68 and 1.65%, respectively. Accessions NDF, ADF, cellulose and lignin ranged between 62.94-75.14, 38.31-50.45, 29.09-34.63 and 5.51-12.42%, respectively. Sorghum accessions mean value for moderately degradable protein fraction (P_{B2}) was 32.32% of CP and lignin bound protein fraction (P_C) was 1.21% of CP. Slowly degradable cell wall carbohydrate fraction (C_{B2}) and intermediately degradable carbohydrate fraction (C_{B1}) contents were 52.5 and 0.67% of CHO, respectively in the accessions. Sorghum accessions differed (P<0.05) in methane production and ranged between 90.4 to 99.13 g/kg DDM. Intake, IVDMD and relative feed values of accessions differed significantly (P<0.05). Accessions energetic efficiency mean values for lactation (NE_L), maintenance (NE_M) and gain (NE_G) were 1.09, 1.14 and 0.421 Kcal/g, respectively. Sorghum accessions IC-355475, IC-355479 and IC-355-483 were rich in protein, low to medium in fiber, NDIP and SC, high in TDN, DMI, RFV and low in methane production.

Keywords: Carbohydrate fraction, Methane, Nutritive value, Protein fraction, Sorghum accessions

Abbreviations: ADF: Acid detergent fiber; **ADIN:** Acid detergent insoluble nitrogen; **C_A:** Rapidly degradable sugars; **C_{B1}:** Intermediately degradable starch and pectin; **C_{B2}:** Slowly degradable cell wall; **C_C:** Unavailable/ lignin bound cell wall; **CHO:** Total carbohydrates; **CP:** Crude protein; **DDM:** Digestible dry matter; **DE:** Digestible energy; **DMI:** Dry matter intake; **EE:** Ether extract; **IVDMD:** *In vitro* dry matter digestibility; **ME:** Metabolisable energy; **NDF:** Neutral detergent fiber; **NDIN:** Neutral detergent insoluble nitrogen; **NE_G:** Net energy for gain; **NE_L:** Net energy for lactation; **NE_M:** Net energy for maintenance; **NPN:** Non-protein-nitrogen; **NSC:** Nonstructural carbohydrates; **RFV:** Relative feed value; **SC:** Structural carbohydrates; **SP:** Soluble protein; **TDN:** Total digestible nutrients

Introduction
Sorghum (*Sorghum bicolor* L. Moench) is one of the important cereal crops in semi arid tropics globally to provide human food, animal feed and raw materials for industrial use. In the present context of global climate change this crop is likely to become more important due to its adaptability to high temperature, water scarcity and salt tolerant conditions (Rajarajan and Ganesamurthy, 2014; Brouk and Bean, 2011; Sanchez *et al*., 2002). It's tolerance to drought and salt makes sorghum a valuable feed resource for saline soils in arid and semi-arid regions (Fahmy *et al*., 2010). India contributes 16% of global sorghum production and traditionally it is grown both as fodder and grain crop in all states of India. Three southern states *viz*., Maharashtra, Karnataka, and Andhra Pradesh are accounting nearly 75% of sorghum cultivable area and 85% of country's total sorghum production. Sorghum is grown as green fodder in rainy season from July to mid October (*Kharif*) and later for grain as food-feed crop. Apart from grain as food for human and feed for non-ruminants and ruminant livestock, sorghum residue (stover) is an important source of dry roughage for ruminants in tropics including India. The nutritive value of sorghum stover in terms of protein, energy and digestibility is low and even does not constitute the maintenance diet of ruminants. In view of growing importance of crop residues for livestock feed, improving the nutritive value of sorghum stover is an important objective in the tropics (Rattunde *et al*., 2001). Blummel and Reddy (2006) reported substantial variation in the fodder value of sorghum stovers, and supported the concept of genetic enhancement to improve dual-

purpose sorghum cultivars. Genetic variability in sorghum for various morphological and nutritional traits has been reported (Chand *et al.,* 2017; Youngquist *et al*., 1990; Singh *et al.,* 2014). However there is paucity of systematic information on nutritive value of improved forage sorghums, which is important for scaling of forage cultivars (Akabari and Parmar, 2014). There is need to screen the genetic diversity of available sorghum germplasm for higher protein, energy and digestibility in order to select and breed sorghum varieties or hybrids with higher fodder value and at the same time not compromising to grain yield (Rattunde, 1998; Hash *et al*., 2000). The objective of the study was to screening 19 indigenous accessions of sorghum developed under the sorghum breeding programme at ICAR-Indian Grassland and Fodder Research Institute (ICAR-IGFRI), Jhansi for variability in protein, carbohydrate, digestibility and methane production.

Materials and Methods

***Accessions, sample collection and processing*:** Nineteen sorghum accessions (IC-355466, IC-355467, IC-355468, IC-355469, IC-355470, IC-355471, IC-355472, IC-355473, IC-355474, IC-355475, IC-355476, IC-355477, IC-355478, IC-355479, IC-355480, IC-355481, IC-355482, IC-355483 and IC-355484) with two checks (CSV-15 and SSG59-3) were planted in a randomized block design with three replications. Each accession was accommodated in plots of 5x4 m^2 spaced at 45 cm row to row and 15 cm plant to plant distance. A basal dose of nitrogen and phosphorous 80 and 40 kg/ ha, respectively was applied, while top dressing of nitrogen as urea was done twice @ 60 kg and 40 kg, respectively. Accessions were grown under similar soil conditions and agronomic practices. A composite sample was taken from 3 replications of each accession at 50% flowering stage. The plants were chopped and initially dried in shade and later at 60-65 ^{0}C for 96h to have constant weight. Dried samples were grind through 1-mm sieve using electrically operated Willey mill and stored in plastic containers for chemical and biochemical analysis.

***Chemical analysis*:** Dry matter (DM), crude protein (CP), ether extracts (EE) and ash contents were estimated as per method of AOAC (2000) in all the sorghum accessions. Fiber contents viz. NDF, ADF, cellulose and lignin (ADL) were determined following procedure of Van Soest *et al.* (1991) using fiber analyzer. Carbohydrate fractions of sorghum samples were estimated following Cornell Net Carbohydrate and Protein (CNCP) system (Sniffen *et al*., 1992). Total carbohydrate (CHO%DM) was determined mathematically by subtracting CP, EE and ash contents from 100. Structural carbohydrates (SC) were calculated as the difference between NDF and NDIP while non-fiber carbohydrates (NFC) were estimated as the difference between total carbohydrate (CHO) and SC (Caballero *et al*., 2001). Starch was estimated using ethyl alcohol and perchloric acid as per standard procedure (Sastry *et al*., 1991). Crude protein fractions of accessions were estimated following procedure of Sniffen *et al*. (1992) modified by Licitra *et al.* (1996). Neutral detergent insoluble protein (NDIP), acid detergent insoluble protein (ADIP) and non-protein nitrogen (NPN) of accessions were estimated according to Licitra *et al., (*1996). Soluble protein (SP) was estimated by treating the samples in borate–phosphate buffer of pH 6.7–6.8 (Krishnamoorthy *et al*., 1982). *In vitro* dry matter digestibility (IVDMD) of accessions was estimated following two stage technique of Tilley and Terry (1963) by incubating 0.5 g of sample in sheep inoculums.

***Intake, digestible dry matter, feed value, and energy and methane emission estimations*:** Dry matter intake (DMI), digestible DM (DDM), relative feed value (RFV), total digestible nutrients (TDN) and net energy (NE) for different animal functions *i.e*., lactation (NE_L), gain (NE_G) and maintenance (NE_M) were calculated based on empirical equations given by Undersander *et al.* (1993). Digestible energy (DE, kj/g DM) and net energy (NE, kj/g DM) values were calculated using equations of Fonnesbeck *et al*. (1984) and Khalil *et al*. (1986), respectively. *In vitro* methane production (g/ kg DDM) of accessions was calculated by equation of Singh *et al*. (2012).

***Statistical analysis*:** Data were subjected to analysis of variance to test the accessions variability for different chemical constituents, dry matter digestibility and methane production. Means of parameters estimated for sorghum accessions were compared for significance at P<0.05 level (Snedecor and Cochran, 1994). Data analyses were carried using statistical software SPSS, V13.0.

Results and Discussion

Protein and cell wall contents: Higher crude protein and low cell wall contents (NDF, ADF, cellulose and lignin) are indices of good fodder quality. Mean CP and EE contents of sorghum accessions were 7.68 and 1.65%, respectively, with highest CP of 10.6% observed in IC-355475 (Table 1). Accessions cell wall fractions varied

Table 1. Chemical composition of sorghum accessions (% DM basis)

Accessions	CP*	OM*	NDF*	ADF*	Cellulose	Lignin*	EE
IC-355466	8.7	91.48	62.94	38.31	30.82	5.51	2.20
IC-355467	7.7	92.39	73.28	41.87	32.14	7.43	1.24
IC-355468	7.3	92.61	70.41	42.72	33.41	6.96	2.30
IC-355469	7.7	93.4	74.31	45.98	34.33	9.29	2.25
IC-355470	7.5	93.07	71.26	43.21	33.01	8.30	2.35
IC-355471	6.3	93.27	66.08	41.92	30.77	8.98	2.70
CSV-15	8.4	91.15	68.96	45.18	33.86	8.61	1.54
SSG59-3	6.6	94.01	73.99	50.45	32.62	12.42	1.09
IC-355472	6.6	93.51	68.62	42.13	30.68	9.39	1.53
IC-355473	7.8	93.30	74.15	46.19	34.63	9.75	1.13
IC-355474	9.4	92.67	72.58	43.76	31.26	10.56	1.81
IC-355475	10.4	92.63	68.73	43.26	30.58	10.83	1.04
IC-355476	7.7	93.21	72.57	40.82	31.89	7.04	1.22
IC-355477	6.6	93.63	71.79	40.00	31.64	8.02	1.34
IC-355478	8.2	93.37	75.14	42.46	32.81	8.13	1.79
IC-355479	8.9	90.99	70.93	38.74	31.70	5.96	1.14
IC-355480	7.0	94.12	74.69	42.35	33.53	7.22	1.50
IC-355481	7.66	92.80	72.01	42.58	32.12	8.57	1.67
IC-355482	6.3	93.43	75.26	43.31	30.64	11.08	1.68
IC-355483	9.6	91.35	71.72	41.68	31.90	7.72	2.00
IC-355484	4.9	94.13	70.34	39.92	29.09	9.09	1.12
Mean	7.68	92.89	71.38	42.71	32.06	8.62	1.65
SEM	0.29	0.212	0.693	0.608	0.315	0.383	0.11

*Differ significantly at P<0.05 level

from 62.94 to 75.14% for NDF, 38.31 to 50.45% for ADF, 29.09 to 34.63% for cellulose and, 5.51 to 12.42% for lignin. Among all the accessions, IC-355466 had lowest NDF (62.94%), ADF (38.3%) and lignin (5.51%) content. Hamed *et al*. (2015) reported genetic variability in sorghum varieties for NDF, ADF and lignin from 59.9 to 79.3; 46.4 to 70.0 and, 9.2-13.5%, respectively which commensurate with the present observations. In a study Mahmood *et al.* (2013) evaluated 15 sorghum cultivars at 2 sites and found that protein, EE, ash, NDF and ADF varied between sites and confirmed that both genetics and location influences the chemical makeup of crop. Even variability in mean CP (7.43-11.7%) and lignin (3.59-5.68%) contents of 55 of sorghum genotypes grown for two successive years were reported earlier (Aruna *et al.,* 2015). The NDF content of the forage can vary greatly depending on the crop cycle, the night temperatures and carbohydrate levels (NRC, 2001). The differences in accessions for protein might be due to relative contribution of leaves to total biomass and concentration of protein in dry matter.

Carbohydrate and protein fractions: NSC and SC contents differ significantly among sorghum accessions. NSC and SC ranged from 11.26 to 20.85 and 59.73 to 72.78 % DM, respectively in different accessions (Table 2). The mean concentration of SC and NSC among different sorghum accessions was 68.53 and 15.03 % DM, respectively. carbohydrate fractions viz. rapidly degradable sugars (C_A), intermediately degradable starch and pectin (C_{B1}), slowly degradable cell wall (C_{B2}) and unavailable/lignin bound cell wall (C_C) differ significantly amongst the sorghum accessions. Mean concentration of C_{B2} and C_{B1}fraction was highest (52.50) and lowest (0.67 % CHO), respectively. Carbohydrate accumulation in fodder crops is influenced by several factors like species, variety, growth stage and environmental conditions during growth (Buxton and Fales, 1994). Such variability in carbohydrate fractions of dual purpose sorghum hybrids at 50% flowering stage was also observed earlier (Singh *et al*., 2014). Carbohydrate fraction; (C_A+C_{B1}), C_C and C_{B2} reported by Viana *et al.* (2012) for sorghum silage and, nonstructural carbohydrate; C_{B2} and C_C contents (298.0, 122.7 and 122.7 g/kg DM) reported by Gupta *et al*. (2011) for sorghum forage were more or less similar to our results.

Protein fractions NDIP, ADIP, NPN and soluble protein varied significantly (P<0.05) amongst the sorghum accessions with mean 37.7, 16.05, 41.58 and 44.82 %

Table 2. Carbohydrate (% DM) and its fractions (% CHO) in different sorghum accessions

Accessions	CHO	NSC*	SC*	C_C	C_A*	C_{B1}*	C_{B2}*
IC-355466	80.58	20.85	59.73	16.41	29.35	0.48	53.8
IC-355467	83.45	13.32	70.13	21.37	19.84	0.36	58.4
IC-355468	83.01	15.84	67.17	20.12	22.59	0.60	56.7
IC-355469	83.45	12.85	70.60	26.72	20.30	0.40	52.6
IC-355470	83.22	15.02	68.20	23.94	22.52	0.36	53.2
IC-355471	84.27	20.77	63.51	25.57	29.04	0.38	45.0
CSV-15	81.21	14.80	66.41	25.45	23.39	0.72	50.4
SSG59-3	86.32	15.07	71.25	34.53	22.41	0.51	42.5
IC-355472	85.38	19.78	65.60	26.39	27.07	0.62	45.9
IC-355473	84.37	12.45	71.93	27.73	19.06	0.83	52.4
IC-355474	81.46	12.15	69.31	31.11	21.09	0.91	46.9
IC-355475	81.19	15.76	65.43	32.01	25.92	0.91	41.2
IC-355476	84.29	13.90	70.40	20.05	19.56	0.67	59.7
IC-355477	85.69	16.76	68.93	22.46	22.75	0.56	54.2
IC-355478	83.38	10.72	72.66	23.40	16.86	0.66	59.1
IC-355479	80.95	13.21	67.74	17.67	19.67	0.81	61.8
IC-355480	85.62	13.69	71.93	20.24	18.57	0.82	60.4
IC-355481	84.01	14.98	69.01	24.62	22.45	0.65	52.5
IC-355482	85.45	12.67	72.78	31.12	19.15	0.98	48.8
IC-355483	79.75	11.26	68.50	23.23	18.92	1.09	56.8
IC-355484	88.11	19.69	68.42	24.76	24.88	0.80	49.6
Mean	83.56	15.03	68.53	24.71	22.15	0.67	52.5
SEM	0.479	0.676	0.714	1.060	0.774	0.05	1.33

*Differ significantly at $P<0.05$ level

of CP, respectively (Table 3). NDIN and ADIN contents of sorghum hybrid silages were in the range of 53.17 to 71.16 % and 36.58 to 57.96 % harvested at different stages of growth (Teixeira *et al.*, 2014). Sorghum accessions average protein fraction P_{B2} contents were highest (32.32) and of lignin bound protein fractions (P_C) were lowest (1.21%). Protein is one of the limiting nutrients in most cereal fodders and straws in tropics. The data on the protein fractions of sorghum fodder is limited, however the pattern of protein fraction contents is similar to the protein fractions values of forage crops reported earlier (Gupta *et al.*, 2011; Singh *et al.*, 2014; Yu *et al.*, 2003).

Energy value and its energy efficiency: Sorghum accessions mean energy values in terms of total digestible nutrients (TDN), digestible energy (DE) and metabolisable energy (ME) were 49.36%, 2.25 K cal/g and 1.85 Kcal/g, respectively (Table 4). Net energy efficiency values of accessions for lactation (NE_L), maintenance (NE_M) and gain (NE_G) differed significantly ($P<0.05$) with mean 1.09, 1.14 and 0.421 kcal/g, respectively with highest vlues observed for IC-355466 (1.31, 1.23 and 0.59) and lowest for SSG59-3(0.84, 0.85 and 0.129 kcal/g). Variability in TDN contents for sorghum hybrids were reported earlier (Stalling, 2005). The observed values of different sorghum accessions in this study for TDN and ME were within the range of 53.0-55.43% and 1.91-2.01Mcal/kg DM, respectively recorded by Khan *et al.* (2007) and 54.07 to 54.88 % by Singh and Sumeriya (2012) for different sorghum genotypes. Mean DE and ME contents in silage of sorghum hybrids (9.75 and 7.99 Kj/ g DM) recorded by Neumann *et al.* (2002) and Stalling (2005) were also within the range of present values. In sheep, DE values reported for different sorghum hybrid silages varied from 2.15 to 2.44 kcal/g (Teixeira *et al.,* 2014), which was in agreement to observed values in this study. Studies on the net energy efficiency of sorghum hybrids for different animal production functions are limited. Few workers reported net energy values of sorghum hybrids, corn silage and sudan grass silage for different animal functions (Colombo *et al.,* 2007; Singh and Shukla, 2010). Energy values of a feed for different functions vary with the carbohydrate contents and OM digestibility. According to Machado *et al.* (2015) the net energy efficiency for maintenance of silage form sorghum hybrids harvested at different stages of maturity varied from 0.53 to 0.76 in sheep.

Table 3. Nitrogen fraction of sorghum accessions (% CP)

Accessions	NDIP	ADIP	NPN	SP	P_A*	P_{B1}*	P_{B2}*	P_{B3}*	P_C*
IC-355466	36.93	19.40	31.83	33.16	10.55	22.61	47.62	17.53	1.69
IC-355467	40.91	15.75	33.41	48.11	16.07	32.04	25.52	25.16	1.21
IC-355468	44.35	23.97	36.63	39.10	14.32	24.78	38.77	20.38	1.75
IC-355469	48.21	24.51	42.03	41.23	17.33	23.90	33.18	23.70	1.89
IC-355470	40.83	16.17	37.16	36.46	13.55	22.91	37.66	24.67	1.21
IC-355471	40.87	22.12	47.76	43.33	20.69	22.64	36.53	18.75	1.39
IC-355472	45.74	18.37	36.37	47.27	17.19	30.08	24.15	27.37	1.21
IC-355473	28.53	11.14	42.15	48.67	20.51	28.16	33.07	17.39	0.87
IC-355474	34.77	14.83	45.26	55.63	25.18	30.45	23.03	19.95	1.39
IC-355475	31.73	10.04	46.95	49.71	23.34	26.37	27.55	21.69	1.04
IC-355476	28.25	15.91	50.32	36.88	18.56	18.32	49.56	12.34	1.23
IC-355477	43.37	15.53	42.98	49.92	21.46	28.46	21.21	27.84	1.03
IC-355478	30.26	12.73	39.27	52.50	20.62	31.88	28.93	17.53	1.04
IC-355479	35.88	9.761	42.29	57.07	24.13	32.94	15.94	26.12	0.87
IC-355480	39.46	10.00	33.78	39.14	13.22	25.92	30.70	29.46	0.70
IC-355481	37.57	15.98	41.69	45.00	19.01	26.06	31.01	23.21	1.01
IC-355482	39.38	16.57	59.93	44.92	26.92	18.00	31.22	22.82	1.04
IC-355483	33.59	10.94	46.11	52.10	24.02	28.08	24.19	22.66	1.05
IC-355484	39.16	21.56	30.52	30.61	9.342	21.27	50.73	17.60	1.06
CSV-15	30.36	18.60	33.20	43.09	14.31	28.78	43.59	11.76	1.56
SSG59-3	41.48	13.16	53.57	47.57	25.48	22.09	23.25	28.31	0.87
Mean	37.70	16.05	41.58	44.82	18.84	25.98	32.32	21.65	1.21
SEM	1.27	1.01	1.698	1.59	1.133	0.972	2.16	1.49	0.07

*Differ significantly at $P<0.05$ level

Table 4. Energy value of sorghum accessions and its efficiency for animal functions

Accessions	TDN (%)*	DE(kcal/g)*	ME (kcal/g)*	NE_L (kcal/g)*	NE_M (kcal/g)*	NE_G (kcal/g) *
IC-355466	55.09	2.37	1.95	1.23	1.31	0.588
IC-355467	50.46	2.23	1.83	1.12	1.17	0.453
IC-355468	49.35	2.22	1.82	1.09	1.14	0.421
IC-355469	45.10	2.02	1.66	0.99	1.02	0.298
IC-355470	48.71	2.36	1.94	1.07	1.12	0.403
IC-355471	50.39	2.21	1.82	1.11	1.17	0.451
CSV-15	46.15	2.04	1.68	1.01	1.05	0.328
SSG59-3	39.28	1.93	1.59	0.84	0.85	0.129
IC-355472	50.12	2.33	1.91	1.11	1.16	0.443
IC-355473	44.83	2.16	1.77	0.98	1.01	0.290
IC-355474	47.99	2.12	1.74	1.06	1.10	0.382
IC-355475	48.65	2.32	1.90	1.07	1.12	0.401
IC-355476	51.82	2.08	1.71	1.15	1.21	0.493
IC-355477	52.89	2.28	1.87	1.18	1.24	0.524
IC-355478	49.69	2.37	1.95	1.10	1.15	0.431
IC-355479	54.53	2.67	2.19	1.22	1.29	0.571
IC-355480	49.83	2.60	2.13	1.10	1.16	0.435
IC-355481	49.41	2.19	1.90	1.10	1.09	0.430
IC-355482	48.58	2.39	1.96	1.07	1.12	0.399
IC-355483	50.70	2.16	1.77	1.12	1.18	0.460
IC-355484	52.99	2.23	1.83	1.18	1.25	0.527
Mean	49.36	2.25	1.85	1.09	1.14	0.421
SEM	0.791	0.04	0.03	0.02	0.02	0.023

*Differ significantly at $P<0.05$ level

Table 5. Predicted intake, digestibility and feed value of sorghum accessions

Accessions	DMI (%)*	DDM (%)*	IVDMD (%)*	RFV (%)*	Methane (g/kg DDM)*
IC-355466	1.91	59.06	49.41	87.26	99.13
IC-355467	1.64	56.28	45.35	71.43	91.87
IC-355468	1.70	55.62	47.34	73.47	95.00
IC-355469	1.61	53.08	36.14	66.43	92.36
IC-355470	1.68	55.24	45.09	72.09	94.43
IC-355471	1.82	56.24	40.42	79.16	98.31
IC-355472	1.75	56.08	43.03	76.01	96.60
IC-355473	1.62	52.92	40.31	66.37	91.70
IC-355474	1.65	54.81	42.13	70.23	90.05
IC-355475	1.75	55.20	46.91	74.69	92.44
IC-355476	1.65	57.10	40.81	73.18	95.20
IC-355477	1.67	57.74	45.15	74.80	96.02
IC-355478	1.60	55.82	46.06	69.09	92.89
IC-355479	1.69	58.72	52.92	76.99	90.76
IC-355480	1.61	55.91	51.60	69.62	96.34
IC-355481	1.67	55.58	42.38	73.01	94.01
IC-355482	1.59	55.16	43.98	68.16	90.04
IC-355483	1.67	56.43	35.54	73.17	89.53
IC-355484	1.71	57.80	40.69	76.42	97.48
CSV-15	1.74	53.70	40.99	72.43	90.04
SSG59-3	1.62	49.60	34.11	62.34	91.27
Mean	1.68	55.63	43.40	72.67	93.57
SEM	0.02	0.473	1.090	1.160	0.659

*Differ significantly at P<0.05 level

Dry matter intake, dry matter digestibility and methane production: Intake and digestibility are one of the main objectives of most cereal fodder crops breeding programmes for quality improvement in the perspective of livestock production. *In vitro* dry matter digestibility (IVDMD), relative feed value and dry matter intake differed significantly (P<0.05) and mean values were 43.4, 72.67 and 1.68 %, respectively (Table 5). Sahoo *et al.* (2010) reported dry matter intake (DMI) of 1.4% in sheep fed green sorghum fodder which was marginally lower than present values. According to NRC (2001), DMI of sheep ranges from 1.1 to 4.1% of live body weight. The variability in DMI of different accessions might be attributed to the differences in their NDF contents. Mean DMD of sorghum accessions was 55.63% with significant (P<0.05) variation among the accessions. Mean DMD was in agreement to 54.49% DDM reported on sheep fed green sorghum fodder (Sahoo *et al.*, 2010). The mean IVDMD of different accession observed were in agreement to Teixeira *et al.* (2014) who reported DMD of 55.22 to 58.20% in sorghum hybrid silages in sheep. Aruna *et al.* (2015) reported that 55 sorghum genotypes grown over two years had IVDMD values between 45.7 to 55.4% where lower values were in agreement with IVDMD observed, while upper limit was in agreement with esti--mated DMD in the present study. Variability in IVDMD and DDM values of accessions might be attributed to large variation in ADL contents rather cellulose content. Bani *et al.* (2007) reported an inverse relationship between forage fiber contents and DM digestibility. Nitrogen content and cell wall polysaccharides determine the digestibility of a crop (Seven and Cerci, 2006). RFV of sorghum accessions recorded were lower than sorghum hybrids values (90-100) reported by Steven (2007), but values were within the range (69.8-118.9) reported by Singh and Shukla (2010).

Estimated *in vitro* methane production (g/kg DDM) of the sorghum accessions was ranged from 89.53 to 97.48 g/kg DDM with mean 93.57 g/kg DDM. These values were relatively higher than most of the reported values. Gas and methane production from the feeds depends on their degradability and contents of carbohydrates and proteins (Paya *et al.*, 2007; Singh *et al.*, 2012). In vitro methane production on low protein diet (58.0 ml/g DM) at 24 h (Elghandour *et al.,* 2017) and 37.4 g/kg DMI on alfalfa pasture in heifers (Chaves et al., 2006) were closer to our values. Chemical composition and extent of nutrients degradability of a fodder/feed primarily influence the CH_4 production. Influence of nature of carbohydrates (cellul-

-ose, hemicelluloses and soluble residue) and their digestibility on methane production were reported earlier (Takahashi, 2001; Santoso *et al*., 2003). Variability in methane production from 40.6 to 44.2 ml/g OMD and 41.8 to 46.4 ml/g OMD for brown mid rib and normal sorghum genotypes, respectively were also observed (Ouda *et al*., 2005) and confirmed that hybrids differ in methane production potential because of chemical composition and rate of nutrients degradability. Methane production in sheep fed silage prepared from different sorghum hybrids harvested at different stages of maturity ranged from 24.1 to 34.4 g/kg DDM (Machado et al., 2015) and was lower than the present values. The difference might be due to tannin contents in these hybrids.

Conclusion

Results revealed that significant genetic variability exists among sorghum accessions for protein, fiber, dry matter digestibility, protein fractions, carbohydrate fractions, energy and its efficiency and *in vitro* methane production. Sorghum accessions IC-355475, IC-355479 and IC-355-483 were rich in protein, low to medium in fiber, NDIP and SC, high in TDN, DMI, RFV and low in methane production.

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