DIGESTIBILITY OF A ROMANIAN SORGHUM HYBRID USED AS ENSILAGE FOR RUMINANTS

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Abstract

Forage sorghum hybrid F.135 – ST (Sorghum bicolor (Linn.) Moench) is a Romanian hybrid established in 2017. In this study, samples of forage were harvested at four different growing stages (panicle emergence stage (GS_1), milky stage (GS_2), dough stage (GS_3) and hard grain stage (GS_4)), respectively at 6, 12, 15 and 17 weeks-old. The effect of advancing maturity on chemical composition, and in vitro digestibility and degradability was investigated. The dry matter DM and lignin content increased from 237.97 to 403.67 g kg^{-1}, and respectively, from 3.15 to 3.71 g kg^{-1}DM between first and last growth stage. In contrast, the CP content decreased from 52.30 to 45.32 g kg^{-1}DM, and also the crude fiber content decreased from 328.23 to 256.87 g kg^{-1}DM over the same period. The NDF content started at 694.7 g kg^{-1}DM, and decreased to 563.5 g kg^{-1}DM at the last growing stage while ADF increased from 3.15 to 3.71 g kg^{-1}DM. The OM digestibility declined with advancing age of the plant, and also, the CP rumen degradability. At the dough stage, the suitable harvesting time for a good ensiling quality, the OM digestibility was 57.58% and the CP rumen degradability was 68.91%.

Key words: sorghum whole-plant, ensiling, digestibility, protein degradability

INTRODUCTION

Sorghum is on the 5-th position on the top of the most important cereals at world level due to its importance in the animal feeding, in producing bioethanol and green energy, and due to its good impact on environment. It can be considered among the main crops of the future agriculture. It is cultivated all over the continents due to its resistance to drought, production potential, low inputs and production cost. It is an alternative to maize crop being more utilized as substituent in animal diets. Sorghum could be used as fresh forage during summer season for cattle, sheep and goats, and also as silage and hay in the winter season.

Romania is situated in a suitable geographical area for producing sorghum, but the cultivated area with sorghum was very small until 2012. After that the cultivated area with this crop increased year by year. Important experiments were achieved by National Institute for Biology and Animal Nutrition (IBNA) Balotesti, Romania, in order to partially replace maize in ruminant animal diets. The tested recipes included sorghum in various forms such as fresh forage, and silage, but also as hay. The sweet sorghum varieties F-436 Prut and F-465 Doina, created at Fundulea Research Institute (Romania), had a high production potential, had rich sugar content and are suitable for green grass and silage [20]. Also, it was noticed that the two Sorghum hybrids mentioned above have a nutritive and energetic potential, in terms of nutritive units, close to the one of maize, a reason to replace sorghum [19].The experiments based on proportion 68/32 sorghum silage/wheat bran have lead to satisfactory results in sheep fattening [21]. Sorghum silage is similar to maize silage being rich in sugar and minerals. Some authors mentioned that sorghum silage could be used as a supplement for growing steers grazing high quality pastures [1] and other authors tested sorghum grains instead of maize and barley [17; 18].

Recently, Romanian sorghum hybrid F.135 – ST (*Sorghum bicolor* (Linn.) Moench)

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has its renewal in 2017. It is cultivated and frequently used as silage for cows in the experimental farm of the IBNA Institute. This paper reports the results of the study conducted to determine the effect of advancing maturity of this sorghum forage on the quality aspects like chemical composition, the digestibility and the rumen degradability.

MATERIALS AND METHODS

Forage sorghum - cultivation and sampling

The sorghum hybrid F.135 – ST (*Sorghum bicolor* (Linn.) Moench) was grown under uniform recommended agronomic practices during year 2017 spring-summer season at the IBNA Institute, located in the S-E of Romania. To achieve the forage quality, plants were harvested at four different growing stages (GS): panicle emergence stage at 6-weeks old (GS_1), milky stage at 12-weeks old (GS_2), dough stage at 15 weeks-old (GS_3) and hard-grain stage at 17-weeks old (GS_4). The experimental design was a randomized complete block with growing stage as the main plot; five subplot squares 2.5 x 2.5 m, having 4 rows (with inter-row spacing of 80 cm) were selected after sowing seeds at 25 kg/ha and 5 cm deep drilled. Representative grabs of the freshly harvested forage were made per subplot: in the centered two rows five plants were randomly selected. Then, they were chopped in pieces of 2 cm length, mixed thoroughly and 2 composite sub-samples were taken for chemical composition analyses, digestibility testing and degradability study. All the sub-samples were dried in a forced-draft oven to constant weight at 65°C for dry matter content. Dried samples were ground in a mill to pass a 1 mm screen for the subsequent laboratory analyses.

The chemical composition of the samples

It was evaluated by the commonly accepted methods [7] for dry matter (DM), crude protein (CP), crude fibre (CF), ether extractives (EE) and ash. NDF (neutral detergent fibre), ADF (acid detergent fibre) and acid detergent lignin were analyzed according to the Van Soest, 1991 method [15] by adding alfa-amylase without sodium sulfite.

The organic matter (OM) in vitro digestibility (IVOMD)

It was tested by Tilley-Terry, 1963 method [13]. 0.5 g of the feed samples was weighed into 100 ml glass tube and 50 ml of buffered rumen fluid (collected from fistulated wethers) were added and gassed with carbon dioxide. Each tube was closed with rubber plug. All the samples tubes were incubated 48 h at 39°C in a water bath, further centrifuged, the sediment retained, and 50 ml of pepsin solution (2 g per liter in HCl 0.1N solution) were added. Upon the incubation for 48 h at 39°C and centrifugation, the sediment which represents the residue of digestion was collected in crucible, then dried at 103°C and weighed. The crucibles with residues were incinerated at 550°C and also, weighed. Calculations for the digested part of the samples are based on difference between initial (sample) and final (residue) organic matter.

Protein degradation testing

The technique of Aufrere [2] was applied for measuring *in vitro* degradability by using the protease enzyme extracted from *Streptomyces griseus* (type XIV, Sigma P5147) and the feeds samples hydrolysis for 16 h in a borate-phosphate enzyme buffer at pH 8 (20 mg enzyme/ liter). The samples, each of 0.5 g in triplicate, were weighed in centrifuge tubes, followed by the addition of 50 ml of enzyme buffer. The tubes were incubated in a water bath at $39^{O}C$ for 16 h. After incubation, the tubes were placed in ice water for 10 min., then filtered, and the collected filter residue samples were analyzed for nitrogen N content.

The feed enzyme degradability was calculated first as DE = (Nt-Nr)/ Nt, where Nt = total N in the original sample (g/kg DM); Nr = N in the sample dried residue after incubation with enzyme and degraded (g/kg DM). The Aufrere's equation for calculation of protein degradability in vitro, $D_{T(in\ vitro)}$ is from INRA France [8] and it is mentioned for cereals without maize:

$D_{T(in\ vitro)} = 0.364 \times DE + 47.9 + 11$ and where DE is represented as percent.

RESULTS AND DISCUSSIONS

Effect of plant maturity on nutrient concentration

The DM content increased from 237.97 g/kg at GS_1 to 403.67 g/kg at GS_4 as was expected as the forage advanced in age (Table 1). The DM content of forage crops at harvest is one of the most important factors for successful ensilage [12; 5] and according to [6], minimal DM content is 247 g kg-1 for suitable ensilage conditions. The DM yield is influenced by the sorghum cultivar type as previous researchers reported [23; 22]. The present results for sorghum hybrid F.135 – ST suggested that harvesting after dough stage (GS_3) have risk for the success of ensilage.

The CP values obtained for F.135 – ST hybrid were lower than an expected average value of 100-110 g kg^{-1}DM indicated for in whole-crop sorghum silages in Western Europe [16]. The CP content has a slightly increase in GS_2 (55.81 g kg^{-1}DM) comparing cu GS_1 (52.30 g kg^{-1}DM) but then decreased ($p<0.01$) with plant maturity. The value in GS_2, at the milky stage, is lower than 69 g kg^{-1}DM, presented by [8] for whole-crop forage sorghums grown in Western Europe, where the protein content started at a high level of 190 g kg^{-1}DM at bolting and then dropping. This reduction in the CP content is a reflection of the increasing plant height with maturity and because the accumulation of DM occurs at a greater rate than the accumulation of protein [14]. Increased plant height may also reduce CP concentrations because of decreased leaf: stem ratio's associated with increased height [9].

Concentration of ether extractives (EE) and organic matter (OM) exhibited inconsistent change pattern with advancing maturity of the plant.

The crude fiber (CF) content ranged between 328.23 g kg^{-1}DM and 256.87 g kg^{-1}DM depending on growing stage. It was higher at GS_1 as compared with subsequent stages, while in the GS_3 and GS_4 it was similar.

The observed concentration of fibre components NDF and ADF, tended to decrease ($p<0.001$) with the advancement of forage growth. The NDF content started at 694.7 g kg^{-1}DM in GS_1, decreased and remain constant for the next two stages (657.3 g kg^{-1}DM in GS_2 and 653.9 g kg^{-1}DM in GS_3), then decreased to 563.5 g kg^{-1}DM in the final stage GS_4. The ADF content was continously decreasing from 412.8 g kg^{-1}DM in GS_1 to 297.4 g kg^{-1}DM in GS_4. The tendency of both NDF and ADF decreasing is being consistent with whole-crop forage sorghums presented by [8] where NDF was 629 g kg^{-1}DM in GS_1 and 607 g kg^{-1}DM in GS_2, and ADF was 372 g kg^{-1}DM in GS_1 and 354 g kg^{-1}DM in GS_2.

The lignin content tended to increase with advancement in maturity. The values obtained in GS_1 and GS_2 were relatively similar, but significantly lower than that of the GS_3 and GS_4 stages. The average value of GS_2, GS_3 and GS_4 is 34.2 g kg^{-1}DM, similar with 33 g kg^{-1}DM, average value of [8].

Effect of plant maturity on the OM digestibility

As known, the forage consumption by animals is related to the forage quality which decreases with advancing maturity, more precisely the forage digestibility is decreasing with plant maturity [3]. As an example of the variation in the OM digestibility values for fresh whole sorghum grown in Western Europe - this was 71% at bolting stage, decreasing to 61% at heading, and more or less stabilizing after that stage [8]. The obtained OM digestibility (IVOMD, %) values in this study (Table 1) also decreased with advancing maturity: in GS_1 it was 62.63, decrease in GS_2 to 58.62 and stabilize to around 57 in GS_3 and GS_4. The decreasing of the digestibility as aging prolongs was explained by the NDF content which is decreasing and the lignin content which is increasing. Some previous studies observed that higher lignin content was resulted in lower in vitro DM digestibility [12; 5; 23]. This observation was confirmed by our study where the lignin content was negatively correlated with IVOMD values

(r=-0.78). Also, in our study the decreasing of IVOMD along the 4 stages is positively correlated with NDF content (r=0.72) and ADF content (r=0.94) and this is similarly with observation of Van Soest [14] that the correlation between ADF and digestibility is known to be greater than the correlation between NDF and digestibility. Vignau-Loustau, 2008 [16] considers sorghum silage to be more fibrous and less digestible than maize silage, and more specific to be close to that of a medium-quality maize silage.

Table 1 The chemical composition and the OM digestibility of forage sorghum cuttings at different stages of growth (g kg^{-1}DM except where stated)

	Growth stages					
	GS_1	**GS_2**	**GS_3**	**GS_4**	**SEM**	**p**
Dry matter (g kg^{-1})	237.97^a	252.23^b	309.64^c	403.67^d	5.66	***
Organic matter	944.47^a	953.55^b	944.90^a	940.57^a	2.33	**
Crude protein	52.30^a	55.81^a	49.39^a	45.32^b	1.87	**
Ether extract	17.47^a	17.95^a	16.79^b	16.57^b	0.33	**
Crude fiber	328.23^a	322.56^a	255.57^b	256.87^b	2.14	**
Neutral detergent fiber	694.7^a	657.3^b	653.9^b	563.5^c	4.17	***
Acid detergent fiber	412.8^a	361.0^b	341.9^b	297.4^c	3.42	***
Acid detergent lignin	31.5^a	30.2^a	35.2^b	37.1^c	0.30	***
OM digestibility, %	62.63^a	58.62^b	57.58^c	57.41^c	0.46	**

GS_1, GS_2, GS_3 and GS_4 stands for panicle emergence, milky, dough, hard-grain stages, respectively. SEM: standard error of the means ; **p<0.01; *** p<0.001

Effect of plant maturity on the protein degradability

A decline in the protein degradability with advancing plant maturity has been recorded, it started from 72.11 in GS_1 and 73.71 in GS_2, with a slight increase, but ended with 68.91 in GS_3, and 63.49 in GS_4. (Table 2). The decline was also observed by other authors who evaluated effective degradability by *in sacco* method. Lanyasunya, 2007 [11] for *Sorghum almun* at 6, 10 and 14 weeks of plant age obtained for crude protein degradability values like 48.61%, 42.37% and 32.81% at rumen pasage rate of 0.05/h; the reason for variation of degradability was above mentioned, respectively the decreasing of more degradable cell wall components (NDF) and the accumulation of ligno-cellulose fractions as plant growing. Calabro (2007) determined degradability of OM by gas production method and obtained 66.1% for sorghum plant at age for ensilage. Kiliçalp, 2018 [10] obtained the greatest value of effective dry matter degradability (average value of 280 g/kg) for sorghum at milky cutting stage among the other stages (234 g/kg in mid-flowering stage and 264 g/kg in hard dough).

Table 2 The forage sorghum protein degradability by *in vitro* method

	Growth stages					
	GS_1	**GS_2**	**GS_3**	**GS_4**	**SEM**	**p**
DE	0.3629	0.4068	0.2749	0.1262		
in vitro protein degradability $D_{T(in\ vitro)}$, %	72.11^a	73.71^a	68.91^b	63.49^c	5.77	***

DE = *Streptomyces griseus* enzyme degradability = (Nt-Nr)/ Nt, where Nt = total N in the original sample (g/kg DM); Nr = N in the sample residue after degradation (g/kg DM

There were significant differences of degradability among the different cutting stages of maturity from milky stage (GS_2) to hard dough stage (GS_4) (p<0.001). As known the appropriate harvesting time for ensiling sorghum is the medium dough stage when plant moisture is 65-70%, but this is, also, the moment when degradability is already in decline. In conclusion, the optimum time to harvest sorghum for silage making is the GS_3 stage. Even that sorghum in GS_2 stage has a better degradability, the required humidity is

more important for a successful ensiling. For sorghum breeders, the selection of an adequate cultivar of forage sorghum is the result of conciliation of good productivity, digestibility and medium rumen degradability.

CONCLUSIONS

The results of the present study show that F.135 – ST sorghum hybrid represents an acceptable source of feeding for ruminants. Its composition depends first on its stage of maturity. As in most forages, nutritive value declines with growing maturity. For a successful forage sorghum ensiling the dough stage is the appropriate harvesting time when the F.135 – ST sorghum hybrid has a dry matter content of 309.64 g/kg DM, and the OM digestibility is 57.58% and the protein rumen degradability is 68.91%.

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