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NUTRITIVE VALUE OF FRESH, DRIED (HAY) AND ENSILED VINES OF FOUR SWEET POTATO (*Ipomoea batatas*) VARIETIES GROWN IN SOUTHERN ETHIOPIA

[VALOR NUTRITIVO DEL FOLLAJE DE CUATRO VARIEDADES DE CAMOTE (*Ipomoea batatas*) ENSILADO, FRESCO, SECOS (HENO) CULTIVADO EN EL SUR DE ETIOPÍA]

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SUMMARY

Chemical composition and in vitro true dry matter digestibility (IVTDMD) of fresh, dried (hay) and ensiled vines of two early maturing (Belela and Temesgen) and two medium maturing varieties (Beletech and Tulla) were investigated. Hay was made by sun drying for 3 days. Silages were S1: vine alone, S2: vine+2%molasses, S3: vine+4% molasses, S4: vine+10% sweet potato root (SPR, % of wilted vine weight), S5: vine+20%SPR and S6: vine+30%SPR. They were ensiled in plastic buckets (8 liter) with airtight press cape in triplicate for 90 days in a lab at room temperature of 22^0C. Data were analyzed using SPSS version 20. Hay of Belela, Temesgen, Beletech and Tulla had 17.5, 13.9 and 15.2 %CP (%DM); 36.3, 35.6, 40.5 and 38.8% NDF (%DM) and 81.1, 82.2, 75.0 and 76.7% IVTDMD, respectively, were found. There was a decrease in pH of silages ($p<0.05$), with increasing levels of both molasses and SPR, respectively (3.91-3.66 and 3.91-3.64 in Belela; 3.92-3.72 and 3.92-3.68 in Temesgen; 3.99-3.81 and 3.99-3.75 in Beletech; 4.02-3.92 and 4.02-3.74 in Tulla); CP (19.8-15.8 and 9.8-13.9 in Belela; 20.0-14.2 and 20.0-12.3 in Temesgen; 17.2-11.2 and 17.2-10.9 in Beletech; 17.9-14.3 and17.9-11.6 inTulla); NDF (29.9-27.7 and 29.9-22.9 in Belela; 26.4-25.0 and 26.4.0-20.8 in Temesgen;36.1-29.3 and 36.1-25.4 in Beletech; 34.5-29.0 and 34.5-24.4 in Tulla); ADF (26.7-18.2 and 26.7-15.5 in Belela; 25.5-17.1 and 25.5-14.7 in Temesgen;30.0-20.2 and 30.0-16.0 in Beletech;29.3-19.1 and 29.3-16.2 in Tulla); and ADL (7.1-4.6 and 7.1-3.5 in Belela; 6.9-4.1 and 6.9-2.7 in Temesgen;9.1- 5.1 and 9.1-4.9 in Beletech; 7.9-5.0 and 7.9-4.1 in Tulla) but increased IVTDMD (82.5-85.7 and 82.5-87.4, in Belela; 82.1-86.1 and 82.1-88.2 in Temesgen; 79.1-84.1 and 79.1-86.1 in Beletech; 78.9-84.0 and 78.9-85.6 in Tulla). Silages at all additive levels had acceptable pH and good IVTDMD, but 4% molasses, 20 and 30% SPR gave higher IVTDMD. Hay had lower nutrient content and IVTDMD than fresh vine and silages. In conclusion, Belela and Temesgen had better nutritive value than Beletech and Tulla; silage making was better than hay making. Animal evaluation is recommended for further confirmation of the results.

Key words: Chemical composition; In vitro true dry matter digestibility; Sweet potato varieties.

RESUMEN

La composición química y digestibilidad verdadera *in vitro* de la materia seca (IVTDMD) en fresco, seco (heno) y ensilados de dos variedades de camotes de maduración temprana (Belela y Temesgen) y dos variedades de maduración media (Beletech y Tulla) fueron investigados. El heno fue hecho por secado al sol durante 3 días. Ensilajes fueron S1: follaje sólo, S2: follaje + 2% de melaza, S3: follaje + 4% de melaza, S4: follaje + 10% batata (% del peso del follaje marchito), S5: follaje + 20% batata y S6: follaje + 30% batata. Se realizó el ensilados en baldes de plástico (8 litros) con tapa hermética de prensa por triplicado durante 90 días en un laboratorio a temperatura ambiente de 22 °C. Los datos fueron analizados con el programa SPSS versión 20. El heno de Belela, Temesgen, Beletech y Tulla tenía 17.5, 13.9 y 15.2% de PC (% MS); 36.3, 35.6, 40.5 y 38.8% de FDN (% MS) y de 81.1, 82.2, 75.0 y 76.7% IVTDMD, respectivamente. Hubo una disminución en el pH de los ensilajes ($p <0.05$), con niveles crecientes de melaza y batata, respectivamente (3.91 a 3.66 y de 3.91 a 3.64 en

Belela; 3.92 a 3.72 y de 3.92 a 3.68 en Temesgen; 3.99 a 3.81 y 3.99 -3.75 en Beletech; 4.02 a 3.92 y de 4.02 a 3.74 en Tulla); CP (19.8 a 15.8 y 9.8 a 13.9 en Belela; 20.0-14.2 y 20.0-12.3 en Temesgen; 17.2-11.2 y 17.2-10.9 en Beletech; 17.9-14.3 and17.9-11.6 enTulla); NDF (29.9-27.7 y 29.9-22.9 en Belela; 26.4-25.0 y 26.4.0-20.8 en Temesgen; 36.1-29.3 y 36.1-25.4 en Beletech; 34.5-29.0 y 34.5-24.4 en Tulla); ADF (26.7-18.2 y 26.7-15.5 en Belela; 25.5-17.1 y 25.5-14.7 en Temesgen; 30.0-20.2 y 30.0-16.0 en Beletech; 29.3-19.1 y 29.3-16.2 en Tulla); y ADL (07.01 a 04.06 y de 07.01 a 03.05 en Belela; 06.09 a 04.01 y de 06.09 a 02.07 en Temesgen; 9.1- 5.1 y 9.1 a 4.9 en Beletech; 7.9-5.0 y 07.09 a 04.01 en Tulla) pero aumentó IVTDMD (82.5-85.7 y 82,5 a 87.4, en Belela; 82.1-86,1 y 82.1-88.2 en Temesgen; 79.1-84.1 y 79.1-86.1 en Beletech; 78.9-84.0 y 78.9-85.6 en Tulla). Los ensilados en todos los niveles de aditivos tenían pH aceptable y buena IVTDMD, pero 4% de melaza, 20 y 30% de batata resultaron en mayor IVTDMD. El heno tenía menor contenido de nutrientes y IVTDMD tanto en el follaje fresco como el ensilaje. En conclusión, Belela y Temesgen tuvieron mejor valor nutritivo que Beletech y Tulla; y el ensilaje es mejor que el heno. Se recomienda la evaluación con animales para confirmar el valor nutritivo.

Palabras clave: Composición química; In vitro verdadera digestibilidad de la materia seca; Variedades de camote.

INTRODUCTION

Ethiopia's livestock population is believed to be the largest in Africa. This sector has a significant contribution to the country's economy and is still expected to support its economic development (CSA, 2012). However, the contribution of the sector at either macro or micro level is below its potential (Solomon *et al*., 2010) and the performance of animals is poor because of different factors of which feed shortage is a major one. Feed shortage is more aggravated during dry season in both highlands and lowlands of Ethiopia (Alemayehu, 2006).

Sweet potato (*Ipomoea batatas*) is a dry land crop, tolerant to diverse edaphic and climatic conditions and is typically a smallholders' crop grown on marginal soils with limited inputs (Lebot, 2009). The root and vine can be fed to ruminant and monogatric animals (Woolfe, 1992). Sweet potato root is rich in carbohydrates (Lebot, 2009), but low in protein and fats (Truog *et al*., 2011), while its vine serves as a source of protein and vitamins; having over 20% crude protein, about 70% digestibility and 4-6 tons per ha of DM yield (Adugna, 2008).

In many parts of Ethiopia, sweet potato is primarily cultivated for its root production while its by-products are commonly fed to ruminants or left on the field at harvest (Tsega and Tamir, 2009). Sweet potato vines and damaged roots, unfit for human consumption, can serve as valuable livestock feeds (Adugna, 2008). However, the availability of the vines is for a very short period (Netsanet, 2006), usually concentrated during root harvesting times. Sweet potato vines could deteriorate within 2 or 3 days of harvest (Heuzé *et al*., 2011) and the leaves can be more rapidly and easily shattered. Hence, conservation of this biomass (vines) during period of surplus production as hay and/or silage could be a possible solution to overcome this problem (Ruiz *et al*., 1981; Heuzé *et al*., 2011).

Sweet potato vines can be preserved by ensiling (Ruiz *et al*., 1981; Hoang, 2001; An *et al*., 2004; Kaya and Caliskan, 2010; Ly *et al*., 2010). Although, sweet potato vines are rich in protein, they are low in easily fermentable carbohydrates, and hence a source of readily fermentable carbohydrate should be added for good quality silage making (Ruiz *et al*., 1981; Stathers *et al.*, 2005). Different additives including combination of urea and sweet potato roots (Ruiz *et al*., 1981), rice bran together with common salt (Ly *et al*., 2010), molasses and ground wheat (Kaya and Caliskan, 2010), cassava root meal, sweet potato root meal and sugar cane molasses (An *et al*., 2004) have been tested and showed different results. It is also reported that, sweet potato vines ensiled with no additive were shown to exhibit excellent characteristics (Ruiz *et al*., 1981). However, there is no sufficient information with regard to different types and levels of additives for effective preservation of sweet potato vines as silage. Therefore, undertaking further research is required to increase the current information on the effect of additives during ensiling of sweet potato vines.

In Ethiopia, there are a number of sweet potato varieties cultivated on both research stations and farmer's field (EARO, 2009). However, information regarding the nutritive value of these varieties as animal feeds and most importantly their conservation potentials is scanty. This study, therefore, was intended to evaluate the nutritive potential of fresh, dried (hay) and ensiled vines of four sweet potato cultivars as animal feed in southern Ethiopia.

MATERIALS AND METHODS

Experimental site

The study was conducted at Hawassa University College of Agriculture, in Hawassa city, which is situated 275 km southwest of Addis Ababa. Hawassa city is located in the rift valley of Ethiopia at 7^0 5′ N latitude and 38^0 29′ E longitude and at an elevation of 1700 m above sea level. Rainfall is bi-modal and in the average annual ranges from 700 and 1200 mm. The mean minimum and maximum temperatures in the study site are 13.5 ^{0}C and 27.6 ^{0}C, respectively (NMA, 2012).

Experimental sample preparations

Cuttings of two early maturing (*Belela* and *Temesgen*) and two medium maturing (*Beletech* and *Tulla*) sweet potato varieties were obtained from Southern Agricultural Research Institute, Ethiopia and cultivated on plots (5.1m x 4.8m) in Hawassa University farm and research center in three replicates. Belela, Temesgen and Beletech were selected because they are the most promising cultivars and widely cultivated by farmers. Tula was selected because it is a newly introduced and being widely distributed to farmers, in various parts of Ethiopia including Hawassa, as a candidate to alleviate vitamin-A deficiency in man (personal communication).

About 30 cm vine cuttings with at least 4 nodes of each variety were planted on plots (5.1 m x 4.8 m) in triplicate at the end of June, 2011. Spacing between rows was 60 cm and between plants 30 cm; 7 rows plot^{-1} allowing 109 plants plot^{-1} (i.e. a density of 55,555 plants ha^{-1}). Earthing and hand weeding was carried at 30 and 60 days after planting.

Five rows from each plot (each 5.1 m x 4.8 m), thus a total of 15 rows (3 plots x 5 rows) for each varieties were harvested at 120 days (for the early maturing varieties) and 150 days (for the medium maturing varieties) after planting to prepare vines samples. After thorough mixing of the total vine harvested from individual plots, the total mix was divided into three equal parts; one part was analyzed as fresh (the chemical composition and *in vitro* dry mater digestibility fresh vine was previously reported by Zereu *et al*., 2014; Table 1), the second and third parts were used for hay and silage preparations.

Vine samples for hay preparation were spread in a plastic mat and sun-dried for 3 days by turning at an interval of about 3 h to facilitate the drying process. Partial dry matter contents were then calculated. The dried samples were ground to pass through 1mm sieve size, put in plastic bags and stored until analyses.

Silages were prepared by chopping the fresh vines to about 2-3 cm and allowed to wilt for 24 hrs. The sweet potato roots used were washed with water to remove sands and cut into small pieces of about 1 cm manually using knife. The wilted vines were ensiled in triplicates of 8 liter capacity cylindrical bucket with airtight press cape, alone (3 kg) or in combination with 2% and 4% molasses and 10, 20 and 30% sweet potato roots (% wilted vine).

The silage samples were packed with a wooden stick. The cape of the cylindrical bucket was closed, further tightened with double plastics bags and stored in a room. After 90 days of ensiling the silage samples of each treatment were completely removed, mixed thoroughly and triplicate sub-samples were taken for immediate pH and DM determinations and the rest were stored at -21^{0}C in a deep freezer until analysis.

After drying the samples hay (at 60^{0}C for 48 hrs) and silage (at 40^{0}C for 24 hrs) they were ground using Thomas Willy mill (model 4) to pass through 1 mm sieve size and were used for chemical analysis and *in vitro* DM digestibility determination.

Table 1: Chemical composition and *in vitro* true dry matter digestibility of vines of four sweet potato varieties.

	Variety					
Parameter	Belela	Temesgen	Beletech	Tulla	S.E.	P
Dry matter (%)	13.9^b	13.2^b	16.3^a	15.9^a	0.21	< 0.001
Ash (% DM)	14.8^a	15.0^a	13.7^b	11.6^c	0.23	< 0.001
Crude protein (% DM)	18.7^a	18.1^b	15.5^d	17.3^c	0.20	< 0.001
Neutral detergent fiber (% DM)	32.7^c	31.4^d	38.3^a	36.9^b	0.31	< 0.001
Acid detergent fiber (% DM)	24.6^b	23.2^c	27.7^a	27.2^a	0.32	< 0.001
Acid detergent lignin (% DM)	6.8^{bc}	6.3^c	9.0^a	7.1^b	0.17	< 0.001
IVTDMD (%)	86.2^a	86.3^a	83.1^b	83.5^b	0.33	< 0.001

After Zereu *et al*. (2014). Means in a row with different superscript letters (a-d) differ significantly ($p < 0.05$); S.E.: Standard error; IVTDMD: *in vitro* true DM digestibility.

In vitro true dry matter digestibility

In vitro true dry matter digestibility (IVTDMD) of hay and silage samples, three replicates for each sample, was determined by ANKOM Technology-DAISY^{II} Incubator. About 0.25 g dried samples ground to pass via 1 mm sieve size were weighed in to ANKOM Filter bag (Ankom® Technology, # F57) and then incubated in the ANKOM jars containing rumen fluid and medium mixture (solution A and B) for 48 hours. The rumen fluid was collected from two fistulated sheep fed twice a day with a diet of grass hay, concentrate and necessary minerals based on their daily requirements. Water was provided *ad-libitum.* After incubating for 48 hrs, the filter bags were washed with tap water until it was clear, soaked with acetone and then further extracted with neutral detergent solution in the ANKOM^{200} fibre analyzer.

Chemical analysis

Chemical analyses were performed on dried and ground hay and ensiled sweet potato vines in three replicates for each sample. DM content of dried (hay) vine samples was determined by drying in an air-forced oven at 105^{0}C for 12 hrs (AOAC, 1990). Silage samples which were stored in a deep freeze were allowed to thaw overnight and DM content was determined by drying in forced-draft oven at 40^{0}C for 24 hrs (Larsen and Jones, 1973) and ground. The total Nitrogen (N) content of all samples was determined by the Kjeldahl method (AOAC, 1990) and then crude protein (CP) content was calculated as N x 6.25. The ash content of the samples was determined by complete burning in a muffle furnace at 600^{0}C for 3 hours (AOAC, 1990). The neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to procedures of Van Soest *et al*. (1991) by using filter-bag (Ankom® Technology, # F57) technique of ANKOM technology (ANKOM A200, ANKOM Technology, Macedon, New York 14502, USA).

Statistical analysis

Data on chemical composition and *in vitro* true DM digestibility were analyzed for ANOVA using the General Linear Model (GLM) procedure of SPSS version 20. Duncan's new multiple range test was used to separate means at 5% level of significance. The following statistical models were used to analyze the data. Model-1chemical composition and IVTDMD of hay: $Y_{ij} = \mu + A_i + e_{ij}$; where Y_{ij} = response variable; µ = overall mean; A_i = effect of variety; e_{ij} = random error; Model-2 used for chemical composition, pH and IVTDMD of silage samples: $Y_{ijk} = \mu + A_i + B_j + AB_{ij} + e_{ijk}$; where Y_{ijk} = response variable; µ = overall mean; A_i = effect of variety; B_j = effect of additive level; AB_{ij} =interaction effect; e_{ijk}= random error.

RESULTS

Chemical composition and in vitro true dry matter digestibility

Sweet potato vine hay

Table 2 shows the chemical composition and IVTDMD of vine hay of the four sweet potato varieties. Belela and Temesgen had similar ash, NDF, ADL and IVTDMD. Beletech and Tulla had higher NDF and ADF contents than Belela and Temesgen ($p<0.05$). Beletech had highest NDF and ADF contents, but lower CP and IVTDMD than the other varieties ($p<0.05$). Belela and Temesgen had higher ash and IVTDMD and lower NDF, ADF and ADL contents than Beletech and Tulla.

Table 2: Chemical composition and *in vitro* true dry matter digestibility of vine hay of four sweet potato varieties

	Variety					
Parameter	Belela	Temesgen	Beletech	Tulla	S.E.	P
Dry matter (%)	88.6^c	90.7^a	90.9^a	89.7^b	0.4	0.002
Ash (% DM)	16.2^a	16.9^a	14.6^b	12.9^c	0.31	< 0.001
Crude protein (% DM)	17.5^a	15.8^b	13.9^c	15.2^b	0.24	< 0.001
Neutral detergent fiber (% DM)	36.3^c	35.6^c	40.5^a	38.8^b	0.5	< 0.001
Acid detergent fiber (% DM)	26.8^c	24.5^d	30.5^a	28.6^b	0.33	< 0.001
Acid detergent lignin (% DM)	7.6^b	8.4^b	10.2^a	9.6^a	0.25	< 0.001
IVTDMD (%)	81.1^a	82.2^a	75.0^c	76.7^b	0.36	< 0.001

Means within a row with different superscript letters (a-d) differ significantly ($P <0.05$); S.E.: standard error; IVTDMD: *in vitro* true DM digestibility

Sweet potato vine silages

The effects of variety and additives on pH, chemical composition and IVTDMD of sweet potato vine silages are shown in Table 3. Addition of molasses and sweet potato root lowered silage pH, CP, NDF, ADF, and ADL contents, but increased DM and IVTDMD, with increasing level of additives, in all varieties in similar manner. However, increasing level of molasses increased ash content while the reverse was observed with increasing level of sweet potato root.

Lower pH values were found in S3 and S6 in all varieties. Belela and Temesgen had lower ($p<0.05$) pH value than Beletech and Tulla, in all treatments, except S3. Increased level of molasses and sweet potato root increased silage DM content in all varieties, the highest being in S3 and S6. The varieties exhibited differences similar to their pre-ensiled characters; Bellela and Temesgen had similar DM ($p>0.05$) but lower than that of Beletech and Tulla in all treatments (Table 3).

Decreasing tendency of CP content was observed in all varieties with increasing levels of molasses and sweet potato root. When silages without additive (S1) were compared Belela and Temesgen had higher ($p<0.05$) CP content than Beletech and Tulla. The highest CP content was found in Belela and lowest in Beletech in all treatments ($p<0.05$).

With the exception of molasses addition at 2% on NDF content of Belela and Temesgen, additives decreased NDF, ADF and ADL in all varieties. Temesgen had the lowest ($p<0.05$) NDF and ADF contents followed by Belela in all treatments. Beletech and Tulla had similar ($p>0.05$), but higher than Belela and Temesgen, contents of NDF in S3 and S6; ADF in S1, S4 and S5 and ADL in S3 and S4 treatments.

Increased level of additives increased ($p<0.05$) IVTDMD in all varieties. Silages of Belela and Temesgen had similar ($p>0.05$) IVTDMD but were higher than those of other varieties. Beletech and Tulla, were also similar ($p>0.05$) in IVTDMD across all treatments.

Effect of hay and silage making on chemical composition and in vitro true dry matter digestibility of sweet potato vines

The overall effect of hay and silage making, relative to vine, regardless of variety is given in Table 4. Hay making increased NDF and ADL contents, but decreased IVTDMD compared to fresh vine and the different silages ($p<0.05$). Hay making also decreased CP content relative to fresh and ensiled vines without additive (S1) but had higher CP content than all silages with additives ($p<0.05$). S1 increased CP content while higher levels of molasses and sweet potato root addition decreased CP ($p<0.05$). Ash contents of hay, S1 and molasses treated silages (S2 and S3) were similar ($p>0.05$), but higher ($p<0.05$) than fresh vine and sweet potato root supplemented silages. With increased level of sweet potato root addition ash content increased ($p<0.05$).

Hay making and S1 had similar ($p>0.05$) but higher ($p<0.05$) ADF than silages with additives. Additives decreased ($p<0.05$) NDF, ADF and ADL contents. IVTDMD was decreased in the order of hay< S1< S2 = S4 < S3 = S5 = fresh vine < S6 ($p<0.05$).

DISCUSSION

Chemical composition and in vitro true dry matter digestibility

Sweet potato vine hay

The chemical composition and IVTDMD of vine hays of the four sweet potato varieties (Table 2) followed similar trends to the analyzed parameters of their fresh vines (Table 1). Sun drying of sweet potato vine increased DM content to 92 to 93% within 2-3 days (Ly *et al.*, 2010). Giang *et al*. (2004) reported a reduction of an initial moisture content of 85.1% to 10% of sweet potato vine via sun drying. In the current study comparable results of moisture reduction by sun-drying were obtained.

Compared to their fresh forms (Table 1) NDF, ADF and ADL contents were increased, but CP content and IVTDMD were decreased in dried (hay) vines (Table 2). The effect of sun drying on chemical composition and IVTDMD is discussed below.

In general, the CP content of hay of all varieties was higher than the minimum levels that are considered to affect intake in mature sheep and cattle and dairy cows (Forbes, 2007). The NDF and ADF contents were also above the recommended minimum levels required for healthy rumen (Target 10, 2002).

Table 3: Effect of molasses and sweet potato roots on pH, chemical composition (%DM) and IVTDMD (%)of vine silages of four sweet potato varieties.

Parameter	Variety	Additive type and level						S.E.	P
		S1	S2	S3	S4	S5	S6		
pH	Belela	$3.91^{a,2}$	$3.71^{bc,3}$	$3.66^{de,3}$	$3.76^{b,3}$	$3.70^{cd,3}$	$3.64^{e,3}$	0.01	<0.001
	Temesgen	$3.92^{a,2}$	$3.81^{c,2}$	$3.72^{d,2}$	$3.86^{b,2}$	$3.73^{d,2}$	$3.68^{e,2}$	0.01	<0.001
	Beletech	$3.99^{a,1}$	$3.87^{c,1}$	$3.81^{d,1}$	$3.89^{b,1,2}$	$3.85^{c,1}$	$3.75^{e,1}$	0.01	<0.001
	Tulla	$4.02^{a,1}$	$3.89^{c,1}$	$3.85^{d,1}$	$3.92^{b,1}$	$3.87^{dc,1}$	$3.74^{e,1}$	0.01	<0.001
DM (%)	Belela	$16.7^{d,3}$	$19.5^{b,2}$	$21.4^{a,2}$	$17.9^{c,3}$	$19.3^{b,2}$	$20.9^{a,3}$	0.21	<0.001
	Temesgen	$16.3^{e,3}$	$19.3^{c,2}$	$21.3^{a,2}$	$17.6^{d,3}$	$18.9^{c,2}$	$20.8^{b,3}$	0.21	<0.001
	Beletech	$19.7^{c,1}$	$20.8^{b,1}$	$23.1^{a,1}$	$20.9^{b,1}$	$21.3^{b,1}$	$22.9^{a,1}$	0.21	<0.001
	Tulla	$18.3^{e,2}$	$21.0^{c,1}$	$22.7^{a,1}$	$19.7^{d,2}$	$20.8^{c,2}$	$22.0^{b,2}$	0.21	<0.001
Ash	Belela	$16.5^{a,1}$	$16.3^{a,1}$	$17.0^{a,1}$	$14.8^{b,1}$	$12.8^{c,1}$	$12.1^{c,1}$	0.27	<0.001
	Temesgen	$16.1^{a,1}$	$15.2^{b,2}$	$16.2^{a,1}$	$12.6^{c,2}$	$10.1^{d,3}$	$9.1^{e,3}$	0.27	<0.001
	Beletech	$14.5^{b,2}$	$15.4^{a,2}$	$15.4^{a,2}$	$13.3^{c,3}$	$11.8^{d,2}$	$9.9^{e,2}$	0.27	<0.001
	Tulla	$12.9^{a,3}$	$12.6^{ab,3}$	$12.7^{a,3}$	$11.8^{b,4}$	$10.8^{b,3}$	$10.1^{c,2}$	0.27	<0.001
CP	Belela	$19.8^{a,1}$	$16.2^{b,1}$	$15.8^{bc,1}$	$16.2^{b,1}$	$15.2^{c,1}$	$13.9^{d,1}$	0.31	<0.001
	Temesgen	$20.0^{a,1}$	$15.9^{b,1}$	$14.2^{c,2}$	$14.0^{cd,2}$	$13.1^{de,2}$	$12.3^{e,2}$	0.31	<0.001
	Beletech	$17.2^{a,2}$	$12.0^{bc,3}$	$11.2^{d,3}$	$12.7^{b,3}$	$11.7^{cd,3}$	$10.9^{d,3}$	0.31	<0.001
	Tulla	$17.9^{a,2}$	$14.5^{b,2}$	$14.3^{b,2}$	$14.0^{b,2}$	$12.4^{c,2,3}$	$11.6^{c,3}$	0.31	<0.001
NDF	Belela	$29.9^{a,3}$	$29.0^{a,3}$	$27.7^{b,2}$	$25.3^{c,3}$	$24.1^{d,3}$	$22.9^{e,2}$	0.36	<0.001
	Temesgen	$26.4^{a,4}$	$26.1^{ab,4}$	$25.0^{bc,3}$	$24.7^{c,3}$	$22.4^{d,4}$	$20.8^{e,3}$	0.36	<0.001
	Beletech	$36.1^{a,1}$	$32.1^{b,2}$	$29.3^{c,1}$	$29.4^{c,1}$	$27.4^{d,1}$	$25.4^{e,1}$	0.36	<0.001
ADF	Belela	$26.7^{a,2}$	$19.1^{b,2}$	$18.2^{b,3}$	$18.8^{b,2}$	$18.5^{b,1}$	$15.3^{c,2,3}$	0.30	<0.001
	Temesgen	$25.5^{a,3}$	$17.5^{b,3}$	$17.1^{b,4}$	$17.3^{b,3}$	$16.0^{c,2}$	$14.7^{d,3}$	0.30	<0.001
	Beletech	$30.0^{a,1}$	$22.6^{b,1}$	$20.2^{c,1}$	$20.8^{c,1}$	$19.2^{d,1}$	$16.0^{e,1,2}$	0.30	<0.001
	Tulla	$29.3^{a,1}$	$19.6^{b,2}$	$19.1^{c,2}$	$20.0^{b,1}$	$19.3^{b,1}$	$16.2^{c,1}$	0.30	<0.001
ADL	Belela	$7.1^{a,3}$	$5.0^{b,2}$	$4.6^{b,1,2}$	$4.8^{b,2}$	$3.9^{d,2}$	$3.5^{d,3}$	0.21	0.037
	Temesgen	$6.9^{a,3}$	$4.3^{b,3}$	$4.1^{bc,2}$	$4.6^{b,2}$	$3.6^{c,2}$	$2.7^{d,4}$	0.21	0.037
	Beletech	$9.1^{a,1}$	$6.0^{b,1}$	$5.1^{c,1}$	$5.8^{b,1}$	$5.1^{c,1}$	$4.9^{c,1}$	0.21	0.037
	Tulla	$7.9^{a,2}$	$5.5^{b,1,2}$	$5.0^{b,1}$	$5.2^{b,1,2}$	$5.0^{b,1}$	$4.1^{c,2}$	0.21	0.037
IVTDMD	Belela	$82.5^{d,1}$	$84.0^{c,1,2}$	$85.7^{b,1}$	$84.9^{b,1}$	$85.5^{b,1,2}$	$87.4^{a,1}$	0.33	0.001
	Temesgen	$82.1^{d,1}$	$85.9^{b,1}$	$86.1^{b,1}$	$84.1^{c,1}$	$86.2^{b,1}$	$88.2^{a,1}$	0.33	0.001
	Beletech	$79.1^{e,2}$	$82.8^{cd,2,3}$	$84.1^{bc,2}$	$81.7^{d,2}$	$84.3^{b,2,3}$	$86.1^{a,2}$	0.33	0.001
	Tulla	$78.9^{e,2}$	$83.1^{d,2}$	$84.0^{b,2}$	$82.4^{c,2}$	$84.0^{b,2}$	$85.6^{a,2}$	0.33	0.001

Means with different superscript letters (a-e) within a row for a given parameter and variety differed significantly ($p<0.05$); Means with different numerical- superscripts (1-4) within a column for a given parameter differed significantly ($p<0.05$); DM: dry matter; CP: crude protein; NDF: neutral detergent fiber; ADF: neutral detergent fiber; ADL: acid detergent fiber; IVTDMD: in vitro true DM digestibility; S.E.: standard error; S1: vine, S2: vine+2% molasses, S3: vine+4% molasses, S4: vine+ 10% sweet potato root (SPR) of wilted vine weight, S5: vine+20% SPR and S6: vine+30% SPR.

Sweet potato vine silages

Nutrient losses and intake of silage by livestock are affected by the type of fermentation that occurs during ensiling (Kaizer and Piltz, 2004), which could be evaluated by silage fermentation quality parameters such as pH (Kaya and Calsikan, 2010). Anaerobic fermentation of water soluble carbohydrates of ensiled forage crops by lactic acid bacteria in to lactic acid, lowers the pH of silages in to a level that inhibits the activities of plant enzyme, clostridia and entrobacteria (McDonald *et al*, 2002; Saarisalo *et al*., 2007). However, the achievement of desired pH is affected by contents of DM and soluble carbohydrates, species/variety of the forage crop and type of fermentation (Kaizer and Piltz, 2004).

Table 4: Effect of preservation method (hay and silage making) on composition (%DM) and IVTDMD (%) of sweet potato vines (mean of the four varieties).

Parameter	Preservation method								S.E.	P
			Vine silages							
	Fresh vine	Vine hay	S1	S2	S3	S4	S5	S6		
pH	-	-	3.96^{a}	3.82^{c}	3.76^{e}	3.86^{b}	3.79^{d}	3.70^{f}	0.01	<0.001
DM (%)	-	-	17.8^{e}	20.2^{c}	22.1^{a}	19.0^{d}	20.1^{c}	21.1^{b}	0.10	<0.001
Ash	13.7^{b}	15.2^{a}	15.0^{a}	14.9^{a}	15.3^{a}	13.1^{b}	11.4^{c}	10.3^{d}	0.31	<0.001
CP	17.4^{b}	15.6^{c}	18.7^{a}	14.7^{d}	13.9d^{e}	14.2^{d}	13.1^{e}	12.2^{f}	0.31	<0.001
NDF	34.5^{b}	37.8^{a}	31.7^{c}	29.6^{d}	27.7^{e}	26.8^{e}	24.9^{f}	23.3^{g}	0.52	<0.001
ADF	25.3^{b}	27.6^{a}	27.9^{a}	19.7^{c}	18.6^{cd}	19.2^{cd}	18.3^{cd}	15.5^{e}	0.37	<0.001
ADL	7.2^{c}	8.9^{b}	7.7^{b}	5.2^{c}	4.7^{cd}	5.1^{c}	4.4^{d}	3.8^{e}	0.19	<0.001
IVTDMD	84.8^{b}	78.7^{e}	80.6^{d}	83.9b^{c}	85.0^{b}	83.3^{c}	85.0^{b}	86.8^{a}	0.36	<0.001

Means in the same row with different superscript letters (a-g) differed significantly ($p<0.05$); DM: dry matter; CP: crude protein; NDF: neutral detergent fiber; ADF: neutral detergent fiber; ADL: acid detergent fiber; IVTDMD: in vitro true DM digestibility; S.E.: standard error; S1: vine, S2: vine+2% molasses, S3: vine+4% molasses, S4: vine+ 10% sweet potato root (SPR) of wilted vine weight, S5: vine+20% SPR and S6: vine+30% SPR.

Additive level and variety affected pH of all silage treatments in the current study (Table 4). In all varieties the silage without additive had higher pH than those with additives. However, pH of all silages was within range 3.5-4.2 that is considered optimal to preserve low DM silages (Kaizer and Piltz, 2004). Sweet potato vines could be preserved well without additive with pH value of less than 4 (Ruiz *et al*., 1981; Kaya and Calsikan, 2010) and this supports the current results.

The decreased pH with increasing level of molasses and sweet potato root could be due to their supply of water soluble carbohydrate sources that would be utilized by microbes. Low pH is usually achieved by fermentation of sugars by lactic acid bacteria to lactic acid, which promotes inhibition of the activities of undesirable microbes like clostridia and entrobacteria (McDonald *et al*., 2002). Decreased pH and improvement of fermentation due to molasses addition in ensiled materials has been vastly reported. The carbohydrate content of sweet potato roots ranged from 80-90% on DM basis (Dominguez, 1992; Lebot, 2009) and this could be therefore a good source of fermentable sugars when added to sweet potato vine silages.

Increasing molasses and sweet potato root levels increased silage DM content in all varieties, due to higher DM contents of both additives than sweet potato vines which agrees with earlier reports (Kaya and Calsikan, 2010; Giang *et al*., 2004). However, the DM contents of all silage samples in the present study were lower than the recommended 30% DM optimum for good silage production (Titterton and Bareeba, 1999).

Addition of molasses had no effect on ash content in all varieties except in Temesgen where 2 % molasses decreased ash content. Similar results were reported by Kaya and Calsikan (2010) for sweet potato vine silage.

The decreased CP, NDF and ADF contents with increasing levels of molasses and sweet potato root, in the current study, could have resulted from the low contents of these nutrients in the additives. This result agreed with Kaya and Calsikan (2010) who reported similar trends with increased level of molasses in sweet potato vine silages. Giang *et al*. (2004) also reported decreased CP and NDF contents in mixture sweet potato vine and root silages with increasing level of sweet potato roots. Furthermore, Baytok *et al*. (2005) reported, decreased NDF and ADF contents with increasing level of molasses in corn silage, because of low NDF and ADF contents of molasses and increased fermentation resulted from the high sugar content of molasses.

IVTDMD of all varieties were increased with increased level of additives, highest IVTDMD were found at the higher levels of additives and this may be attributed to improved fermentation and low cell wall contents of the additives.

Effect of hay and silage making on chemical composition and in vitro true dry matter digestibility of sweet potato vines

Hay and silage making affected chemical composition and IVTDMD of sweet potato vines compared to vine (Table 4). The higher DM content of the silages than fresh could be due to wilting of the materials prior to ensiling and higher DM content of the additives treated silages. Hay making and addition of molasses and sweet potato root decreased CP content, while silage without additive (S1) increased CP content compared to vine. The increased CP content in S1 could be due to microbial protein synthesis (Rahman and Aneela, 2004). The reduction of water soluble carbohydrates during fermentation can also promote a proportional increment in CP content at the expense of reduction in true protein due to protein fermentation (McDonald *et al*., 1991).

CP content in hay could be reduced due to volatilization (Merchem and Satter, 1983); this could be one reason for the reduction of hay CP in the present study. The reduced CP content in additive treated silages could be due to low protein contents of the additives.

Sun-drying can increase NDF, lignin and N contents because of disproportionate loss of carbon dioxide (CO_2) (Van Soest, 1994) which agrees with the increment of NDF and ADL contents of sweet potato vine hay in the present study. Similar results to the present study reduced; CP and increased NDF and ADF was reported by Muller *et al*. (2008) in comparison of fresh and dried lucerne due to DM losses during drying process. According to Salamone *et al*. (2012) NDF content may be increased due to soluble carbohydrates being incorporated into the NDF component via the maillard reactions that occurred during drying.

NDF and ADF contents of ensiled materials decrease due to hemicelluloses degradation (Snyman and Joubert, 1995; Salamone *et al*., 2012; Taher-Maddah *et al*., 2012). However, Hilla *et al*. (2001) reported that ensiling had no effect on lignin and ADF contents as lignin and cellulose are relatively stable to hydrolysis during silo fermentation. Pinho *et al*. (2004) also reported higher NDF and ADF contents, lower cellulose but similar lignin content in cassava top hay than its wilted and non-wilted silage. The reduction in NDF content of SPV0 in the present study agreed with above reports, but the observed increased contents of ADF and ADL contradicts.

The additives decreased cell wall contents (NDF, ADF and ADL) which could be due to their low cell wall contents and improved silage fermentation resulted from higher sugar contents (Baytok *et al*., 2005). However, the NDF and ADF contents of all additive treated silages were below the minimum of 30% and 19% respectively, required for healthy rumen of dairy cows (Target 10, 2002); suggesting additional fibrous feeds should be added during feeding.

In vitro DM digestibility in the order of; hay < silage without additive < fresh sorghum forage (Snyman and Joubert, 1995) and *in vivo* DM and organic matter digestibility by dairy cows in the order of; hay < silage < freez dried Master Graze (Salamone *et al*., 2012) were reported. In the present study, hay making, ensiling without additive (S1), ensiling with 2% molasses (S2) and 10% sweet potato root (S4) decreased IVTDMD compared to fresh vine in the order of hay < S1 < S2 = S4 < vine. Pinho *et al*. (2004) concluded that cassava top analyzed in fresh or ensiled forms had better values than cassava hay that could be possibly due to higher extent of oxidation that occurred during drying processes. The reduction in IVTDMD of S2 and S4 could be due to the supply of soluble carbohydrates was not sufficient enough to promote desirable fermentation. On the other hand, addition of 4% molasses (S3) and 20% sweet potato root (S5) had no effect on IVTDMD compared to fresh vine, while 30% sweet potato root (S6) increased IVTDMD. This could suggest that these additive levels were sufficient to provide the sugar contents required for the desired fermentation.

Ruiz *et al*. (1981) observed that addition of sweet potato root slightly improved *in vitro* DM digestibility of sweet potato vine silages. Backer *et al*. (1980) also reported that *in vitro* DM digestibility in combinations of sweet potato vine and root, increased as the proportion of sweet increased. The increased IVTDMD of S6 could also be attributed to its low cell wall contents as they are negatively related to it (Kamalak *et al*., 2004).

CONCLUSION

The chemical composition and IVTDMD of fresh, hay and ensiled vines of the four sweet potato varieties were studied. Sweet potato vines can be conserved as hay or silage for dry season feeding. In both hay and silages, the varieties had exhibited differences similar to their pre-ensiled characters in which Belela and Temesgen showed similar and better results than Beletech and Tulla in most of parameters measured. Higher CP and IVTDMD and lower NDF, ADF and ADL contents were observed in Belela and Temesgen than Beletech and Tulla in fresh, hay and silage forms. This variation could indicate that it is important to select varieties with higher nutritive value for ruminant feeding. All silage treatments were acceptable in terms of pH and other measured parameters, although the best were found at 4% molasses, 20 and 30% sweet potato root additions. Hay making increased nutrient losses compared to fresh vine and all silage treatments. Silage making is a better preserving method than hay making as it resulted in better quality product but it requires some technical skills and additional costs.

Where users can not afford the extra cost incurred in silage making, they can go for hay because it is simple and suitable to various environmental conditions.

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