Potential Nutritive Value of Sweet Corn as a Silage Crop with or Without Corn Ear

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Abstract: This study was conducted to compare the nutritive value of the whole crop sweet corn or sweet corn residue silages with regular silage corn or its residue silages using the chemical composition, gas production kinetics, energy and digestibility. Although, Dry Matter (DM) contents of whole crop Sweet Corn Silage (SCS) and Sweet Corn Residue Silage (SCRS) were significantly ($p<0.001$) lower than those obtained for counterparts, Crude Protein (CP) contents of SCS and SCRS were significantly ($p<0.001$) higher than those of conventional counterparts. Neutral Detergent Fibre (NDF) content of SCS was significantly ($p<0.001$) higher than that of Corn Silage (CS) whereas the NDF content of SCRS was similar to that of Stover Silage (SS). Although, Acid Detergent Fibre (ADF) content of SCS was similar to that of corn silage CS, the ADF content of SCRS was lower than that of SS. The Lactic acid content of SCS and SCRS were significantly ($p<0.001$) higher than those of CS and SS. The potential gas production (a + b) of SCS was lower than that of CS, whereas the potential gas production (a + b) of SCRS was similar to that of SS. The ME of SCS and SCRS were 8.6 and 6.91 MJ kg^{-1} DM, respectively. The OMD of SCS and SCRS were 57.89 and 46.88%, respectively. These results indicate that sweet corn and its residue may be preserved satisfactorily by ensiling. Based on the chemical composition, fermentation parameters and some estimated parameters, SCS and SCRS have potential nutritive value for ruminant animals.

Key words: Sweet corn, silage, gas production, digestibility, metabolisable energy

INTRODUCTION

In most parts of the world significant amounts of sweet corn (*Zea mays* L. var. rugosa) are grown for human consumption, providing considerable amount of Sweet Corn Residues (SCR) (Jaster *et al.*, 1983; Mustafa *et al.*, 2004). Sweet corn residue silage consists of husk leaves, cobs, discarded kernels and small amount of stalks (Fritz *et al.*, 2001). Although, the residue is attractive forage for ruminant animals, the residue is not well utilized due to plenty of green forage when the residue is available. Generally the residue is left over and causes pollution problem (Cheva-Isarakul *et al.*, 2001). The storage of SCR is limited by low dry matter content. Ensiling of SCR may be a viable option to increase the economic value of SCR due to the high cost of artificial drying (Mustafa *et al.*, 2004). Through this approachment, sweet corn residue may be utilized as feed during the winter. Actually, whole crop sweet corn silage utilization

have increased to meet the feed demands of ruminants. However, there is limited information about the whole crop sweet corn and its residue silages. Chemical composition, *in vitro* gas production, OMD and ME are important in an evaluation of forage nutritive values (Evityani *et al.*, 2004; Fujihara *et al.*, 2005; Karabulut *et al.*, 2007; Dongmei *et al.*, 2008).

The aim of the study, was to compare the nutritive value of the whole crop sweet corn and its residue silage with conventional corn silage for chemical composition, gas production kinetics and some estimated parameters such as metabolizable energy and organic matter digestibility.

MATERIALS AND METHODS

Silages: A conventional corn hybrid (Dekalp) was sown in June, 2007 with N (250 kg ha^{-1}) fertilization as a second crop. A sweet corn hybrid (Merit) was sown in July, 2007

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also with N (250 kg ha^{-1}) fertilization as a second crop. Both maize hybrids crops were harvested in September, 2007 and divided into 2 portions to prepare whole crop silage and its stover silages. Representative whole maize plants and their stover were chopped to about 2-3 cm in length. Chopped plant materials were ensiled in plastic experimental silos with a capacity of 2 kg. Conventional corn hybrid (Dekalp) and its stover silages were used as counterparts for 'Merit' sweet corn hybrid (RM 90 days) and its stover silage, respectively.

After 2 months storage, silage samples were taken and dried at 60°C in a air forced drier. Dry samples were ground to pass a 1 mm screen and used for the analyses.

Chemical analysis: Dry matter content was determined by drying the samples at 105°C overnight and the ash by igniting the samples in a muffle furnace at 525°C for 8 h. Nitrogen (N) content was measured by the Kjeldahl method. The CP was calculated as N×6.25. Ammonia N was determined in the silages extraction by blending 40 g samples with 360 mL distilled water for 5 min. The extract was filtered through Whatman paper (No: 1) and 100 mL of extract was used for distillation in a Kjeltech auto analyser without a digestion step. Neutral Detergent Fiber (NDF) was determined by the method Van Soest and Wine (1975) and ADF were determined by the method of Goering and Van Soest (1963). The pH of silages was determined using a combination electrode of a pH meter (SensION HACH, USA). VFA composition of silages were analyzed using GC (Agriculture Branch, Agri-Food and Biosciences Institute, Hillsborough, Co Down, Northern Ireland). All chemical analyses were triplicated except for VFA analysis which was duplicated.

Fleigh Points of the silages were calculated using the equation given below:

$$\text{Fleigh Points} = 220 + (2 \times DM\% - 15) - (40 \times pH)$$

where, Fleigh Points denote that values between 85 and 100, very good quality; 60 and 80, good quality; 55 and 60, moderate quality; 25 and 40, satisfying quality; <20, worthless.

***In vitro* gas production:** Rumen fluid was obtained from 2 fistulated sheep fed twice daily with a diet containing alfalfa hay (60%) and concentrate (40%). The samples (0.200 g) were incubated *in vitro* with rumen fluid in the serum bottles following the procedures of Theodorou *et al.* (1994). Three serum bottles with only buffered rumen fluid were incubated and considered as the blank incubation. Each incubation was completed in triplicate. The serum bottles were prewarmed to 39°C

before the injection of 50 mL rumen fluid-buffer mixture into each bottle followed by incubation in a water bath at 39°C. Gas production was recorded at 3, 6, 12, 24, 48, 72 and 96 h after incubation using a pressure transducer and LED digital readout voltmeter (Bailey and Mackey Ltd, Birmingam, UK). Cumulative gas production data were fitted to the exponential equation (Orskov and McDonald, 1979):

$$y = a + b \, (1 - \exp^{-ct})$$

where:

y = The gas production at time t

a = The gas production from the immediately soluble fraction (mL)

b = The gas production from the insoluble fraction (mL)

c = The gas production rate constant

a + b = The potential gas production (mL)

t = Incubation time (h)

The ME (MJ kg^{-1} DM) of silages was calculated using equations of Menke *et al.* (1979) as follows:

$$\text{ME (MJ kg}^{-1}\text{ DM)} = 2.20 + 0.136\,GP + 0.057\,CP \quad R2 = 0.94$$

where:

GP = The 24 h net gas production (mL/200 mg)

CP = Crude protein (%)

The OMD of silages was calculated using equations of Menke *et al.* (1979) as follows:

$$\text{OMD (\%)} = 14.88 + 0.889\,GP + 0.45\,CP + 0.0651\,XA$$

where:

GP = The 24 h net Gas Production (mL/200 mg)

CP = Crude Protein (%)

XA = Ash content (%)

Statistical analysis: One-way Analysis of Variance (ANOVA) was carried out to compare the mean chemical composition, pH, gas production, estimated parameters, *in vitro* DMD and ME values using General Linear Model (GLM) of Statistica for windows. Significance between individual means was identified using the Tukey's multiple range test (Pearse and Hartley, 1966). Mean differences were considered significant at p<0.05. Standard errors of means were calculated from the residual mean square in the analysis of variance.

As a complement of ANOVA procedure, Principal Components Analysis (PCA) were performed using chemical composition, fermentation parameters and gas production parameters as variables and silage type as

classification criterion. The PCA analysis allows detection of the degree of association between variables by means of their relative position in a multivariate space, which is reduced to orthogonal directions of maximum variance in the original data (Afifi and Clark, 1996). The biplot display proposed by Gabriel (1971) was used. Data were analysed using the SYSTAT 10 statistical software.

RESULTS AND DISCUSSION

Chemical composition: Chemical compositions of the silages are given in Table 1. There was considerable variation among silages in terms of chemical composition. Although, DM content of silages ranged from 19.76-24.13%. The DM content of silages studied in the current study was sufficiently high to avoid secondary fermentation by clostridia, as indicated by low level of butyric acid. The CP contents of silages ranged from 7.72-10.31%. Crude protein of Silage SCS is significantly higher than those of the other silages. The CP contents of CS and SCS consistent with those reported by Paulson (2007) who reported that CP of both of CS and SCS were 9%. The DM and CP contents of CS were also consistent with findings of Cerci *et al.* (2002) who found that DM and CP contents of CS harvested at milk stage were 25.10 and 9.22%, respectively.

As shown in Table 2, there are also significant differences among silages in terms of cell wall contents. The NDF and ADF contents varied with silage type in the range 42.90-53.28 and 25.17-36.59%, respectively. Although, the NDF content of SS was significantly higher than those of SCS and CS the ADF content of SS was significantly higher than the others.

On the other, the ash content of SCRS was significantly (p<0.001) higher than the others. As can be seen Table 2 NDF and ADF contents of SCRS and SS significantly (p<0.001) higher than those of SCS and CS due to dilution effect of stover which is rich in cell wall contents (NDF and ADF).

Although, NDF content of SCS was considerably lower than that reported by Paulson (2007) CP content of SCS was similar to that reported by Paulson (2007) who reported that CP, NDF and TDN contents were 9.55 and 67%. The chemical composition of SCRS was comparable with that reported by Jaster *et al.* (1983) who reported that DM, NDF, ADF, CP and ash contents were 21, 59.4, 37.4 10.8 and 7.1%, respectively. The chemical composition of SCRS was also comparable with that reported by Mustafa *et al.* (2004) who reported that DM, NDF, ADF, CP and ash contents were 23.9, 58.2, 28.3 9.6 and 3.4%, respectively.

Table 1: Chemical compositions of sweet corn, conventional corn and their residue silages

Items	Silages					
	SCS	SCRS	CS	SS	SEM	Sig.
DM	20.89b	19.76b	24.13a	22.67ab	0.643	***
CP	10.31a	9.14b	9.46b	7.72c	0.109	***
NDF	42.90c	52.32a	47.82b	53.28a	0.378	***
ADF	25.17c	34.04b	26.32c	36.59a	0.328	***
Ash	5.76c	7.80a	4.93d	6.80b	0.110	***

SCS: Sweet Corn Silage, SCRS: Sweet Corn Residue Silage, CS: Corn Silage, SS: Stover Silage, Means within the same row with differing superscript are significantly different. ***p<0.001, SEM: Standard Error of Mean

The NDF and ADF contents of CS were in agreement with findings of Pirmohammadi *et al.* (2006) who reported that NDF and ADF contents of CS were 463 and 260%, respectively. The NDF and ADF contents of CS silage obtained in the current experiment were considerably lower than those reported by Aksu *et al.* (2004) who found that 57.6 and 36.1%, respectively.

The fermentation parameters of the silages are given in Table 2. There was considerable variation among silages in terms of the fermentation parameters.

The pH of silages ranged from 3.72-3.84, indicating that all silage materials ensiled very well. All of the silages obtained in the current experiment had pH values that were less than that (4) required for achieving stability during the fermentation (McDonald *et al.*, 1991). The pH value of SCRS was also consistent with that reported by Jaster *et al.* (1983) and Mustafa *et al.* (2004) who reported that the pH values of SCRS were 3.9 and 3.45, respectively.

The lactic acid content of forages ranged from 58.15-107.17 g kg^{-1} DM. The lactic acid contents of SCS and SCRS were significantly higher than those of CS and SS. This result is in agreement with findings of Jaster *et al.* (1983) who also found that lactic acid concentration of SCRS was 24% greater than for corn silage. There are no significant (p>0.05) difference among silages in term of acetic, propionic, butyric, valeric acid contents. The ammonia content of silages ranged from 104.8-145 g kg^{-1} DM with lowest content in CS. It is well known that the proteolysis is an inevitable consequence of ensiling process. The ammonia contents of SCRS and SS were considerably higher than those of SCS and CS, possibly due to extensive degradation of crude protein in SCS and CS. The ammonia content of SCRS is consistent with finding of Mustafa *et al.* (2004) who found that ammonia content of SCRS was 140 g kg^{-1} N.

The FP values of silages ranges from 90.79 and 103.50, indicating that all silages were very good quality according to the Fleigh Point Scale.

Table 2: Mean values of fermentation parameters of sweet corn, conventional corn and their residue silages

Items	Silages					
	SCS	SCRS	CS	SS	SEM	Sig.
pH	3.72b	3.84a	3.74ab	3.76ab	0.024	*
Lactic acid (g kg⁻¹ DM)	97.21a	107.17a	58.15b	61.34b	2.49	***
Acetic acid (g kg⁻¹ DM)	14.64	10.14	11.98	15.19	2.219	ns
Propionic acid (g kg⁻¹ DM)	0.20	0.12	0.55	0.32	0.101	ns
Butiric acid (g kg⁻¹ DM)	0.46	0.30	0.35	0.37	0.039	ns
Valeric (g kg⁻¹ DM)	0.06	0.06	0.10	0.025	0.013	ns
Ethanol (g kg⁻¹ DM)	33.52a	26.70b	22.76b	10.00c	1.114	***
Ammonia (g kg⁻¹ N)	126.0ab	144.8a	104.8b	145.0a	6.487	*
FP	97.71a	90.79b	103.5a	99.67a	1.501	***

SCS: Sweet Corn Silage, SCRS: Sweet Corn Residue Silage, CS: Corn Silage, SS: Stover Silage, FP: Fleigh Points, Means within the same row with differint letters are significantly different. *p<0.05, ***p<0.001, ns: non significant, SEM: Standard Error of Mean, Sig: Significance level

The organic acid contents of SCRS were comparable to that reported by Jaster *et al.* (1983) who reported that acetic, propionic, butyric, lactic acids were 10, 0.5, 0.2, 80.2%, respectively.

On the other hand, the lactic acid content of SCRS was twice that of SCRS reported by Mustafa *et al.* (2004).

All silages were well preserved and dominated by lactic acid fermentation with a low level of butyric acid. Low WSC content has been reported to be responsible for the poor fermentation quality as well as aerobic instability of silage (Kristensen, 1992; Weissbach, 1996; Adesogan *et al.*, 1998). Therefore, the low pH values of silages in the current study may be attributable to their high level WSC content. During the vegetative stage water soluble carbohydrates build up in leaves and stalk (Phipps *et al.*, 1984) and start to decline after silking under temperate climatic condition (McAllan and Phipps, 1977; Phipps and Weller, 1979; Oldeburg and Laws, 1993) when the developing kernels turn into the main sink for photosynthesis (Tollenaar, 1977; Hawker *et al.*, 1991; Schussler and Westgate, 1994). The good fermentation characteristics reflect the availability of WSC and low buffering capacity (Valente *et al.*, 2003). This is the reason why SCRS and SS were well fermented and have low pH value required for achieving stability during the fermentation.
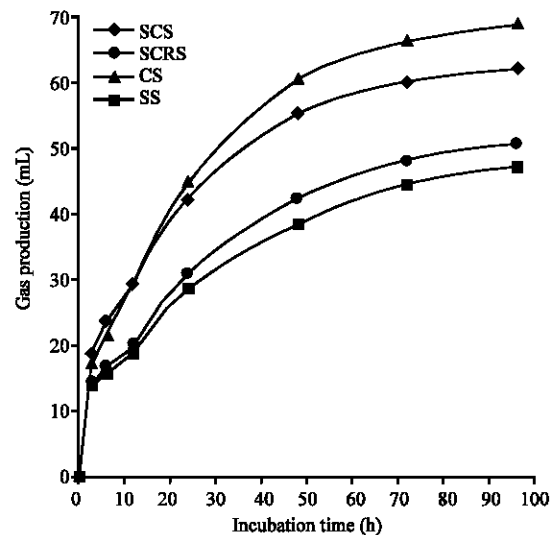
***In vitro* gas production:** The data of gas production during the fermentation period are shown in Fig. 1. The cumulative volume of gas production increased with increasing time of incubation. There were significant (p<0.001) differences among silages in terms of gas production at all incubation times. Gas produced after 96 h incubation ranged between 47.15 and 68.15 mL.

The estimated parameters are given in Table 3. There were significant (p<0.01, p<0.001) differences between silages in terms of estimated parameters. The gas production rate (c) of SCS and CS were significantly (p<0.01) higher than those of SCRS and SS. The gas production from quickly soluble fraction (a) of SCS and

Table 3: *In vitro* gas production kinetics, metabolizable energy and organic matter digestibility of sweet corn, conventional corn and their residue silages

Parameters	Silages					
	SCS	SCRS	CS	SS	SEM	Sig.
c	0.052a	0.038b	0.042ab	0.036b	0.002	**
a	5.37ab	5.63a	4.54b	4.92ab	0.202	**
b	55.92b	43.92c	64.65a	42.78c	1.662	***
a + b	61.30b	49.55c	69.20a	47.70c	1.543	***
ME	8.60a	6.91b	8.83a	6.60b	0.181	***
OMD	57.89a	46.88b	59.29a	44.70b	1.178	***

SCS: Sweet Corn Silage, SCRS: Sweet Corn Residue Silage, CS: Corn Silage, SS: Stover Silage, c: is the gas production rate constant, a: is the gas production from the immediately soluble fraction (mL), b: is the gas production from the insoluble fraction (mL), a + b = the potential gas production (mL), ME: Metabolizable Energy, OMD: Organic Matter Digestibility, Means within the same row with differing superscript are significantly different. ** p<0.01, *** p<0.001, ns: non significant, SEM: Standard Error, Sig: Significance level

Fig. 1: *In vitro* gas production of sweet corn, conventional corn and their residue silages

CS were significantly (p<0.01) higher than that of CS. The gas production from slowly degradable fraction (b) of SCS and CS were significantly higher than those of SCRS and SS.

The total potential gas production (a + b), ME and OMD values of SCS and CS were also significantly higher than those of SCRS and SS. The ME and OMD values ranged from 6.60-8.83 and 44.70-59.29%, respectively. The *in vitro* gas production results and estimated parameters suggest that microbial colonization and substrate utilization were greater in SCS and CS than SCRS and SS. Although SCS and CS silage resulted from fermentation of leaves, stalk and ear the SCRS and SS resulted from fermentation of leaves and stalk. A corn ear consists of immature grain and cob. The ear is very rich in fermentable carbohydrate. Therefore, fermentation of SCS and CS silage by micro-organisms resulted in higher gas production than those of SCRS and SS. As a result, the estimated parameters such as ME and OMD were significantly higher than those obtained for SCRS and SS.

Gas production is related with Volatile Fatty Acid (VFA) production following fermentation of substrate so the more fermentation of a substrate the greater the gas production, although the fermentation end products do affect more closely with gas production (Blummel and Orskov, 1993). Differences between total gas productions could be explained by the differences in total VFA production and molar proportion of VFA (Beuvink and Spoelstra, 1992). Doane *et al.* (1997) found a significant correlation between gas production and VFA production.

The OMD values of SCRS obtained in the current experiment is considerably lower than those reported by Jaster *et al.* (1983) and Mustafa *et al.* (2004). The ME values of SCRS was comparable with that reported by Idris *et al.* (2008) who reported that ME values of SCRS was 5.86 MJ kg^{-1} DM.

On the other hand, the estimated OMD value of CS obtained in the current experiment was comparable with that obtained by Mustafa *et al.* (2004) but Tatli *et al.* (2001) and Cerci *et al.* (2002) who reported that *in vivo* OMD values 72.72 and 67.90%, respectively. The estimated OMD value of CS obtained in the current experiment was also considerably lower than that obtained by Meeske and Basson (1998) who reported that *in vitro* OMD value of CS 74.5%.

Compared with CS, SCRS had about 22.32% lower OMD and 26.47% lower ME. This result is in agreement with findings of Jaster *et al.* (1983) and Mustafa *et al.* (2004) who reported that 17.93 and 14.47% higher apparent total tract digestibility for corn silage versus SCRS.

The differences in chemical composition, fermentation profiles and digestibility parameters can be attributed to hybrid differences in maturity, grain to stover ratio, grain composition, stover composition and methods of forage analysis (Coors *et al.*, 1994).
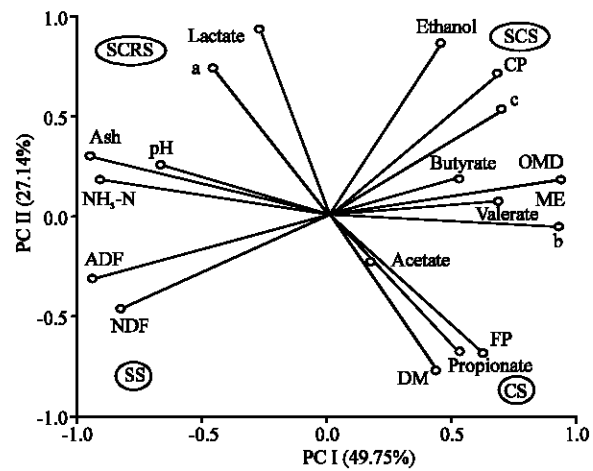

Fig. 2: Biplot displays derived from principal components analysis using silage type as classification criterion

The analysis of the first two principal components using silage type classification criterion is given in Fig. 2. First 2 components explained 76.89% of the total variation.

The variables NH$_3$-N, ash, NDF, ADF, pH, c, b, ME, OMD and valarete showed the highest factor loading: -0.909, -0.949, -0.828, -0.939, -0.670, 0.687, 0.941, 0.959, 0.957 and 0.679, respectively, explaining 49.75% of the variability among silages through the first component (PC I). The variables ethanol, lactate, propionate, a, FP, CP and DM showed the highest factor loading: 0.859, 0.937, -0.681, 0.739, -0.691, 0.712 and -0.774, respectively, explaining 27.14% of the variability among silages through the second component (PC II).

As can be seen from Fig. 2 although SCS could be characterised by high Ethanol, CP, c, OMD, ME and butyrate SCRS could be characterised by high lactate, a, ash, pH and ammonia contents. On the other hand, CS could be characterised by high DM, propionate, acetate, b and FP whereas SS could be characterised by high NDF and ADF contents.

The principal component analysis allowed better understanding of complex correlations among the parameters related to chemical composition and fermentation parameters of silages. The principal component analysis also allowed discrimination among silage in terms of chemical composition and fermentation parameters.

SCRS contained 21.9 and 35.2% more NDF and ADF than did SCS, which would have contributed to the low OMD and ME of SCRS as compared to SCS. As shown in Fig. 1 NDF and ADF contents were negatively correlated with OMD and ME. This results is agreement with findings of Kamalak *et al.* (2005).

Osbourn *et al.* (1974) reported that forage intake was inverse function of cell wall concentration in forage dry matter. Therefore relative intakes of SCRS is likely lower as compared with SCS and CS.

CONCLUSION

These data have provided some preliminary information on the ensiling of SCS and SCRS. These results indicate that sweet corn and sweet corn by product can be preserved satisfactorily by ensiling.

Based on the chemical composition, fermentation parameters and some estimated parameters, SCS and SCRS have potential nutritive value for ruminant animals. Current study results will be helpful to livestock producers because it provides information about ensilability and nutritive value of sweet corn silage or corn silage without ear.

ACKNOWLEDGEMENT

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