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Relationships Between Chemical Composition, *in vitro* Dry Matter, Neutral Detergent Fiber Digestibility and *in vitro* Gas Production of Corn and Sorghum Silages

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Abstract: Five corn (*Zea mays*) and four sorghum (*Sorghum bicolor* L. Moench) silages were used to investigate the relationship between chemical composition, *In Vitro* Dry Matter Digestibility (IVDMD), *In Vitro* Neutral Detergent Fiber Digestibility (IVNDF) and *in vitro* Gas Production (GP) measured after 1, 2, 3, 4, 5, 6, 9, 12, 24, 48 and 72 h of incubation. Then, the capability to predict IVDMD and IVNDFD based on chemical composition and GP data was examined. Silage contents of NDF, ADF and lignin were negatively correlated ($p<0.05$) with IVDMD. A negative relationship ($p<0.05$) between CP and asymptotic GP was also observed. The NDF, ADF and lignin contents of silages were positively correlated ($p<0.0001$) with time to reach half-maximal GP, however, the relationship of half-maximal GP with Non-Fibrous Carbohydrate (NFC) was negative ($p<0.0001$). After the 1st h of incubation, GP was negatively related with lignin content and positively correlated with NFC ($p<0.001$ and $p<0.05$, respectively). After h 9 of incubation, the correlations between NDF and ADF with GP were highest ($p<0.01$) until 48 h of incubation and decreased at 72 h ($p<0.05$). Chemical composition combined with GP data adequately predicted IVDMD.

Key words: *In vitro* gas production, chemical composition, *in vitro* dry matter digestibility, *in vitro* neutral detergent fiber digestibility, ADF

INTRODUCTION

Silage, either corn or sorghum is one of the most common forages utilized in dairy rations in Mexico; however, its nutritive value is greatly influenced by its chemical components (Getachew *et al*., 2004) and digestibility (De Boever *et al*., 2005). Chemical composition is one of the most critical factors that affect the rate and extent of silage digestion (Getachew *et al*., 2004) and can also have a large impact on voluntary feed intake (Forbes, 1995).

In vivo, *in situ* and *in vitro* techniques to determine the rate and extention of digestion have been described (Getachew *et al*., 1998). Determinations of intake and *in vivo* digestibility are expensive, laborious and time-consuming (Carro *et al*., 1994); this could limit their use in countries like Mexico. In contrast *in vitro* techniques are less expensive and can possess high repeatability. In the last decade, the *in vitro* gas production technique has received much attention as a tool to estimate the nutritional quality of feeds (Getachew *et al*., 1998). Also, in recent years this technique has been used to examine the relationships between *in vitro* GP and *in vivo* feed intake (Getachew *et al*., 2004; Blummel *et al*., 2005; Hetta *et al*., 2007) close correlations were reported. These results suggest that the *in vitro* GP technique can be a useful tool to characterize and compare forages (Hetta *et al*., 2003). The objective of this study was to investigate the relationship between chemical composition and *in vitro* Dry Mater (DM) and Neutral Detergent Fiber (NDF) digestibility in forages utilized in the dairy industry in Northern Mexico.

MATERIALS AND METHODS

Five corn (*Zea mays*) and four sorghum (*Sorghum bicolor* L. Moench) silages were used. The corn hybrids used were VIRGI (Caussade Semences), 33J56 and 33G66 (Pioneer Hi-Bred International, Des Moines, IA). All the corn and sorghums were cultivated in the central region of Chihuahua State in Mexico. This

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region has a large modern dairy industry. Corn hybrids were harvested at one-half milk line and sorghum varieties in soft dough stage, chopped at 0.95 cm of theoretical length of cut (Bal *et al*., 2000) and ensiled in laboratory silos (n = 3 in each silage sample). After 45 days the laboratory silos were opened and tested for pH using a manual pH meter. Silages were dried in a 60°C forced-air oven, ground to pass a 1 mm sieve in a Wiley mill and then used for chemical composition, IVDMD, IVNDFD and *in vitro* GP analyses. Absolute DM was determined by drying at 135°C for 4 h (AOAC, 1990) and Organic Matter (OM) was determined by incineration at 600°C for 5 h.

The NDF, Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) contents were sequentially determined in the ANKOM^{200} fiber analyzer (Ankom Technology, Fairport, NY, USA) using reagents described by Van Soest *et al*. (1991). Sodium sulfite and α-amylase were used in the NDF determination. The CP was determined as N×6.25 (AOAC, 1990) after Kjeldahl analysis. Fat content was determined by ether extraction in the Tecator Soxtec system (AOAC, 1990). The Non-Fiber Carbohydrate (NFC) content of feeds was calculated by subtraction of CP, NDF, fat and ash from total DM (Sniffen *et al*., 1992). The IVDMD and IVNDFD were estimated using 48 h incubations in a Daisy^{II} incubator (Ankom Technology, Fairport, NY, USA). For the incubation of the samples, ANKOM F57 filter bags (Ankom Technology, Fairport, NY, USA) were used.

Bags were rinsed with acetone and dried in a forced air oven at 60°C for 6 h. Approximately 0.25 g of each sample were weighed into triplicate bags, heat sealed and placed in digestion jars. The incubation media and procedure were as suggested by the manufacturer.

After 48 h, jars were removed from the incubation chamber, the incubation solution was discarded and bags rinsed four times with distilled water. The IVDMD was determined by loss of dry matter. For IVNDFD determination, bags were placed in an ANKOM^{200} fiber analyzer to determine NDF content as described before. Bags were removed, soaked twice in acetone for 5 min at each soaking and dried at 100°C for 24 h.

The IVNDFD was calculated as the difference between the amount of NDF incubated and the residue after NDF determination. The *in vitro* GP procedure was as described by Menke and Steingass (1988) except that glass flasks (50 mL) were used in the experiment and the GP was recorded using a pressure transducer (Theodorou *et al*., 1994). Samples (200 mg) were weighed and put into the flasks. Buffered mineral solution (Menke and Steingass, 1988) was prepared and maintained at 39°C under continuous flushing with CO_2. Rumen fluid was obtained 15 min before the morning feeding from three ruminally fistulated Pelibuey ewes fed alfalfa hay twice (8:00 and 16:00 h) daily. Rumen fluid was pumped with a manually operated vacuum pump and transferred into a pre-warmed thermos, combined, filtered through four layers of cheesecloth and flushed with CO_2 maintained in a water bath at 39°C.

Mineral solution and ruminal fluid were then combined (ratio 2:1 v/v) to obtain the ruminal inoculum. All handling was under continuous flushing with CO_2. About 30 mL of ruminal inoculum was dispensed into glass flasks containing the silage samples. Flasks were then capped with rubber a stopper and sealed with an aluminum ring. The flasks were incubated at 39°C and gently agitated continuously. The GP of all the silages was determined in three runs, each sample was analyzed in triplicate in order to make a average; also a blank (ruminal inoculum without sample) was included for each sample. Gas volumes were corrected for GP in the blanks.

Cumulative GP was recorded at 1, 2, 3, 4, 5, 6, 9, 12, 24, 48 and 72 h using a syringe adapted to an automated transducer (Theodorou *et al*., 1994). Metabolizable energy was estimated using 24 h gas production as well as the CP, fat and ash contents of each sample as described by Menke and Steingass (1988). Cumulative GP data for each sample were fitted to a monophasic model as described by Groot *et al*. (1996) (Eq. 1) using SAS NLIN (SAS, 2002). The sigmoid equation predicts the GP (mL gas/200 mg DM) at a given time t (h):

$$GP = \frac{A}{1+\frac{B^C}{t^C}} \quad (1)$$

Where:

A = The asymptotic GP
B (h) = The time after the incubation at which half of the GP has been reached
C = A constant describing the sharpness of the switching characteristic of the profile

Also, the fractional rate of substrate digestion (R) and time after the start of incubation at which R is maximal (t_{RM}) were calculated as described by Groot *et al*. (1996). Correlations between chemical composition of the silages and GP parameters were calculated using the Pearson's product moment correlation coefficient. Relationships between IVDMD, IVNDFD and silage variables were evaluated with simple and multiple linear regressions; latter using the stepwise routine (SAS, 2002). Only equations with variables contributing ($p<0.05$) to variation of the dependent variable were included.

RESULTS AND DISCUSSION

The chemical composition of the silages is shown in Table 1. No differences were observed in DM content. However, sorghum silages tended to have low organic

Table 1: Chemical composition (g/kg of DM) of individual silage samples used

		Chemical composition*									
Silage	Type	pH	DM	Ash	CP	EE	NDF	ADF	Lignin	NFC	ME
1	VIRGI	3.70	942.30	56.10	70.4	32.0	447.7	230.7	16.5	336.0	5.7
2	33J56	3.80	939.70	47.80	75.2	39.8	354.2	193.9	14.7	422.6	6.0
3	33G66-20	3.70	939.70	75.20	77.1	26.0	489.0	262.9	25.6	272.4	4.7
4	33G66-40	4.00	492.60	75.10	76.8	36.3	473.2	269.3	17.5	281.2	5.2
5	33G66-60	3.70	935.90	69.70	68.0	45.6	431.9	242.8	18.1	320.6	6.3
6	S.M.	3.70	923.50	88.80	66.7	22.5	505.1	294.6	25.4	240.4	5.0
7	G.V.	3.90	929.70	81.80	67.9	23.6	482.3	273.5	21.2	274.0	4.9
8	8641	4.00	939.80	72.90	119.2	37.6	472.6	264.0	28.4	237.4	5.3
9	855F	4.00	944.40	84.80	88.4	19.0	538.2	305.4	35.3	214.0	4.9
Mean	-	2.80	887.50	72.50	78.9	31.4	466.0	259.7	22.5	288.7	5.3
SE	-	0.05	49.41	4.40	5.5	3.0	17.3	11.2	2.2	21.2	0.2

*pH; DM = Dry Matter; Ash; CP = Crude Protein; EE = Ether Extract; NDF = Neutral Detergent Fiber; ADF = Acid Detergent Fiber; Lignin; NFC = Non-Fiber Carbohydrates; ME = Metabolizable Energy; 1 = Corn hybrid VIRGI; 2 = Corn hybrid 33J56 (Pioneer); 3 = Corn hybrid 33G66 (Pioneer) cut at 20 cm above soil surface; 4 = Corn hybrid 33G66 (Pioneer) cut at 40 cm above soil surface; 5 = Corn hybrid 33G66 (Pioneer) cut at 60 cm above soil surface; 6 = Sorghum variety Silo Miel; 7 = Sorghum variety Gigante Verde; 8 = Sorghum variety 8641 (Pioneer); 9 = Sorghum variety 855F (Pioneer)

Table 2: *In vitro* dry matter and neutral detergent fiber degradability and fermentation parameters

Silage	IVDMD[1]	IVNDFD[2]	A[3]	B[4]	C[5]	R[6]	t_{RM}[7]
1	697.96^{A}	479.21^{BCD}	63.94^{ABC}	18.79^{D}	1.12^{CD}	1.00^{B}	1.90^{BC*}
2	712.90^{A}	551.35^{ABC}	65.33^{ABC}	14.60^{D}	1.33^{AB}	1.80^{B}	3.60^{BC}
3	548.85^{C}	488.35^{BCD}	64.87^{ABC}	30.86^{B}	1.45^{A}	7.50^{A}	9.80^{A}
4	536.25^{C}	481.65^{BCD}	73.86^{AB}	28.55^{BC}	1.19^{BCD}	2.50^{B}	4.40^{B}
5	618.30^{B}	470.50^{BCD}	74.64^{A}	17.05^{D}	1.22^{BC}	1.60^{B}	3.10^{BC}
6	693.54^{A}	416.44^{D}	73.14^{ABC}	28.80^{BC}	1.11^{CD}	1.40^{B}	2.90^{BC}
7	683.81^{A}	446.81^{CD}	66.64^{ABC}	25.04^{C}	1.07^{CD}	0.90^{B}	1.80^{BC}
8	605.59^{B}	571.52^{AD}	59.75^{BC}	26.51^{BC}	1.16^{BCD}	1.90^{B}	3.50^{BC}
9	573.56^{BC}	623.34^{A}	58.73^{C}	38.19^{A}	1.02^{D}	0.40^{B}	0.70^{C}
Mean	630.00	503.24	66.70	35.37	1.18	5.83	3.52
SD	22.88	21.87	1.97	2.48	0.04	2.91	0.86

[1]*In vitro* dry mater digestibility (g kg^{-1} of DM); [2]*In vitro* neutral detergent fiber digestibility (g kg^{-1} of NDF); [3]Asymptotic gas production (mL gas/200 mg of DM); [4]Time when half of the gas is produced (h); [5]Switching character of the curve (dimensionless); [6]Fractional rate of substrate digestion; [7]Time after the start of the incubation at which R is maximal; *Different letters between rows denote statistical difference (p<0.05)

Table 3: *In vitro* gas production at different time of fermentation (mL gas/200 mg of DM)

Silage	GP_1	GP_2	GP_3	GP_4	GP_5	GP_6	GP_9	GP_{12}	GP_{24}	GP_{48}	GP_{72}*
1	3.6^{AB}	14.0^{A}	19.0^{A}	22.6^{A}	26.0^{A}	29.8^{A}	35.8^{A}	41.4^{AB}	54.20^{A}	65.3^{A}	70.4^{AB}
2	2.8^{B}	12.8^{A}	17.6^{A}	20.8^{A}	24.1^{A}	28.0^{A}	37.0^{A}	45.2^{A}	58.20^{A}	69.3^{A}	74.9^{A}
3	1.5^{C}	1.7^{D}	2.6^{D}	3.4^{D}	4.7^{D}	6.6^{D}	8.2^{E}	20.5^{E}	27.00^{D}	42.6^{D}	50.0^{F}
4	4.6^{A}	6.4^{C}	7.8^{C}	9.7^{C}	11.0^{C}	13.0^{C}	17.3^{D}	22.9^{DE}	37.80^{C}	51.8^{C}	58.2^{E}
5	4.2^{A}	6.5^{C}	8.2^{C}	10.3^{C}	12.8^{C}	15.6^{C}	22.6^{C}	30.0^{CD}	46.18^{B}	57.4^{B}	63.9^{CDE}
6	1.3^{C}	9.6^{B}	13.9^{B}	16.7^{B}	19.0^{B}	22.0^{B}	26.4^{BC}	32.0^{CD}	45.90^{B}	59.5^{B}	66.1^{BCD}
7	0.9^{C}	9.0^{B}	13.4^{B}	16.3^{B}	18.7^{B}	21.8^{B}	26.0^{BC}	31.0^{CD}	43.80^{B}	55.5^{BC}	61.3^{DE}
8	1.5^{C}	10.7^{B}	13.8^{B}	17.0^{B}	20.0^{B}	22.5^{B}	27.5^{B}	34.0^{BC}	46.90^{B}	59.2^{B}	68.2^{BC}
9	1.1^{C}	10.0^{B}	13.8^{B}	17.0^{B}	20.0^{B}	22.4^{B}	25.9^{BC}	31.0^{CD}	43.10^{B}	54.9^{BC}	63.9^{CDE}
Mean	2.3	9.0	12.2	14.9	17.4	20.2	26.2	32.0	44.80	57.3	64.0
SE	0.5	1.2	1.7	2.0	2.2	2.5	2.9	2.6	3.00	2.6	2.4

*Gas production at different hours of incubation

matter contents. The CP contents ranged from 66.7-119.2 g kg^{-1} of DM between silages. The NDF, ADF and ADL contents tended to be lower in corn silages than sorghum silages. The IVDMD was similar between silages whereas IVNDFD was very variable with values that ranged from 416.4-623.3 g kg^{-1} of DM (Table 2). The GP differed (p<0.05) among silages at all incubation times (Table 3).

Also, the pattern of fermentation was distinctly different between corn and sorghum silages (Fig. 1 and 2). There were differences (p<0.05) among silages in the asymptotic GP, the time after incubation at which half GP had been produced and shape of the GP curves (Table 2). The fractional rate of substrate digestion was similar between silages except in corn silage 33G66-20 which tended to be higher (p<0.05). Also, differences in t_{RM} were observed between silages (p<0.05).

The DM content was positively correlated with IVNDFD (p<0.05). The CP content was also positively correlated with IVNDFD (p<0.01) but negatively correlated with parameter A (p<0.05). The NDF and ADF contents were negatively correlated with IVDMD, parameter C and

Table 4: Correlations between chemical composition and gas production parameters

Measure[1]	DM	CP	NDF	ADF	Lignin	NFC	IVDMD	IVNDFD	A	B	C	R	t_{RM}
CP	0.237												
NDF	-0.130	0.183											
ADF	-0.230	0.186	0.961***										
Lignin	-0.017	0.548**	0.738**	0.750***									
NFC	0.157	-0.436*	-0.942***	-0.942***	-0.808***								
IVDMD	-0.313	-0.360	-0.513*	-0.497*	-0.496*	0.555**							
IVNDFD	0.454*	0.599**	0.018	0.028	0.449*	-0.100	-0.324						
A	-0.367	-0.419*	-0.073	-0.020	-0.450	0.089	0.100	-0.603**					
B	0.038	0.261	0.849***	0.817***	0.720**	-0.818***	-0.602**	0.146	-0.126				
C	0.160	-0.075	-0.440*	-0.433*	-0.241	0.040	-0.190	-0.008	-0.099	-0.298			
R	0.151	-0.021	0.032	-0.037	0.021	-0.029	-0.462*	-0.124	-0.050	0.198	0.807***		
t_{RM}	0.133	-0.010	-0.049	-0.091	-0.033	0.028	-0.440*	-0.120	-0.059	0.100	0.865***	0.983***	
GP_1	0.302	-0.216	-0.384	-0.369	-0.629**	0.422*	0.074	-0.102	0.425*	-0.515**	-0.044	-0.278	-0.212
GP_2	0.103	0.044	-0.360	-0.371	-0.252	0.372	0.724***	0.196	-0.221	-0.443	-0.432*	-0.710**	-0.677**
GP_3	0.046	0.038	-0.332	-0.341	-0.209	0.344	0.759***	0.176	-0.253	-0.407	-0.440*	-0.698**	-0.671**
GP_4	0.046	0.060	-0.312	-0.320	-0.188	0.320	0.746***	0.189	-0.258	-0.391	-0.465*	-0.717**	-0.690**
GP_5	0.058	0.076	-0.320	-0.329	-0.174	0.322	0.740***	0.211	-0.277	-0.401	-0.448*	-0.709**	-0.681**
GP_6	0.051	0.040	-0.358	-0.368	-0.216	0.364	0.767***	0.184	-0.251	-0.441*	-0.419*	-0.694**	-0.665**
GP_9	0.056	0.010	-0.495*	-0.480*	-0.315	0.483*	0.781***	0.189	-0.182	-0.575**	-0.321	-0.688**	-0.640**
GP_{12}	0.065	0.031	-0.557**	-0.528**	-0.277	0.547*	0.711**	0.277	-0.260	-0.678**	-0.100	-0.558**	-0.499*
GP_{24}	0.027	0.011	-0.603**	-0.566**	-0.406	0.565**	0.772**	0.143	-0.043	-0.683**	-0.244	-0.673**	-0.611**
GP_{48}	0.017	-0.008	-0.612**	-0.579**	-0.426	0.568**	0.778***	0.109	0.005	-0.666**	-0.214	-0.625**	-0.563**
GP_{72}	0.053	0.140	-0.540*	-0.506*	-0.293	0.460*	0.703*	0.208	-0.043	-0.561**	-0.251	-0.694**	-0.575**

*p<0.05; **p<0.01; ***p<0.0001; [1]DM = Dry Matter; CP = Crude Protein; NDF = Neutral Detergent Fiber; ADF = Acid Detergent Fiber; Lignin; NFC = Non-Fiber Carbohydrates; IVDMD = *In Vitro* Dry Matter Digestibility; IVNDFD = *In Vitro* Neutral Detergent Fiber Digestibility; A = Asymptotic gas production; B = Time when half of the gas is produced; C = switching character of the curve; R = fractional rate of substrate digestion; tR_M = time after the start of the incubation at which R is maximal; GP = Gas Production at different hours of incubation

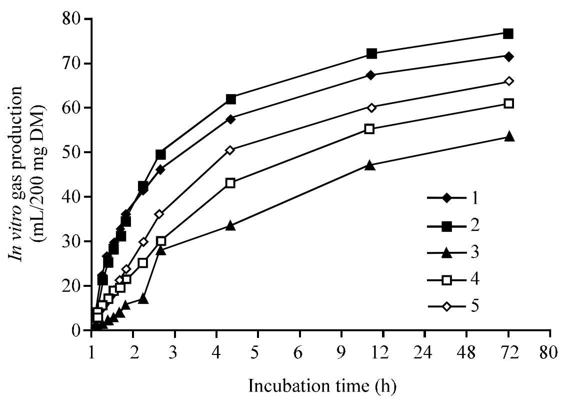

Fig. 1: Pattern of *in vitro* gas production (fitted with Logistic Model) on incubation of corn silages in buffered rumen fluid. 1 = VIRGI; 2 = 33J56; 3 = 33G66-20; 4 = 33G66-40; 5 = 33G66-60

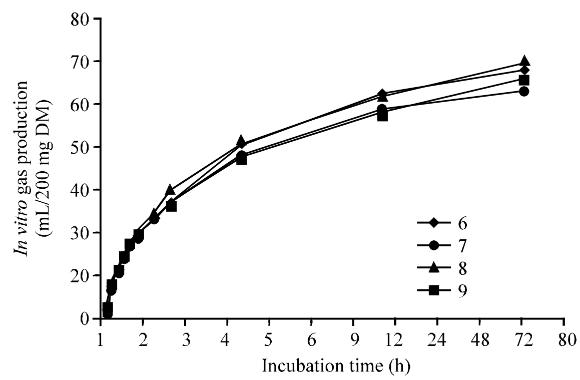

Fig. 2: Pattern of *in vitro* gas production (fitted with logistic model) on incubation of sorghum silages in buffered rumen fluid. 6 = Silo Miel; 7 = Gigante Verde; 8 = 8641; 9 = 855F

GP at 9, 12, 24, 48 and 72 h ($p<0.05$) and positively correlated ($p<0.001$) with parameter B. Lignin content was negatively correlated with IVDMD and parameter B ($p<0.01$). Parameters R and t_{RM} were negatively related with IVDMD ($p<0.05$) and GP. A positive correlation was observed between NFC content and IVDMD; however, a negative correlation between NFC and parameter B ($p<0.0001$) was observed (Table 4). Stepwise linear regression indicated that chemical composition alone is a poor predictor of IVDMD. Prediction of IVDMD was improved when GP data and fermentation parameters were included in the model (Table 5). In the case of IVNDFD, the GP data had little or no effect on its prediction. The chemical compositions of corn and sorghum silages were in the range reported by NRC (2001), Darby and Lauer (2002), Getachew *et al.* (2004) and Kung *et al.* (2008).

However, wide variability was observed between samples, probably because of differences between varieties. The CP value of the 8641 sorghum variety was much higher than the average, possibly because of differences in the sorghum maturity stage. The negative correlation between CP and asymptotic gas production

Table 5: Linear regression analysis to predict IVDMD and IVNDFD

Equation	R^2	Adj. R^2	p-values
$IVDMD = 1176.18-174.0\times pH+9.8\times GP_3$	0.79	0.77	<0.0001
$IVDMD = 1635.3+2.4\times Ash-189.1\times pH+1.2\times NDF+11.1\times GP_6-4.4\times GP_{72}$	0.93	0.90	<0.0001
$IVDMD = 1782.2+2.2\times Ash-213.0\times pH-1.7\times NDF+1.3\times ADF+16.1\times GP_3 4.6\times GP_{48}$	0.93	0.90	<0.0001
$IVNDFD = -53.1+3.9\times CP+23.6\times B+29.0\times t_{RM}-26.0\times GP_3+78.3\times GP_{24}-56.8\times GP_{72}$	0.68	0.53	0.0065
$IVNDFD = -101.2-3.6\times Ash+168.2\times pH+7.2\times Lignin+0.9\times GP_{72}$	0.67	0.58	0.0009
$IVNDFD = -35.3-3.8\times Ash+171.0\times pH+7.2\times Lignin$	0.66	0.60	0.0003

IVDMD = *In Vitro* Dry Matter Digestibility; IVNDFD = *In Vitro* Neutral Detergent Fiber Digestibility; GP = Gas Production at different time of fermentation; t_{RM} = Time after the start of the incubation at which R is Maximal

(parameter A) is in agreement with Getachew *et al.* (2004). The average GP at different incubation times is in agreement with results of De Boever *et al.* (2005) and Hetta *et al.* (2007).

However, GP in the first 3 h of incubation was more variable than GP from 3-24 h and from 24-72 h (CV of 26.3, 7.5 and 6.8%, respectively) which is likely related to differences in chemical composition among silage samples. The GP during the first phase mainly results from fermentation of the soluble fraction, while during the second phase the insoluble but degradable fraction (starch and NDF) is fermented and during the third phase GP is related to microbial turnover (Cone *et al.*, 1997). In the present experiment, this theory is supported by the strong negative correlation between GP at 24 and 48 h with NDF and ADF contents which decreased at 72 h of fermentation. These findings agree with previous experiments (De Boever *et al.*, 2005; Getachew *et al.*, 2004) in which the negative impact of NDF and ADF on GP is evidenced. Also, NDF content had a negative impact on IVDMD in concordance with previous results (Iantcheva *et al.*, 1999; Getachew *et al.*, 2004). In the same way, NDF, ADF and lignin contents were positively correlated (Table 4) with parameter B which indicates that if more NDF, ADF and lignin are in the silage, more time is required to reach the half-asymptotic GP (parameter A); mainly because of a low R.

The same results were noted by De Boever *et al.* (2005). Contrary to Getachew *et al.* (2004) reported no effect of GP on *in vitro* digestibility, in the experiment GP affected IVDMD from 2-72 h of incubation. Lack of an effect during the first hour of incubation is in agreement with Getachew *et al.* (2004) and could be because fat and protein components contribute little to GP.

Chemical composition of the silages alone was a poor predictor of IVDMD but predictability increased markedly when GP data were included in the model (Table 5) similar results were observed by Getachew *et al.* (2004). They concluded that a combination of chemical composition and GP data best predicted digestibility. In contrast, IVNDFD was poorly predicted when GP data were included in the model however when GP data were ignored, R^2 and adjusted R^2 were improved (Table 5).

CONCLUSION

There was a negative correlation of NDF and ADF contents with GP after 9 h of incubation which became strong at 12-48 h of incubation then decreased at 72 h of incubation. The same behavior was observed for NSC except that the correlation was positive. Fermentation parameter B was most influenced by the chemical composition of the silages. Chemical composition alone was a poor predictor of IVDMD but a good predictor of IVNDFD. Based on the correlation between chemical composition of the silages and *in vitro* GP data, the *in vitro* GP technique is a good tool to evaluate forages and when combined with chemical composition data, can be a good predictor of IVDMD.

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