Research Article **AJAR (2020), 5:93**

American Journal of Agricultural Research (ISSN:2475-2002)

Relative plant parts, chemical composition and in vitro gas production evaluation of different Watania corn hybrids silage

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ABSTRACT

Four Commercial corn hybrids included 3 white hybrids, single crosses (SC) Watania 4 (W4) and Watania 6 (W6) and three-way cross (TWC) Watania 11 (W11) and 1 yellow hybrid (SC) Watania 97 (W97) were cultivated at 30 thousand plants per feddan, harvested at 92 days, chopped and ensiled in plastic bags for 35 days. Results revealed that W6 showed the highest ear content (36.60%), W97 the highest stems content (52.47%) W11 had the highest leaves content (18.65%). Watania 11 showed higher CP content and W97 had higher CF and fiber fractions content, while W6 had higher contents of EE, NFE and NFC in comparison with the other hybrids. Gas production at different incubation times as well as gas production from the immediately soluble fraction (a), insoluble fraction (b) and soluble and insoluble fractions (a + b) as well as the gas production rate constant for the insoluble fraction (c) values were significantly ($P<0.05$) higher for W6 than that of W97 with insignificant differences with both W4 and W11. Gas production from the fermentation of soluble fraction (GPSF) of W6 and insoluble fraction (GPNSF) of W4 and W6 were significantly ($P<0.05$) compared to W97. The concentration of SCFA was significantly ($P<0.05$) higher for W4 and W6 compared to W97 and not significantly ($P>0.05$) different with W11. The predicted dry matter intake (DMI) and organic matter digestibility (OMD) of corn silage were higher significantly ($P<0.05$) for W6 than that of W97, whereas were nearly similar for W4 and W11 and insignificantly ($P>0.05$) different with both W6 and W97. The predicted metabolizable energy (ME, Mcal/kg DM) and net energy (NE, Mcal/kg DM) contents were nearly similar for the different corn hybrids silage without significant differences ($P>0.05$). Microbial protein yield (MP) was higher significantly ($P<0.05$) for both W4 and W6 compared to W97, whereas MP yield for W11 not significantly ($P>0.05$) differences with W4, W6 and W97.

Keywords: Corn hybrids silage, composition, gas production, energy content, microbial protein.

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How to cite this article:
Gaafar, H.M.A.; W.A. Riad; Ghada S. El-Esawy and M.E.A. Nasser. Relative plant parts, chemical composition and in vitro gas production evaluation of different Watania corn hybrids silage. American Journal of Agricultural Research, 2020,5:93.

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Website: https://escipub.com/

INTRODUCTION

Maize silage is used extensively in diets for dairy and beef cattle in most part of the world. Maize silage is normally high energy forage with high dry matter yield relative to the other forage crops (Coors, 1996). Whole-plant corn silage (CS) is commonly used in rations of dairy cows in many parts of the world. It has a high content of starch and generally good ensiling characteristics (Khan *et al*., 2015). The increased demand for animal feed and the low availability of land for cultivation has necessitated the search for new varieties of hybrid maize (Johnson *et al*., 2003; Ivan *et al.*, 2005), which implies the need for new alternatives with heterosis for increased nutritional value in both forage and grain. The method of silage preservation is based on converting the soluble carbohydrates in organic acids, mainly lactic acid, under anaerobic conditions by lactic acid bacteria (McDonald *et al.*, 1991). In the past decades much research has been done to establish the optimal ensiling conditions, such as harvest date (Mayombo *et al.*, 1993; Hartmann *et al.*, 2000), dry matter content of the plants at harvest (Yahaya *et al.*, 2002), genotype (Schwarz *et al.*, 1996; Argillier and Barriere, 1996; Johnson *et al.*, 2003), weather conditions during growth (Meisser and Wyss, 1998), breeding strategies (Barriere *et al.*, 1997; Bavec and Bavec, 2002), and physical properties of the ensiled material (Stockdale and Beavis, 1994; Johnson *et al.*, 2003). The introduction of new maize hybrids has provided new raw materials with a range of nutritional characteristics. Large differences in nutritional value may exist between silage made from different maize hybrids (Hunt *et al.*, 1993).

The technique of in vitro gas production (Menke and Steingass, 1988), or the modifications by Theodorou *et al.* (1994) in simulating the digestive processes generated from microbial production (Getachew, 1998), allows us to know the fermentation and degradation of food according to the nutritional quality and availability of nutrients for ruminal bacteria.

There are a number of factors that affect fermentation of feeds in vitro and could cause intra- or inter-laboratory differences. These are mainly associated with the nature of rumen fluid inoculum, although breed of animal, its physiological condition, diet, time of feeding, time of collection of rumen fluid relative to feeding time (Craig *et al*., 1987), method of rumen fluid collection (i.e. liquid or solid phase) (Craig *et al*., 1987; Cecava *et al*., 1990), and time elapsed between rumen fluid sampling and inoculation (Robinson *et al*., 1999) are all factors that have been shown to influence microbial activity in vitro.

Since high correlation existed between digestibility measured in vivo and predicted from an in vitro rumen gas production technique in combination with chemical composition, a considerable number of researchers has used in vitro gas techniques to study associative effects of various types of feedstuffs, and examine influences on rumen fermentation (Liu *et al.*, 2002; Getachew *et al.*, 2003). Assessment of in vitro gas production (GP) is largely used to evaluate the nutritive value of ruminant feeds by incubating substrate in buffered rumen fluid (Cone *et al.*, 1996; Getachew *et al*., 1998; Dijkstra *et al.*, 2005).

The aim of the present study was to investigate relative plant parts, chemical composition, *in vitro* gas production, energy value, organic matter digestibility, dry matter intake and microbial protein production of different corn hybrids silage.

MATERIALS AND METHODS

Four Commercial corn hybrids included 3 white hybrids, single crosses (SC) Watania 4 (W4) and Watania 6 (W6) and three-way cross (TWC) Watania 11 (W11) and 1 yellow hybrid (SC) Watania 97 (W97) were cultivated in the Experimental Farm of National Seed Company, Minya El Qamh, El Sharkeya Governorate, Egypt.

A split plot design with four corn hybrids, the size of each plot was 175 m^2 (14 rows each row 17.86 m long and 70 cm rows spacing). All hybrids were cultivated at 20 June with planting density 30 thousand per feddan using 15 kg corn grains for all hybrids. Grains were planted in hills spaced 17 cm apart within the row. Maize plants were later thinned to one plant per hill.

Handing hoeing's was done before the first and second irrigations and pesticides were sprayed as necessary. Organic fertilizer was added to the soil before plowing at 20-30 cubic meters per feddan and inorganic fertilization were 120 nitrogen units per feddan, equivalent to 6 bags of urea, or 8 bags of nitrate, 150 kg super phosphate and 50 kg potassium sulphate per feddan, and therefore to obtain the highest production and divide the compost in the first two steps after the haze and before the prehistoric and the second before the next larvae of the soil and add compost below and below plants.

The first irrigation was applied after 21 days from sowing, while the following irrigations were applied at 2 or 3 weeks interval and stopping irrigation before harvesting about two weeks.

Three sub-plots with area of 1 m per row for each corn hybrid were taken randomly to estimate the yield of whole plant corn forage crop its parts. Ears, stems and leaves were weighed for each sub-plot of each corn hybrid and calculated per feddan. Whole corn plants were harvested at the dough stage of maturity after 92 days of planting, chopping using Holland Chopper machine to 1-1.5 cm of length and ensiled in double plastic bags for 35 days.

Representative samples of different silages were analyzed according to the methods of AOAC (1990). Fiber constituents, neutral detergent fiber (NDF) was determined according to Van Soest and Marcus (1964). Acid detergent fiber (ADF) and acid detergent lignin (ADL) was determined according to Van Soest (1963).

In vitro gas production was undertaken according to the procedure described by Menke and Steingass (1988). Samples (100 mg) of the air-dry feedstuffs were accurately weighted into 50 ml calibrated glass syringe fitted with plungers. The buffer solution was used in vitro gas production defined as MB9 (Onodera and Handerson, 1980). The buffer consisted of 2.8 g NaCl; 0.1 g CaCl2; 0.1 MgSO4.7H2O; 2.0 g KH2PO4; 6.0 g Na2HPO4 which dissolved in distilled water and mad up to 1 L. Then the pH adjusted at 6.8 and CO2 flushed for 15 min. Rumen contents (50% solid: 50% liquid, Bueno et al., 2005) were collected from three rumen cannulated sheep which were fed with rice straw ad lib and commercial concentrate mixture. The rumen contents were collected were before the morning feeding of the animals. Liquids and solids were placed in pre-warmed (39 ºC) insulated flasks and transported under anaerobic conditions to the laboratory. The rumen contents were squeezed through four layers of cheese-cloth and kept in a water bath at 39 ºC with CO_2 saturation until inoculation took place. The buffer and inoculant (2:1 v/v) were mixed and kept in a water bath at 39 ºC with CO_2 saturation (Sallam, 2005; Soliva *et al*., 2005 and Nasser *et al*., 2006). Buffered rumen fluid (15 ml) is pipetted into each syringe, containing the feed samples, and the syringes are immediately placed into the water bath at 39 ºC. Three runs were performed for each experiment. Syringes of each run included two syringes contain only buffered rumen fluid are incubated and considered as the blank. The syringes are gently shaken every 2hr, and the incubation terminated after recording the 96 h gas volume. The gas production was recorded after 3. 6. 9. 12. 24. 48. 72 and 96hr of incubation. Total gas values are corrected for the blank incubation and reported gas values are expressed per 200 mg of DM. Fermentation kinetics was described according to Ørskov and McDonald (1979) as:

$$Y = a + b(1 – e\text{-}ct)$$

Where: Y is gas production (ml/g OM) at time t, a is gas production from the immediately soluble fraction, b is gas production from the insoluble fraction and c is gas production rate constant for fraction b. As a new approach to evaluate feeds from those parameters, gas production caused by fermentation of the soluble fraction (GPSF) was estimated by gas produced after 3hr (GP3) of incubation. Gas production caused by fermentation of the insoluble fraction (GPNSF) could be estimated from the gas production between 3hr (GP3) and 24hr (GP24) of incubation according to Van Gelder *et al.* (2005) as follows:

GPSF= GP 3hr * 0.99 - 3

GPNSF= 1.02*(GP 24hr – GP 3hr) + 2

Where: GP 3hr is 3hr net gas production (ml/200mg DM), GP 24hr is 24hr net gas production (ml/200 mg DM), GPSF is gas production from soluble fraction (ml/g DM) and GPNSF is gas production from non-soluble fraction (ml/g DM).

The energy values were calculated from the amount of gas produced at 24hr of incubation with supplementary analyses of crude protein, ash and crude fat. This approach was developed by the research group in Hohenheim (Germany) and is based upon extensive in vitro incubation of feedstuffs (Menke *et al.*, 1979 and Menke and Steingass, 1988).

ME (Mcal/kg DM) = (2.2 + 0.136*GP 24hr + 0.057*CP + 0.0029*CF^2)/4.186

NE (Mcal/kg DM) = (2.2 + 0.136*GP 24hr + 0.057*CP + 0.0029*CF^2 + 0.149*EE)*2.2/ 14.64

Where: ME is the metabolizable energy (Mcal/kg DM), GP is 24hr net gas production (ml/200 mg DM), CP is crude protein (% of DM) and EE is either extract (% of DM).

OMD (%) = 14.88 + 0.889*GP 24hr + 0.45*CP + 0.0651*Ash

Where: OMD is organic matter digestibility (%), GP is 24hr net gas production (ml/200mg DM), CP is crude protein (% of DM), Ash (% of DM). Short chain fatty acids (SCFA) were calculated according to the Getachew *et al.* (2005) as follow:

SCFA (mM) = (- 0.00425 + 0.0222*GP 24hr)*100

Where: GP is 24hr net gas production from the soluble fraction (ml). Dry matter intake (DMI) was calculated according to Blummel and Ørskove (1993) as follow:

DMI = 1.66 + 0.49 * (a) + 0.0297 * (b) – 4 * (c)

Where: a = the gas production from the soluble fraction (ml), b = the gas production from the insoluble fraction (ml), c = the gas production rate (ml/hr).

Microbial protein (MP) production was calculated as 19.3 g microbial nitrogen per kg OMD according to Czerkawski (1986).

MP (g/kg DM) = OMD * 19.3 * 6.25/100

The data were subjected to statistical analysis using factorial model procedure adapted by IBM SPSS Statistics (2014) for user's guide with one-way ANOVA. Duncan test within program SPSS was done to determine the degree of significance between the means (Duncan, 1955).

RESULTS AND DISCUSSION

Relative plant parts:

The relative weight of plant parts in Table (1) revealed that W6 showed the highest ear content (36.60%) followed by W4, whereas W97 had the lowest value (29.84%). W97 showed the highest stems content (52.47%) followed by W11, but W6 had the lowest content (46.71%). Moreover, the highest leaves content was in W11 (18.65%) followed by W97, while W4 had the lowest one. These results agreed with those obtained by Bendary *et al*. (2001) who found that the differences in the relative parts may be attributed to the potential hybrid as well known as the scientific fact. Even though the grains to stalk ratio and whole plant dry matter (DM) yields are important determinants of the adaptability of a corn hybrid to silage production (McDonald *et al*., 1991). Corn hybrids should have a grain content of at least 35% in order to maximize profits and output for TDN and DCP; furthermore, these relationships should be incorporated in the respective plant breeding programs in the future (Gaafar, 2004). Earlier results obtained by Avcioglu *et al.* (2003) proved that yield, plant height, protein and ash contents of the maize varieties were significant differ among them.

Table 1. Relative plant parts of different corn hybrids.

Item	W4	W6	W11	W97	SEM
Relative plant parts (% of whole plant)					
Ear	33.64[b]	36.60[a]	30.47[c]	29.84[c]	0.84
Stems	49.72[b]	46.71[c]	50.88[ab]	52.47[a]	0.68
Leaves	16.64[c]	16.69[c]	18.65[a]	17.69[b]	0.28

a, b, c: Values in the same row with different superscripts differ significantly (P<0.05).

Chemical composition:

Chemical composition of corn hybrids silage in Table (2) revealed that DM was slightly higher in W97 than that of the others hybrids and this might be due to that yellow hybrid mature early than white hybrids. The contents of OM and ash were typically similar among the different corn hybrids. Watania 11 showed higher CP content and W97 had higher CF content, while W6 had higher contents of EE and NFE in comparison with the other hybrids. The contents of OM, EE and NFE increased with increasing ear content (r= 0.65, 0.91 and 0.92, respectively). The content of CP increased with increasing leaves content (r= 0.89) and contents of CF and ash increased with increasing stems content (r= 0.90 and 0.52, respectively). Similar results were obtained by Gaafar (2001) and Bendary *et al.* (2001) who found some differences in chemical composition among the different corn hybrids due to the differences in relative plant parts content. Gaafar (2004) indicated that the contents of DM, OM and NFE increased and the contents of CP, CF, EE and ash decreased significantly (P<0.05) with increasing grain content.

Table 2: Chemical composition and fiber fractions of different corn hybrids silage.

Item	W4	W6	W11	W97
DM, %	31.20	31.65	31.80	33.45
Composition of DM, %				
OM	93.65	93.54	93.44	93.40
CP	7.82	7.86	8.15	8.04
CF	26.53	25.89	27.02	27.92
EE	2.83	2.91	2.73	2.61
NFE	56.47	56.88	55.54	54.83
Ash	6.35	6.46	6.56	6.60
Fiber fractions, %				
NDF	50.84	49.87	52.88	53.05
ADF	30.60	29.31	31.61	31.93
ADL	5.81	5.43	5.83	6.02
Hemicellulose	20.24	20.56	21.27	21.12
Cellulose	24.79	23.88	25.78	25.91
NFC	32.16	32.90	29.68	29.70

Fiber fractions:

Fiber fractions and non-fiber carbohydrates of different corn hybrids silage in Table (2) revealed that the contents of all fiber fractions (NDF, ADF, ADL, hemicelluloses and cellulose) were mostly slightly higher in W11 and W97 followed by W4 and were lower in W6. However, non-fiber carbohydrate (NFC) revealed opposite trend, which was slightly higher in W6 followed by W4 and was lower in W11 and W97. Similar results obtained by Hemken *et al*. (1971) and Joanning *et al*. (1981) who showed that increasing grain content resulted in diluting the fiber components.

Cumulative gas production:

Cumulative gas production for different corn hybrids silage is shown in Table (3). Gas production differ significantly (P<0.05) among the different corn hybrids silage at the different incubation time. Gas production at different incubation time was significantly (P<0.05) higher for W6 than that of W97. Whereas, gas production at the different incubation time was slightly similar for both W4 and W11 and not differ significantly (P>0.05) with both W6 and W97. Incubation of feedstuff with buffered rumen fluid in vitro, the carbohydrates are fermented to short chain fatty acids (SCFA), gases mainly CO and CH and microbial cells. Gas production is basically the result of fermentation of carbohydrates to acetate, propionate and butyrate. Gas production from protein fermentation is relatively small as compared to carbohydrate fermentation while, contribution of fat to gas production is negligible (Beuvink and Spoelstra, 1992 and Blummel and Ørskov, 1993). Fiber quality is extremely important for the complete action of cellulolytic bacteria, responsible for high rates of microbial colonization to the substrate, and resulting in efficient energetic use of the evaluated feeds (Sun *et al*., 2007). Silva and Ørskov (1988) observed that the presence of a source of readily digestible cellulose and hemicellulose increased the numbers of ruminal fibrolytic microorganisms and, consequently, may improve digestibility of other less degradable fiber sources. Gas production is an indirect measure of substrate degradation and it is not always positively related to microbial mass production (Liu *et al.*, 2002). The technique of in vitro gas production (Menke and Steingass, 1988), or the modifications by Theodorou *et al.* (1994) in simulating the digestive processes generated from microbial production (Getachew, 1998), allows us to know the fermentation and degradation of food according to the nutritional quality and availability of nutrients for ruminal bacteria. Haddi *et al.* (2003) reported that there were significant negative correlation between NDF and ADF, and the rate and extent of GP.

Table 3: Cumulative gas production of different corn hybrids silage.

Incubation time (hours)	W4	W6	W11	W97	SEM
3	15.98^{ab}	16.28^{a}	15.67^{ab}	15.07^{b}	0.18
6	24.59^{ab}	25.06^{a}	24.13^{ab}	23.20^{b}	0.27
9	31.19^{ab}	31.78^{a}	30.60^{ab}	29.43^{b}	0.35
12	39.56^{ab}	40.31^{a}	38.81^{ab}	37.32^{b}	0.44
24	53.17^{ab}	54.23^{a}	52.07^{ab}	49.90^{b}	0.59
48	61.11^{ab}	62.26^{a}	59.96^{ab}	57.65^{b}	0.68
72	65.19^{ab}	66.42^{a}	63.96^{ab}	61.50^{b}	0.73
96	67.96^{ab}	69.24^{a}	66.68^{ab}	64.12^{b}	0.76

a, b: Means in the same row with different superscripts differ significantly (P<0.05).

Fractions and rate of gas production

Fractions and rate of gas production of different corn hybrids silage are shown in Table (4). The gas production from the immediately soluble fraction (*a*), insoluble fraction (*b*) and soluble and insoluble fractions (*a* + *b*) as well as the gas production rate constant for the insoluble fraction (*c*) values were significantly (P<0.05) higher for W6 compared to W97, whereas, values of *a, b* and *c* of W4 and W11 were not significantly (P>0.05) different with those of both W6 and W97. Garcıa-Rodriguez *et al.* (2005) reported that differences in parameters *b* and *c* between silages indicate different fermentation patterns. The aforementioned characteristics of whole plant corn are in line with the observations that both the asymptotic GP of the soluble fraction (*a*) and the associated maximum rate of gas production (*c*) decreased with increasing maturity, whereas the half time of maximum GP of the soluble fraction (*a*) increased with increasing maturity. Furthermore, the maximum rate of gas production of the insoluble fraction (*b*) increased with increasing maturity, thereby reflecting the greater digestibility of starch versus NDF (Macome *et al.*, 2017).

Table 4: Gas production fractions and gas production rate of different corn hybrids silage.

Item	W4	W6	W11	W97	SEM
a (ml/g DM)	6.71^{ab}	6.84^{a}	6.58^{ab}	6.33^{b}	0.07
b (ml/g DM)	60.84^{ab}	61.99^{a}	59.69^{ab}	57.40^{b}	0.68
a+*b* (ml/g DM)	67.55^{ab}	68.82^{a}	66.27^{ab}	63.73^{b}	0.75
c (ml/hour)	0.061^{ab}	0.062^{a}	0.060^{ab}	0.057^{b}	0.001

a, b: Means in the same column with different superscripts differ significantly (P<0.05).

Gas production from soluble and insoluble fractions

The gas production from the fermentation of soluble fraction (GPSF) and insoluble fraction (GPNSF) of corn hybrids silage are presented in Table (5). The GPSF of W6 was significantly (P<0.05) higher than that of W97 with insignificant difference with both W4 and W11. While, GPNSF was significantly (P<0.05) for W4 and W6 compared to W97 and not significantly different with W11. The gas production of rice straw silage from the insoluble fraction was about three folds higher than the gas production from the soluble fraction. The ruminant forages are currently described by three different features; the soluble fraction, insoluble fraction and the rate of degradation (Orskov *et al.*, 1988 and Orskov, 1991). The soluble fraction, commonly named washing loss, represents the water soluble components of the organic matter or the dry matter. It includes the soluble sugars and soluble compounds as polyphenolics liberated during the fermentation process (Ly *et al.*, 1997). Besides, these parameters are used for assessing the nutritive value of feeds (Orskov, 1991 and Ly and Preston, 1997).

Short chain fatty acids (SCFA):

The concentration of short chain fatty acids (SCFA) of in vitro fermented corn hybrids silage is shown in Table (5). The concentration of SCFA was significantly (P<0.05) higher for W4 and W6 compared to W97 and not different significantly (P>0.05) with W11. Incubation of feedstuff with buffered rumen fluid in vitro, the carbohydrates are fermented to short chain fatty acids (SCFA) and gases mainly CO and CH (Beuvink and Spoelstra, 1992 and Blummel and Ørskov, 1993). The degradability measurement accounts for feed conversion into all products of microbial degradation and synthesis, essentially microbial biomass, short chain fatty acids (SCFA) and gases, whereas the gas volume measurement reflects feed conversion into SCFA and gases (Grings *et al*., 2005). The complex interactions within a mixed rumen microbial population leading to the conversion of plant components to gas and SCFA (Van Soest, 1994). Getachew *et al.* (2002) reported the close association between SCFA and the in vitro GP, and used the relationship between SCFA and GP to estimate the SCFA production from gas values, which is an indicator of energy availability to the animals. The gas production of different classes of feed incubated in vitro in buffered rumen fluid was closely related to the production of SCFA, s which was based on carbohydrates fermentation (Sallam *et al.*, 2007, Kanak *et al.*, 2012 and Blummel and Oraskov 1993). Concentration of SCFA obtained in the present study ranged from 110.35 to 119.97 Mm/l, which are within the normal range of 70 to 150 mM/L as indicated by McDonald *et al.* (2002).

Table 5: Fermentation of the soluble (GPSF) and insoluble (GPNSF) fractions and short chain fatty acids (SCFA) of different corn hybrids silage.

Item	W4	W6	W11	W97	SEM
GPSF (ml/g DM)	12.82^{ab}	13.12^{a}	12.52^{ab}	11.92^{b}	0.18
GPNSF (ml/g DM)	39.93^{a}	40.71^{a}	39.12^{ab}	37.52^{b}	0.42
SCFA (mM/L)	117.60^{a}	119.97^{a}	115.16^{ab}	110.35^{b}	1.13

a, b: Means in the same column with different superscripts differ significantly (P<0.05).

Dry matter intake (DMI):

From the results in Table (6), we believe that in vitro gas production of corn hybrids silage are valuable predictors of the voluntary intake potential when fed alone or in mixed rations. The predicted DMI of corn silage was higher significantly (P<0.05) for W6 than that of W97, whereas DMI of silage was nearly similar for W4 and W11 and insignificantly (P>0.05) different with both W6 and W97. The predicted DMI for different hybrids silage ranged from 6.24 to 6.60 kg/day and these values were higher compared with the other forages reflecting high palatability of corn silage. Forage intake is mainly restricted by low digestibility, where the content of the cell wall constituents has the greatest impact on digestibility (Blummel and Becker, 1997; Mould, 2003). Several authors have found high correlations between in vitro GP studies and DMI of forages (Blummel and Becker, 1997; Hetta *et al.*, 2007).

Organic matter digestibility (OMD):

Based on the strong relationship between measured digestibility and that predicted from gas production, regression equations have been developed and the method has been standardized. As presented in Table (6) the OMD of W4 and W6 was higher significantly (P<0.05) than that of W97, while OMD of W11 was not significantly (P>0.05) different with W4, W6 and W97. The OMD for W4, W6, W11 and W97 were 66.18, 67.05, 65.26 and 63.19%, respectively. Using the in vitro gas measurement and chemical composition in multiple regression equation, Menke *et al.* (1979), McLeod and Minson (1971) and Van Soest (1994) found a high precision in prediction of in vivo OMD. The effective rumen degradability of OM as well as the total-tract digestibility of OM decreased with advanced maturity of whole plant corn at harvest (Hatew *et al*., 2016).

Table 6: Dry matter intake (DMI) and organic matter digestibility (OMD) of different corn hybrids silage.

Item	W4	W6	W11	W97	SEM
DMI (kg/day)	6.51^{ab}	6.60^{a}	6.42^{ab}	6.24^{b}	0.05
OMD (%)	66.18^{a}	67.05^{a}	65.26^{ab}	63.19^{b}	0.53

a, b: Means in the same column with different superscripts differ significantly (P<0.05).

Metabolizable energy (ME) and net energy (NE):

The predicted metabolizable energy (ME, Mcal/kg DM) and net energy (NE, Mcal/kg DM) from gas production for corn hybrids silage are presented in Table (7). The predicted ME and NE contents were nearly similar for the different corn hybrids silage without significant differences (P>0.05). Values of ME and NE ranged from 2.79 and 1.82 to 2.85 and 1.86 Mcal/ kg DM, respectively. There was a positive correlation between metabolizable energy calculated from 24 hours in vitro gas production together with protein and fiber contents with metabolizable energy value of conventional feeds measured in vivo (Menke and Steingass, 1988). The in vitro gas production method has also been widely used to evaluate the energy value of several classes of feeds (Getachew *et al*., 1998), particularly straws (Makkar *et al*., 1999).

Table 7: Metabolizable energy (ME), net energy (NE) and microbial protein (MP) of different corn hybrids silage.

Item	W4	W6	W11	W97	SEM
ME (Mcal/kg DM)	2.84	2.85	2.83	2.79	0.01
NE (Mcal/kg DM)	1.85	1.86	1.84	1.82	0.01
MP (g/kg DM)	79.83[a]	80.88[a]	78.72[ab]	76.22[b]	0.64

a, b: Means in the same column with different superscripts differ significantly (P<0.05).

Microbial protein:

Improving the yield of rumen microbial protein (MCP) has significant importance in the promotion of animal performance and the reduction of protein feed waste. The amount of energy supplied to rumen microorganisms is an important factor affecting the amount of protein nitrogen incorporated into rumen MCP. An energy-rich diet induces a significant increase in rumen MCP yield, whereas a protein-rich diet has no significant impacts on it (Lu *et al*., 2019). Results in Table (7) showed that microbial protein yield (MP) was higher significantly (P<0.05) for both W4 and W6 compared to W97, whereas MP yield for W11 not significantly (P>0.05) differences with W4, W6 and W97. Microbial protein yield ranged from 76.22 to 80.88 g/kg DMI. The sources and amounts of fed carbohydrate are the major factors affecting the energy, available for rumen microbial growth (synthesis of MCP in particular), and that of fed protein affects the production of microbial dry matter (DM) per unit of carbohydrate fermented (Hoover and Stokes, 1991). In the dairy cow, 12–13% protein content is needed to maximize the ruminal synthesis of MCP (Satter and Roffler, 1975). More protein N is incorporated into rumen MCP only if more non-fiber carbohydrate (NFC), known to be the major energy substrate for ruminal microorganisms, are fed to the animals (Schwab *et al.*, 2005). This microbial protein supplies 60 to 85% of amino acids (AA) reaching the animal's small intestine (Storm *et al*., 1983). In the small intestine, more than 80% of rumen MCP is digested, accounting for 50–80% of the total absorbable protein contained there (Tas *et al*., 1981; Storm *et al*., 1983).

CONCLUSION

From these results it could be concluded that watania 6 corn hybrid silage showed high ear content, non-fiber content, gas production, short chain fatty acids, dry matter intake, organic matter digestibility and microbial protein synthesis. Whereas Watania 11 had leaves and protein contents and Watania 97 had high stems and fiber contents.

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