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Nutritive Value Assessment of Some Saudi Arabian Foliages by Gas Production Technique *in vitro*

A. A. Bakhashwain, S. M. A. Sallam[1] and **A. M. Allam**

Arid Land Agriculture Department, Faculty of Meteorology, Environment and Arid Land Agriculture, King Abdulaziz University, Saudi Arabia, and [1]*Animal Production Department, Faculty of Agriculture, Alexandria University, Alexandria, El-Shatby, Egypt*

Abstract. Chemical composition, microbial rumen fermentation, energetic values and microbial mass of some Saudia Arabia foliages were investigated in comparison with alfalfa as high quality roughage using the Hohenheim gas test. A gas test technique was performed using buffered rumen fluid collected from three rumen fistulated sheep. Cumulative gas production was recorded at 3, 6, 9, 12, 24, 48, 72 and 96 h of incubation *in vitro*. The investigated browses were Blue panic (*Panicuma antidotale*), *Moringa oleifera*, Jojoba (*Simmondsia chinensis*), Canary grass (*Phalaris spp.*) and Millet (*Eleusine coracana*) leaves. The browses were collected at the wet season in Saudi Arabia. Alfalfa and moringa leaves had the highest crude protein (CP) content, while the canary grass and blue panic had the lowest CP content. The neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were higher in blue panic, canary grass, millet and alfalfa, while the moringa leaves showed the lowest content of the fiber constituents. The secondary compounds analyses showed negligible contents of these feeds for total phenol (TP), total tannins (TT) and condensed tannins (CT) except jojoba leaves. Alfalfa, blue panic, moringa, canary grass and millet had negligible CT content, while jojoba leaves had the highest CT content (30.04 eq-g leucocyanidin kg^{-1}DM). The potential gas production was highest ($p<0.05$) for alfalfa, moringa, and millet leaves, while the canary grass and jojoba leaves recorded the lowest gas production. Although, jojoba leaves produced less gas volume, it had the shortest lag time (L, 0.4139 h^{-1}) and lowest rate of gas production (μ h^{-1}). The longest L value (2.379, h^{-1}) was noted with canary grass. There were significant ($p<0.05$) differences in terms of predicted short chain fatty acids (SCFA), metabolizable energy (ME), net energy (NE), organic matter digestibility (OMD) and microbial protein (MP). The moringa and jojoba leaves in comparison with alfalfa showed the highest ($p<0.05$) SCFA, energy content, OMD and MP. The ranking order of the investigated browse species on the basis of their energy content, organic matter degradability and microbial protein was moringa > jojoba > millet > blue panic > canary grass. In conclusion, significant variations in *in vitro* fermentation and degradation were observed among different browse species collected from Saudi Arabia through the wet season. The results suggest that moringa leaves are promising alternative feed resource and could be incorporated in ruminants feed mixtures to replace conventional roughage sources (alfalfa) without major problems.

Keywords. foliages, Saudi Arabia, *in vitro*, gas production, energy content, degradation, microbial mass.

Introduction

Ruminant feeding is mainly based on grazing, specifically of Graminaceae. Grasses yield is in general not enough to satisfy the nutritional requirements of animals in the six months of dry period each year. The dry season causes nutritional stress and consequently decreases animal productivity. Supplementation with concentrates during the dry season is not a profitable practice due to high feeding costs (Benavides, 1994). A potential strategy for increasing the quality and availability of feeds for smallholder ruminant animals in the dry season may be through the use of fodder trees and shrub forages (Pezo, 1991). Most trees and shrubs are easily propagated and do not require high management inputs (fertilizer, pesticides, *etc*.) or advanced technology.

Browse foliages are compensatory components in the diets of cattle, sheep and goats and wild in arid and semi-arid regions. The recognition of the potential of tree foliage to produce considerable amounts of high protein biomass and energy especially in harsh and arid conditions has led to the development of animal farming systems that integrate the use of tree foliages with local bulky feed resources (Devendra, 1990). One of these potential tree forages is Moringa (*Moringa oleifera* Lam) which grows throughout the tropics.

Determining the digestibility of feeds *in vivo* is laborious, expensive, requiring large quantities of feed, and is largely unsuitable for a single feedstuff, thereby making it unsuitable for routine feed evaluation (Getachew, *et al*., 2004). There are numbers of *in vitro* techniques available to evaluate the nutritive value of feeds at relatively low cost. The *in vitro* gas production (GP) technique has been used as a measure of ruminal degradation of feeds (Menke and Steingass, 1988, and Getachew *et al*., 1998) and as an indicator of digestible dry matter intake and growth rate of cattle fed cereal straws (Bümmel and Ørskov, 1993, and Williams *et al*., 1996). Gas production technique also has potential to investigate associative effects between feeds (Liu *et al*., 2003, and Bakhashwain, *et al*., 2009) and evaluate the energy value of several classes of feeds (Getachew *et al*., 1998), particularly straws (Makkar *et al*., 1999) and agro-industrial by-products (Krishnamoorthy *et al*., 1995, and Sallam *et al*., 2008).

Increased interest in the use of non-conventional feed resources has led to an increase in the use of *in vitro* GP techniques to provide useful data on digestion and fermentation kinetics of both the soluble and insoluble fractions of browses and tannin bioassay. Therefore, nutritional evaluation of tree forages in terms of phenolics, *in vitro* gas production, substrate fermentability and fermentation activity were undertaken to assess *in vitro* the nutritive value of some tree foliages in comparison with alfalfa as high quality roughage.

Materials and Methods

The tree foliages were harvested and analyzed at the Department of Arid Land Agriculture, King Abdulaziz University, Saudi Arabia. The gas test was carried out at the Laboratory of Rumen Microbiology, Animal Production Department, Faculty of Agriculture, Alexandria University, Egypt.

Foliages Preparation

Five foliages (blue panic *(Panicuma antidotale)*, moringa (*Moringa oleifera*), Jojoba (*Simmondsia chinensis*),canary grass (*Phalaris spp.*) and millet (*Eleusine coracana*)) leaves grown at Hada Al-Sham Experimental Station, Department of Arid Land Agriculture, King Abdulaziz University, Saudi Arabia were harvested during the winter season 2008. Samples were chopped to 8 mm length and the dry matter content was determined according to AOAC (1995), then ground in mills to pass a 1 mm sieve prior to chemical analyses and *in vitro* gas production measurements.

Chemical Analyses

Plant samples were analyzed according to AOAC (1995) for dry matter (DM), organic matter (OM), crude protein (CP) – as 6.25 × N, acid-detergent fibre (ADF), neutral-detergent fibre (NDF) and acid-detergent lignin (ADL) (Mertens, 2002). Sodium sulphite and alpha amylase were not added to the solution for the NDF determination. Samples were also analyzed for extractable total phenols (TP), total tannins (TT) and condensed tannins (CT). Dried plant material (200 mg) was extracted with acetone: Water (10 ml; 70:30 v/v) in an ultrasonic bath for 20 min. The contents were centrifuged (4°C, 10min, 3000 *g*) and the supernatant was kept on ice until analysis. Total phenols were determined with the Folin-Ciocalteau reagent (Makkar, *et al*., 1993, and Makkar 2003). Extractable tannins were determined as the differences in total phenols (measured by Folin-Ciocalteau reagent) before and after treatment with insoluble polyvinyl polypyrrolidone (PVPP), as this polymer binds strongly to tannins (Makkar *et al*., 1995). TP and TT were expressed as tannic acid equivalents. Condensed tannins were measured by the HCl-butanol method and results were expressed as leucocyanidin equivalent (Makkar, 2003).

In vitro Gas Production

In vitro gas production was completed according to the procedure described by Menke and Steingass (1988). Buffer and mineral solutions were prepared and placed in a water bath at 39^{o}C under continuous flushing with CO_2. Rumen fluid was collected from three fistulated sheep fed on berseem hay and commercial concentrate mixture diet into a pre-warmed thermos flask. The rumen fluid was filtered and flushed with CO_2, and the mixed and CO_2-flushed rumen fluid was added to the buffered mineral solution (1:2 v/v), which was maintained in a water bath at 39oC. Samples (200 ± 10 mg) of the air-dry feedstuffs were accurately weighed into syringes fitted with plungers. Buffered rumen fluid (30 ml) was pipetted into each syringe, containing the feed samples, and the syringes were immediately placed into water bath at 39oC (Blümmel and Ørskov, 1993). Three syringes with only buffered rumen fluid were incubated and considered as blank. The syringes were gently shaken every 2 h, and the incubation was terminated after recording the 72 h gas volume. The gas production was recorded after 3, 6, 9, 12, 24, 48, 72 and 96 h of incubation. Cumulative gas was expressed as milliliter of gas produced per 200 mg of dry matter and corrected for blanks.

Cumulative gas production was fitted iteratively to the exponential model proposed by France *et al*. (1993), $Y = A \{1 - \exp^{[-b(t-L) - c(\sqrt{t}-\sqrt{L})]}\}$, with the exclusion of the intercept, where y is the cumulative gas production (in ml) at time t; A, the asymptote (in ml); b and c, rate constants (in h^{-1}); and L, the lag time (in h). The fractional rate (μ, h^{-1}) was considered to vary with time according to $\mu = (b + c)/(2\sqrt{t})$, $t \geq L$.

Estimated Parameters

As a new approach to evaluate feeds from these parameters, gas accumulated after 3 h (GP3) was considered as an indicator to the fermentation of the soluble fraction (GPSF). While the gas production from 3 h (GP3) and 20 h (GP20) was considered as an indicator to the fermentation of the non soluble fraction (GPNSF) according to Van Gelder, *et al*. (2005).

Energy values (metabolizable energy (ME) and net energy (NE)) of the investigated feedstuffs were calculated from the amount of gas produced at 24 h 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).

$$\text{ME (MJ/kg DM)} = 1.06 + 0.157 \times GP + 0.084 \times CP + 0.22CF - 0.081 \times CA$$

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

Where: OMD is organic matter digestibility

GP is 24 h net gas production (ml/200 mg DM)

CP is crude protein (% of DM)

CA is ash (% of DM)

$$\text{NE (Mcal/lb)} = (2.2 + (0.0272 \times GP) + (0.057 \times CP) + (0.149 \times CF)) / 14.64$$

Where: GP is 24 h net gas production (ml/g DM)

CF is crude fat (% of DM)

Then the NE unit was converted to be MJ/kg DM, microbial protein (MP, g/kg DOM) was calculated according to Czerkawski (1986). Short chain fatty acids (SCFA) were calculated according to Getachew *et al*. (2002).

Statistical Analyses

Data were analyzed by the generalized linear model procedure in SAS (2002). The following model was assumed: $Y_{ij} = \mu + F_i + e_{ij}$

Where: μ is the overall mean, F_i is the plant type, e_{ij} is the random error term. Gas production runs were considered as the experimental units. Each run was repeated three times, and replicates within the same run were considered as repetitions. Differences among means were tested using Duncan multiple range test (Steel and Torrie, 1980).

Results and Discussion

Mean values of the proximate analyses and tannins content on dry matter basis of the investigated foliages are given in Table 1. Result revealed wide variations in the chemical composition of the investigated browses. Alfalfa and moringa leaves had the highest crude protein (CP) content, while the canary grass and blue panic had the lowest CP content. The CP contents of the browses studied had almost similar range as those stated previously (Hove *et al*., 2001, Vitti *et al*., 2005, and Sallam *et al*., 2009). The current data and those of Makkar and Becker (1998) indicated that most tropical browse species contain reasonable content of CP and can be used as a supplement for poor quality roughages. Reyes Sanchez, *et al*. (2006) reported that moringa leaves, petioles and young stems have slightly lower protein content (17.8%) than *Gliricidia sepium* (26%) and *Leucaena leucocephala* (25%). The mean CP concentration of moringa in the current study was 182 g kg^{-1} DM, which is within the range of 156 to 264 reported by other workers (Becker, 1995, and Makkar and Becker, 1996). However, the CP of moringa leaves is of better quality for ruminants than the CP of leaves of Gliricidia or Leucaena leaves because of its high content of bypass protein, 47% versus 30 and 41% respectively (Becker, 1995). Moringa is also rich in carotene, ascorbic acid, iron and in the two amino acids generally deficient in other feeds, *i.e.,* methionine and cystine (Makkar and Becker, 1996, 1997).

Table 1. The proximate analyses and tannins content on dry matter basis of the investigated foliages (g/kg DM).

	C.P	Ash	E.E	NFE	NDF	ADF	ADL	TP	TT	CT
Alfalfa	172	120	13	560	490	348	162	88.0	42.0	12.6
blue panic	82	118	11	511	557	439	257	19.8	15.7	0.7
moringa leaves	182	90	19	620	285	181	70	21.4	17.8	1.5
jojoba leaves	100	92	13	665	352	241	112	28.7	22.0	30.4
canary grass leave	69	105	9.0	583	517	418	251	22.0	17.9	2.0
millet	112	119	14	551	516	403	255	17.2	14.2	1.5

CP: crude protein; EE: ether extract; NFE: nitrogen free extract; NDF: neutral detergent fiber; ADF: acid detergent fiber; ADL: acid detergent lignin; TP: total phenols (eq-g tannic acid/kg DM); TT: total tannins (eq-g tannic acid/kg DM), CT: condensed tannins (eq-g leucocyanidin /kg DM).

The neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were higher in blue panic, canary grass, millet and alfalfa, while the moringa leaves showed the lowest content of the fiber constituents. The mean NDF and ash concentration of moringa were 285 g kg^{-1} and 90 g kg^{-1}, respectively. These values were within the range of 219 to 684 g kg^{-1}and 88.7 to 134 g kg^{-1} reported by other authors (Becker, 1995, and Makkar and Becker, 1996, 1997) for NDF and ash, respectively. The mean NDF content of the investigated foliages varied from 285 g/kg DM in moringa leaves to 557 g/kg DM in blue panic, therefore foliages with high NDF content might be expected to depress intake. Commonly a NDF content of less than 340 g/kg DM in the ration of cattle is fed to achieve maximum intake for dairy cows in feed lots (Mertens, 1992, and Fulkerson *et al*. 2008).

The secondary compounds analyses resulted in negligible contents of these feeds from total phenol, total tannins and condensed tannins except jojoba leaves. Alfalfa, blue panic, moringa, canary grass and millet had negligible condensed tannins (CT) content, while jojoba leaves had the highest CT content (30.04 eq-g leucocyanidin kg^{-1}DM). However, Jamalian and Bassiri (1978) reported that simmondsin is the most prevalent toxicant present in jojoba seeds at 2.3% levels and is also found in hulls, leaves, twigs, core wood, and male inflorescence. Simmondsin

2'-ferulate, the second most prevalent toxicant, occurs in jojoba seeds but was not found in the other plant tissues investigated.

The gas production profiles for the investigated foliages incubated *in vitro* for 96 h are presented in Fig.1. Potential gas production (A, ml g^{-1}DM), rate constants b and c, lag time (L, h), and the fractional degradation rate (μ) are given in Table 2. The potential gas production was highest ($p<0.05$) for alfalfa, moringa, and millet leaves, while the canary grass and jojoba leaves recorded the lowest gas production. Although, jojoba leaves produced less gas volume, they had the shortest lag time (L, 0.4139 h^{-1}) and lowest rate of gas production (μ h^{-1}). The longest L value (2.379, h^{-1}) was noted with canary grass and this might be due to the high fiber fractions content, which were affected negatively on gas production. Since the utilization of roughages is largely dependent upon microbial degradation within the rumen, description of roughages in terms of their degradation characteristics would provide a useful basis for their evaluation (Hovell *et al*., 1986).

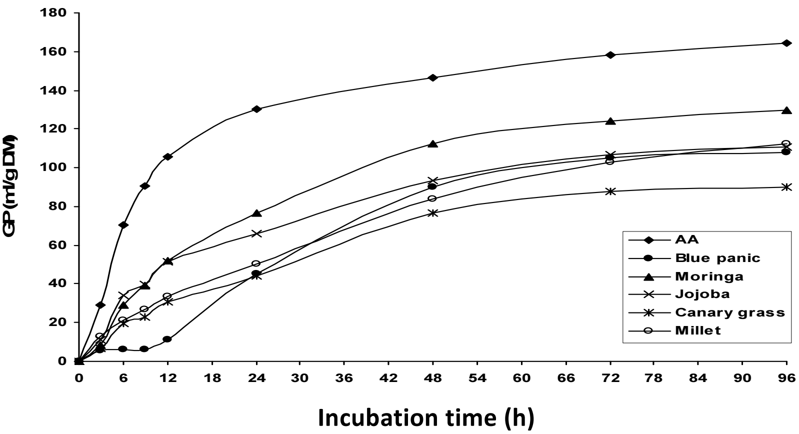

Fig.1. Cumulative gas production profiles for some browses in Saudia Arabia incubated *in vitro* for 96h.

The gas production technique has been widely used for evaluation of nutritive value particularly to various types of tropical plants (Krishnamoorthy *et al*., 1995, Sallam, 2005, and Vitti *et al*., 2005) and different classes of feeds (Getachew *et al*., 1998, and Sallam *et al*., 2007, 2008). The canary grass has high levels of NDF and ADF, while jojoba leaves have the highest levels of phenolic compounds particularly CT indicating that components are of limiting fermentation *in vitro*. This is consistent with the results of Haddi, *et al*. (2003) who reported that there were significant negative correlation between NDF and ADF, and the rate and extent of GP. The negative effect of cell wall content on GP could be due to the reduction of the microbial activity through increasing the adverse environmental conditions as incubation time progresses. However, GP can be regarded as an indicator of carbohydrate degradation and the browses rich in CT reduce GP by CT binding to the carbohydrates and then by the inhibition of enzymes or microorganisms (Griffiths, 1986), complexing with lignocellulose, and preventing the microbial digestion. In contrast, blue panic had negligible concentration of CT (0.7 eq-g leucocyanidin kg^{-1} DM) and produced a very low gas volume. This might be attributed to the high cell wall content of blue panic which is potentially limiting the *in vitro* fermentation. As observed from the kinetics of GP in Table 2, blue panic had the longest lag time indicating that the insoluble fraction in such plant is very high. Sampath *et al*. (1995) noted a significant (p < 0.05) positive associative effect on the *in vitro* gas production when untreated finger millet straw was mixed by different levels of peanut cake.

Table 2. Potential gas production and estimated kinetic parameters for some foliages incubated with rumen fluid *in vitro* for 96 h.

	A(ml/g	b(h^1)	c($h^{-/2}$)	L (h)	µ6(h^{-1})	µ12(h^-)	µ24(h^-)	µ48(h^-)
AA	149.3^{a}	0.0676^{ab}	0.2179^{b}	0.7177^{d}	0.0558^{b}	0.0394^{b}	0.0279^{b}	0.0197^{b}
blue panic	110.3^{b}	0.0851^{a}	0.4142^{a}	6.041^{a}	0.1019^{a}	0.0721^{a}	0.0510^{a}	0.0360^{a}
moringa leaves	133.3^{ab}	0.0635^{b}	0.1208^{bc}	1.4242^{c}	0.0344^{bc}	0.0243^{bc}	0.0172^{bc}	0.0122^{bc}
jojoba leaves	84.9^{cd}	0.0259^{d}	0.0629^{c}	0.4139^{e}	0.0181^{c}	0.0128^{c}	0.0091^{c}	0.0064^{c}
canary grass	92.4^{c}	0.0572^{ab}	0.1766^{b}	2.3794^{b}	0.0477^{b}	0.0337^{b}	0.0239^{b}	0.0169^{b}
millet	117.3^{b}	0.0379^{cd}	0.0940^{c}	1.6632^{c}	0.0269^{c}	0.0190^{c}	0.0135^{c}	0.0095^{c}

a,b,c,d mean within some column with differing superscript are significantly differ (P<0.05). A: potential gas production; b and c: fermentation rate constants; T: lag time; µ6, µ12, µ24, µ48, µ96: fractionation rated at respectively 6, 12, 24, 48 and 96 h of incubation.

The predicted gas production from soluble fractions (GPSF, ml/g DM), gas production from non soluble fractions (GPNSF, ml/g DM), short chain fatty acids (SCFA, mM), metabolizable energy (ME, MJ/kg DM), net energy (NE, MJ/kg DM), organic matter digestibility (OMD,%) and microbial protein (MP, g/kg DOM), are presented in Table 3. There were significant ($p<0.05$) differences in terms of the predicted parameters among the tested foliages. There were wide variations between alfalfa and foliages in term of GPSF and GPNSF. The moringa and jojoba leaves showed higher ($p<0.05$) GPSF, GPNSF, SCFA, energy content, OMD and MP in comparison with alfalfa. The observed increase in OMD of moringa leaves (Table 3) was probably a result of its high CP and low NDF, ADL and phenolic compounds concentrations (Table 1). However, differences in the degradability among investigated browses could be due to the extent of lignification of NDF (Van Soest, 1994), and gas production was negatively correlated with both NDF and lignin. The low *in vitro* degradability of organic matter with canary grass, blue panic and millet leaves (Table 3) could be due to the negative relationships between NDF, lignin and phenolics with digestibility (Ammar *et al.*, 2005). Condensed tannins interfere with microbial attachment to feed particles and show significant detrimental effects on the microbial population inhibiting ruminal fermentation to some extent.

Table 3. Estimated parameters of gas production, energetic values, organic matter digestibility and microbial protein for the investigated Saudia Arabia foliages.

	GPSF	GPNSF	SCFA	ME	NE	OMD	MP
AA	26.0^{a}	115.6^{a}	49.0^{a}	5.74^{a}	3.65^{a}	39.0^{a}	75.3^{a}
blue panic	2.4^{d}	48.0^{d}	19.6^{e}	3.97^{cd}	2.53^{cd}	27.4^{cd}	52.8^{d}
moringa leaves	5.6^{c}	79.9^{b}	33.5^{b}	5.30^{ab}	3.50^{ab}	37.2^{ab}	71.7^{ab}
jojoba leaves	7.8^{b}	70.6^{b}	29.4^{c}	4.93^{b}	3.23^{b}	34.3^{b}	66.1^{b}
canary grass leave	3.6^{d}	45.8^{d}	18.6^{e}	3.82^{d}	2.43^{d}	26.2^{cd}	50.6^{d}
millet	7.0^{b}	55.2^{c}	22.7^{d}	4.3^{c}	2.80^{c}	29.8^{c}	57.5^{c}

a,b,c,d mean within some column with differing superscript are significantly differ ($P<0.05$). GPSF: gas production from soluble fractions (ml/g DM), GPNSF: gas production from nonsoluble fractions (ml/g DM), SCFA: short chain fatty acids (mM), ME: metabolizable energy (MJ/kg DM), NE: net energy (MJ/kg DM), OMD: organic matter digestibility (%), MP: microbial protein (g/kg DOM).

The calculated ME concentration of the moringa leaves in the current study was considerably lower compared with the values estimated by Makkar and Becker (1996). They also used the Hohenheim gas test to estimate the energetic value. Therefore, such variations between the studies are probably not due to methodological differences but could be from actual differences in the chemical composition of moringa leaves. The complex interactions within a mixed rumen microbial population leading to the conversion of plant components to gas and SCFA have been summarized in the form of stoichometric reaction equations (Wolin, 1975, Wolin, 1979, Russell and Wallace, 1988, and 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 lower SCFA predicted from GP for canary grass could be due to a lower absolute GP, which was most evident during the first 24 h of incubation (Table 3). Rocha and Mendieta (1998) fed dairy cows with *Hyparrenia rufa* grass and sorghum straw supplemented with different levels of moringa leaves. Moringa was readily accepted by the animals and did not seem to have any toxic effect or contain any factors limiting intake. Supplementation with moringa leaves at a level of 0.3% of body weight resulted in a milk yield of 5.7 kg cow per day, and this was 13% higher than for the control treatment, which was grazing only. Sarwatt, *et al*. (2004) found that when cotton seed cake was substituted of moringa leaf meal at levels 10, 20 or 30% of DM, milk yield was significantly increased by 1.4, 0.9 and 0.8 kg cow day^{-1} respectively. There were no effects of substituting cotton seed cake with moringa leaf meal on total solids, fat and CP content of the milk. The ranking order of the investigated browse species on the basis of their energy content, organic matter degradability and microbial protein was moringa > jojoba > millet > blue panic > canary grass.

In conclusion, significant variations in the *in vitro* fermentation and degradation were observed among different browse species collected from Saudia Arabia through the wet season. The results suggest that moringa leaves are promising and valuable alternative feed resource and could be incorporated partially in ruminant feed mixtures to replace conventional roughage sources (alfalfa) without major problems.

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تقدير القيمة الغذائية لبعض أوراق النباتات المزروعة بالمملكة العربية السعودية بطريقة إنتاج الغاز معمليا

أحمد عبد الله باخشوين، وصبحي محمد سلام[١]، وعلى محمد علام

قسم زراعة المناطق الجافة- كلية الأرصاد و البيئة و زراعة المناطق الجافة- جامعة الملك عبد العزيز- جدة- المملكة العربية السعودية

و[١]قسم الإنتاج الحيوانى- كلية الزراعة- جامعة الإسكندرية- مصر

المستخلص. أجري هذا البحث لتقدير القيمة الغذائية لخمسة أصناف من النباتات التي تزرع بالمملكة العربية السعودية تحت ظروف المناطق الجافة، وهي (المورينجا، والهوهوبا، والحشيشة الزرقاء، وحشيشة الكنارى، والدخن) وذلك مقارنة بالبرسيم الحجازي.

أوضحت نتائج التحليل الكيميائي ما يلى:

- ارتفاع محتوى أوراق البرسيم الحجازي والمورينجا من البروتين الخام، بينما كانت أوراق الحشيشة الزرقاء، وحشيشة الكنارى الأقل في محتواها من البروتين.
- محتوى الهوهوبا والمورينجا من الألياف المتعادلة، والحامضية، واللجنين الحامضى كان منخفضا جدا مقارنة بباقى الأوراق، والتي كانت مرتفعة في محتواها من هذه المكونات.
- أعطت أوراق البرسيم الحجازي، والمورينجا، والهوهوبا أعلى إنتاج للغاز، ومعدل إنتاج الغاز، وانخفاض فترة الكمون Lag time وذلك مقارنة بالحشيشة الزرقاء، وحشيشة الكنارى، والدخن.

- وجود اختلافات معنوية بين أصناف الأوراق في محتواها من الطاقة الأيضية، والصافية، ومعامل هضم المادة العضوية، والبروتين الميكروبي، والأحماض الدهنية قصيرة السلسلة، وكانت أعلى النتائج لكل من أوراق المورينجا، والهوهوبا مقارنة بالبرسيم الحجازي.

وتوصى النتائج بإمكانية استخدام أوراق نبات المورينجا كمصدر علف مالئ، وكبديل للبرسيم الحجازي.