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SHORT NOTE [NOTA CORTA]

NUTRITIVE VALUE ASSESSMENT OF THE ARTICHOKE (*Cynara scolymus*) BY-PRODUCT AS AN ALTERNATIVE FEED RESOURCE FOR RUMINANTS

[EVALUACIÓN DEL VALOR NUTRITIVO DE SUBPRODUCTOS DE ALCACHOFA (*Cynara scolymus*) COMO UNA FUENTE DE ALIMENTACIÓN ALTERNATIVA PARA EL RUMIANTE]

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SUMMARY

Nutritive value and fermentation characteristics of artichoke by-products (*Cynara scolymus*), alfalfa (*Medicago sative*) and tifton 85 (*Cynodon sp*) hay were evaluated by measuring the gas production *in vitro* and by fitting cumulative gas production against time of incubation in the exponential model. The crude protein contents were 93.8, 150.1 and 181.9 g kg^{-1} DM for Tifton hay, artichoke by-product and alfalfa hay, respectively. The NDF was significantly higher (797.7 g kg^{-1} DM) in tifton hay than artichoke by product (524.1 g kg^{-1} DM) and alfalfa (546.7 g kg^{-1} DM). The secondary compounds analyses resulted in negligible contents of these feeds from total phenol, total tannins and condensed tannins. There are significant differences among feeds in asymptotic gas production. The highest potential gas production was observed in artichoke by-product which, was followed by tifton and alfalfa hay. Artichoke by-products produced gas 16.8% from soluble fractions and 83.2% from insoluble fractions. While, alfalfa and tifton hay were produced gas by 11.7 and 12.3 % from soluble fractions respectively and 88.3 and 87.7% from insoluble fractions, respectively. The methane production was 4.5, 8.1 and 9.8 mL/g DM for tifton, alfalfa hay and artichoke by-products, respectively. There were significant differences among investigated roughages in the dry and organic matter degradation *in vitro*. The artichoke-by products resulted in highest dry and organic matter degradation (786.0 and 804.0 g kg^{-1} at 96h incubation *in vitro*. Partitioning factor (PF) was used as an index to assess the differences in efficiency of microbial protein synthesis of feedstuffs *in vitro*. PF values were did not differ significantly (P<0.05) between artichoke by-products and alfalfa (3.57 and 3.23 mg true digested organic matter/mL gas) but it was low in tifton hay (2.70 mg true digested organic matter/mL gas). The NH$_3$-N concentration was 86.5, 138.6 and 154.0 mg/L for tifton, alfalfa hay and artichoke by-product, respectively. This study suggested that artichoke by-product have potential fermentation efficiency better than alfalfa hay and therefore, artichoke could be incorporated in feed mixtures to replace conventional roughage sources (hay, silage) in ruminant diets without major problem.

Key words: Fermentation; methane; degradation; kinetics; roughages, *in vitro*.

RESUMEN

El valor nutritivo y las características de fermentación de los subproductos de alcachofa (*Cynara scolymus*), heno de alfalfa (*Medicago sative*) y de tifton 85 (*Cynodon sp*) fueron evaluados midiendo la producción de gas in vitro y ajustando la producción de gas acumulada contra el tiempo de incubación en el modelo exponencial. Los contenidos de proteína cruda fueron 93.8, 150.1 y 181.9 g kg^{-1} MS para tifton, subproductos de alcachofa y alfalfa, respectivamente. La FDN fue significativamente mayor (797.7 g kg^{-1} MS) para tifton que para los subproductos de alcachofa (524.1 g kg^{-1} MS) y alfalfa (546.7 g kg^{-1} MS). Los análisis de compuestos secundarios resultaron en contenidos insignificantes de fenol total, taninos totales y taninos condensados. Hay diferencias significativas entre los alimentos y la producción de gas asintótica. La mayor producción de gas potencial fue observada en subproductos de alcachofa, fue seguida por tifton y alfalfa. Los subproductos de alcachofa produjeron 16.8% de gas a partir de las fracciones solubles y 83.2% a partir de las fracciones insolubles. Mientras, Alfalfa y tifton produjeron gas

por 11.7 y 12.3% a partir de las fracciones solubles respectivamente y 88.3 y 87.7% a partir de las fracciones insolubles respectivamente. La producción de metano fue de 4.5, 8.1 y 9.8 mL/g MS para tifton, alfalfa y subproductos de alcachofa, respectivamente. Hubo diferencias significativas en la degradación in vitro de la materia seca y orgánica entre los forrajes investigados. Los subproductos de alcachofa resultaron en la mayor degradación de la materia seca y orgánica (786.0 y 804.0 g kg^{-1} a las 96h de incubación in vitro. El factor de particionamiento (FP) fue usado como un índice para investigar las diferencias en la eficiencia de la síntesis de proteína microbiana de alimentos in vitro. Los valores de FP no difirieron significativamente (P<0.05) entre los

subproductos de alcachofa y alfalfa (3.57 y 3.23 mg materia orgánica digerida verdadera/mL gas) pero éste fue bajo en tifton (2.70 mg materia orgánica digerida verdadera/mL gas). La concentración de N-NH$_3$ fue 86.5, 138.6 y 154.0 mg/L para tifton, alfalfa y alcachofa, respectivamente. Este estudio sugiere que la alcachofa tiene una eficiencia de fermentación potencial más que el heno de alfalfa y por lo tanto podría ser incorporada en mezclas de alimentos para sustituir fuentes de forraje convencionales (heno, ensilaje) en dietas de rumiantes sin mayor problema.

Palabras claves: Fermentación; metano; degradación; cinética; forrajes, *in vitro*.

INTRODUCTION

The livestock sector plays a significant economic role in most developing countries, and is essential for the food security of their rural population. However, among the major constraints limiting the development of livestock production in many developing countries, inadequacy of animal feed resources is most often the crucial factor. However, crop, fruit, and vegetables residues play a key role in animal feeding, especially in developing countries. Consequently, there is a wide range of valuable by-products and residues like artichoke by-product resulting from food cropping systems and food processing, which are often inefficiently or totally under-utilized and wasted. Presently most of the artichoke waste produced is discarded by farmers into nearby rivers, lakes and on to roads, which is a serious environmental concern. Recently, there has been significant interest in efficient use of agro-industrial residues (Rosales *et al.*, 2002) and several processes have been developed to use these materials as substrates in bioprocess for production of single cell protein, organic acids, ethanol, mushrooms, enzymes and biologically important secondary metabolites (Pandey *et al.*, 1999; Massadeh *et al.*, 2001). Use of these agricultural wastes in livestock feeding may provide alternative substrates and furthermore, help to solve environmental problems, which are otherwise caused by their improper disposal.

The nutritive value of a ruminant feed is determined by the concentration of its chemical components, as well as the rate and extent of digestion. Determining the digestibility of feeds *in vivo* is laborious, expensive, requiring large quantities of feed, and it is largely unsuitable for single feedstuff thereby making it unsuitable for routine feed evaluation (Getachew *et al.* 2004). There are a number of *in vitro* techniques available to evaluate the nutritive value of feeds at

relatively low cost. The use of *in vitro* gas method to estimate the digestion of feed is based on measured relationships between the *in vivo* digestibility of feeds and *in vitro* gas production, in combination with the feed's chemical composition (Menke and Steingass 1988). The *in vitro* gas production technique developed by Menke *et al.* (1979) is a very useful tool for the rapid screening of feeds to assess their potential as energy sources for ruminant animals (Blummel and Becker, 1997), assuming that the volume of gas produced reflect the end result of the fermentation of the substrate to short chain fatty acids (SCFA), microbial biomass and the neutralization of the SCFA. The objectives of the current study were to assess the nutritive value of artichoke by products in comparison to conventional alfalfa and tifton hay using *in vitro* gas production technique.

MATERIAL AND METHODS

Feedstuffs

Artichoke by-product is available in plenty during January to April in Egypt. The artichoke by- product was procured locally, and their nutritional worth was assessed in comparison to conventional alfalfa and tifton hay. Three feedstuffs were investigated: Artichoke (*Cynara scolymus* L.) by-product, alfalfa hay (*Medicago sative*) and tifton -85 (*Cynodon sp*) hay. Samples were oven-dried at 50°C for 24 h and ground through a 1 mm screen before chemical analysis and *in vitro* trails.

Chemical analysis

Feedstuffs were analyzed according to AOAC (1995) (DM: dry matter - ID number 930.15; OM: organic matter - ID number 942.05; CP: crude protein – as 6.25 x N- ID number 954.01; and ADF: acid-detergent fibre – ID number 973.18) and (NDF: neutral-

detergent fibre) 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 minutes. The contents were centrifuged (4 °C, 10 min, 3000 g) and the supernatant was kept on ice until analysis. TPs were determined with the Folin-Ciocalteau reagent (Makkar *et al.*, 1993; Makkar, 2003). Extractable tannins were determined as the difference in total phenols (measured by Folin-Ciocalteau reagent) before and after treatment with insoluble polyvinyl polypyrrolidone, as this polymer binds strongly to tannins (Makkar *et al.*, 1995). TP and TT were expressed as tannic acid equivalents (Makkar, 2003). CTs were measured by the butanol-HCl method and the results were expressed as leucocyanidin equivalent (Makkar, 2003).

In vitro gas and methane production

The *in vitro* gas production (GP) assay was carried out using a pressure transducer and data logger (LANA/CENA-USP, Piracicaba/SP, Brazil) for measuring the gas produced in 160 mL serum bottles incubated at 39ºC (Theodorou *et al.* (1994), Mauricio *et al.* 1999). Five adult rumen cannulated sheep grazing tropical grass pasture and a supplement based on maize and soybean meal (0.7 kg/100 kg of live weight, 20% crude protein) plus a mineral mixture were used as inoculum donor. Both solid and liquid rumen fractions (50 % solid: 50 % liquid) were collected before the morning feeding through the cannula using a stainless steel probe (2.5 mm screen) attached to a large capacity syringe. Fluids and solids were placed separately in pre-warmed (39ºC) insulated flasks and transported under anaerobic conditions to the laboratory. Equal volumes of solid and liquid phases of rumen digesta were mixed in a blender and then squeezed through a 35 µm nylon filter and kept in a water bath at 39ºC with CO_2 saturation until inoculation (Bueno *et al.*, 2005).

Ground samples (0.5 g) were incubated in 75 mL of diluted rumen fluid (25 mL mixed rumen fluid + 50 mL of Menke's buffered medium) in 160 mL serum bottles. Once filled, all the bottles were closed with rubber stoppers, crimped with aluminium seals, shaken and placed in the incubator at 39 °C. The bottles were shaken manually after the recording of the gas headspace pressure (P) at 3, 6, 9, 14, 24, 36, 48, 60, 72 and 96 h incubation using a pressure transducer. The six replicates each sample were used, two bottles of each sample were stopped at 24 h, and two for measuring the partitioning factor (PF) and the another two at 96 h for measuring the dry and organic matter

degradability. Four serum bottles containing only rumen fluid were incubated as blanks and used to compensate for gas production in the absence of substrate. Three runs were done for the same samples. The amount of GP at each measuring time was estimated according to the regression equation predicted from unpublished data (n =500, r^2=0.98, P<0.05) between gas volume versus pressure relationship GP (mL) = 0.0112 (P)^2 psi + 7.3358 (P) psi. Methane determination was done in a Shimadzu gas chromatography 2014 using a standard methane gas (99.9%) at 240 °C for the detector and at 60°C for the shincarbon ST micro packed column, Japan. The test of linearity and calibration were accomplished using the standard gas curve in the range of probable concentration of the samples. Methane production at the end of incubation period was estimated from the volume of gas and the gas composition data as "CH4 = [GP + HS] x Conc"; where CH_4 is the volume (mL) of methane, GP is the volume (mL) of gas produced at the end of the incubation, HS is the volume (mL) of the headspace in the serum bottle and Conc is the percentage of methane in the gas sample analyzed (Tavendale *et al.*, 2005).

Ammonia-N, i*n vitro* dry and organic matter degradability and partitioning factor (PF)

After termination of the incubation at 24h incubation, the first two bottles were used for measuring the ammonia-N and dry and organic matter degradation. The bottles were dipped in ice water for 20 min. prior to the filtration; about 3 mL of the bottle fluid were collected and stored at -20ºC until NH_3-N analyses. The NH_3-N concentration was measured in the presence or absence of PEG according to Preston (1995). After that, the bottles content were filtered into previously weighed sintered crucibles (40- 100 µm pore size), washed with hot distilled water, and the extent of sample disappearance (g kg^{-1}), expressed as dry matter apparently digested (DMD) and organic matter apparently digested (OMD), were determined by the weight difference of undegraded filtered residue following oven-drying (100ºC) and ashing (500ºC). GP, DMD and OMD were corrected for gas yield and particulate contamination, respectively by the inclusion of blank fermentation bottles containing inoculum only. The second two bottles were used for measuring the PF. The bottles content were quantitatively transferred into a 600 mL spout-less beaker with a total of 70 mL of neutral detergent (ND) solution (double strength; Blummel and Becker, 1997) and refluxed for 3 h at 105ºC. Residual DM and ash were determined. The ratio of organic matter truly degraded (mg) to gas volume (mL) at 24 h incubation was used as an index of microbial synthesis efficiency (Blummel *et al.*, 1997). The last two bottles were used for measuring the degradation at 96h incubation.

Estimated GPSF, GSNSF, REL1 and REL2

As a new approach to evaluate feeds from those parameters, the ratios REL1, between gas production after 48 and 96 h (G48 and G96, respectively) and REL2, between G96 and potential gas production (A), were compared according the approach proposed by Bueno *et al.* (2005). Gas production caused by fermentation of the soluble fraction (GPSF) was estimated by gas production after 3 h (GP3) of incubation. Gas production caused by fermentation of the insoluble fraction (GPNSF) could be estimated from the gas production between 3 h (GP3) and 20 h (GP20) of incubation according to Van Gelder *et al.* (2005).

Calculations and statistical analysis

Cumulative gas production was fitted iteratively to the exponential model proposed by France *et al.* (1993),

$$Y = A \{1 - \exp^{[-b(t-T) - c(\sqrt{t} - \sqrt{T})]}\},$$

with the exclusion of the intercept, where:
Y = cumulative gas production (in mL) at time t;
A = the asymptote (in mL);
b and c = rate constants (in h^{-1}); and
T = lag time (in h).

The fractional rate (μ, h^{-1}) was considered to vary with time according to:

$$\mu = (b + c)/(2\sqrt{t}), \quad t \geq T.$$

Data were subjected to analysis of variance (ANOVA), using the General Linear Model procedure (GLM) of the SAS software package (2000). The used model was: $Y = \mu + F_i + e$, where μ is overall mean, F_i the forage effect. Experimental units were runs and replicates in the same run considered as repetitions. The significant differences between individual means were identified using Duncan test.

RESULTS

The chemical composition of the evaluated feeds *in vitro* mixed rumen assay is presented in Table 1. The result revealed that there were wide variations concerning crude protein and neutral-detergent fibre (NDF) content. The CP content of artichoke by-product was lower than alfalfa hay but higher than Tifton hay. The NDF was significantly higher (798 g kg^{-1} DM) in tifton hay than artichoke by-product (524 g kg^{-1} DM) and alfalfa (547 g kg^{-1} DM). There was no difference among investigated feedstuffs in ADF. The secondary compounds analyses resulted in negligible contents of these feeds from total phenol, total tannins and condensed tannins.

Table 1. The chemical composition (g/kg DM) of artichoke by-product, alfalfa and tifton hay feedstuffs.

Item	Artichoke by-product	Alfalfa hay	Tifton hay
CP	150.1	181.9	93.8
NDF	524.1	546.7	797.9
ADF	411.7	346.0	367.0
TP	12.7	10.2	7.1
TT	8.1	6.6	4.0
CT	0.3	0.2	0.9

CP: crude protein (g kg^{-1} DM); NDF: neutral-detergent fibre (g kg^{-1} DM); ADF: acid-detergent fibre (g kg^{-1} DM); TP: total phenols (eq-g tannic acid kg^{-1} DM); TT: total tannins (eq-g tannic acid kg^{-1} DM); CT condensed tannins (eq-g leucocyanidin kg^{-1} DM)

Potential gas production (A), estimated kinetic parameters (T, $\mu6$, $\mu14$, $\mu24$, $\mu48$ and $\mu96$), methane production (CH_4), estimated gas production from soluble (GPSF) and insoluble fractions (GPNSF), relation 1 (REL1) and relation 2 (REL2), ammonia-N concentration, dry matter (DMD) and organic matter (OMD) degradation at 24 and 96 h incubation, and partitioning factor (PF) for artichoke, alfalfa and tifton hay incubated with rumen fluid *in vitro* are given in Table 2. The gas production profiles for the feeds incubated in buffered rumen fluid and corrected for blank are shown in Fig.1. There are significant ($P < 0.05$) differences among feeds in asymptotic gas production.

The highest potential gas production was observed in artichoke by-product which, was followed by tifton and alfalfa hay. The initial gas production profile was lower in tifton than alfalfa hay and after 48h incubation was higher than alfalfa hay. Estimated constant rate of gas production ($\mu6$, 14, 24, 48, 96 h^{-1}) differ significantly ($P < 0.05$) between roughages. The highest rate of gas production was observed with artichoke by-product (0.029 h^{-1}) followed by alfalfa (0.0136 h^{-1}) and tifton hay (0.0095 h^{-1}) at 24 h incubation. The gas produced from soluble fraction in artichoke by-products was 16.8% and 83.2% from insoluble fractions. While, in alfalfa and tifton hay the GPSF was 11.7 and 12.3 % respectively and 88.3 and 87.7% from GPNSF respectively. It would be desirable that the major part of digestible nutrients would be fermented within 48 h. Thus, REL1 suggests how much of the fermentation was completed in the first 48 h. While REL2 represents how close G96 (i.e., fermentation), is from potential gas production (A). Thus the closer G96 is to A (higher REL2), the best feed quality and/or the incubation time was long enough to express the fermentation potential of the feed.
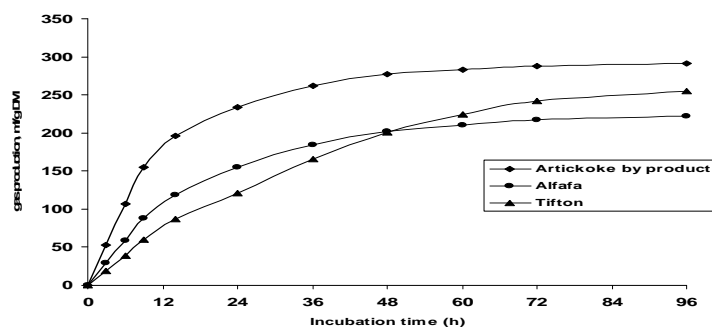
Figure 1. Cumulative gas production profile for the artichoke by product, alfalfa and tifton incubated *in vitro* for 96h.

Table 2. Potential gas production (A), estimated kinetic parameters (T, μ6, μ14, μ24, μ48 and μ96), methane production (CH₄), estimated gas production from soluble (GPSF) and insoluble fractions (GPNSF), relation 1 (REL1) and relation 2 (REL2), ammonia-N concentration, dry matter (DMD) and organic matter (OMD) degradation at 24 and 96 h incubation, and partitioning factor (PF) for artichoke, alfalfa and tifton hay incubated with rumen fluid *in vitro*.

Parameters[1]	Roughages			
	Artichoke	Alfalfa	Tifton	SED[†]
A (mL/g DM)	316.7 [a]	227.9 [b]	262.2 [b]	17.3
T (h)	1.38 [a]	0.80 [a]	1.52 [a]	0.37
μ6 (h^{-1})	0.0580 [a]	0.0273 [b]	0.0190 [b]	0.0097
μ14 (h^{-1})	0.0379 [a]	0.0178 [b]	0.0124 [b]	0.0064
μ24 (h^{-1})	0.0290 [a]	0.0136 [b]	0.0095 [b]	0.0049
μ48 (h^{-1})	0.0205 [a]	0.0096 [b]	0.0067 [b]	0.0034
μ96 (h^{-1})	0.0145 [a]	0.0068 [b]	0.0048 [b]	0.0024
CH₄ (mL/g DM)	9.8 [a]	8.1 [a]	4.5 [b]	0.49
GPSF	35.3 [a]	16.1 [b]	15.2 [b]	1.63
GPNSF	174.9 [a]	121.5 [b]	108.4 [b]	1.68
REL1	0.91 [a]	0.86 [a]	0.72 [b]	0.039
REL2	0.93 [a]	1.01 [a]	0.74 [b]	0.092
NH₃-N (mg/L)	138.6 [a]	154.0 [a]	86.5 [b]	13.5
DMD24h (g/kg DM)	717.0 [a]	446.4 [b]	415.1 [b]	46.1
DMD96h (g/kg DM)	786.0 [a]	518.5 [b]	565.5 [b]	47.5
OMD24h (g/kg DM)	706.2 [a]	446.8 [b]	385.7 [b]	43.5
OMD 96h (g/kg DM)	804.0 [a]	546.7 [b]	565.4 [b]	48.6
PF	3.23 [ab]	3.57 [a]	2.70 [b]	0.31

[a, b] means followed by distinct superscripts, within rows, are significantly different (Tukey test; $P < 0.05$).
[1] A: potential gas production; T: lag time; μ6, μ12, μ24, μ48, μ96: fractionation rated at respectively 6, 12, 24, 48 and 96 h of incubation; REL1: G48/G96, where G48 and G96 are cumulative gas production after 48 h and 96 h of incubation, respectively; REL2: G96/A; where A is the potential gas production, PF: Partitioning factor is a ratio between mg of truly digested organic matter and mL gas produced at 24 h incubation.
[†] SED: standard error of difference between means.

The best ratio of REL1 was observed for artichoke by-products and alfalfa while the lowest ratios were for tifton hay. The REL2 was different significantly among substrates and the best relation was observed with alfalfa and artichoke by-products, while the lowest relation was observed with tifton hay. The methane production results showed that there was no significance ($P<0.05$) difference between alfalfa and

artichoke by-product in methane production (8.1 and 9.8 mL/ g DM, respectively). On the other hand, tifton hay had ($P<0.05$) the lowest methane production (4.5 mL/ g DM) *in vitro*.

The NH₃-N concentration was 86.5, 138.6 and 154.0 mg/L for tifton hay, artichoke by-products and alfalfa hay, respectively. There was no significance difference

between alfalfa and artichoke by-products but it was lower in tifton substrate. There were significant (P<0.05) differences among investigated roughages in the dry and organic matter degradation *in vitro*. The artichoke-by products resulted in highest DMD and OMD (786 and 804 gkg^{-1} at 96h incubation *in vitro*. There were no differences (P>0.05) between alfalfa and tifton hay either DMD or OMD. The PF values were 2.70, 3.23 and 3.57 for tifton hay, artichoke by-products and alfalfa hay, respectively.

DISCUSSION

Since gas production on incubation of feeds in buffered rumen fluid is associated with feed fermentation, and carbohydrate fractions so, the higher GP in artichoke by-product and lower GP from tifton and alfalfa hay could be related to fibre fractions content. This is consistent with De Biover *et al.* (2005), who reported that GP was negatively related with NDF content and positively with starch. The negative effect of cell wall content on GP in alfalfa and tifton hay could be due to reduce the microbial activity through increasing the adverse environmental conditions as incubation time progress.

Kinetics of gas production is dependent on the relative proportions of soluble and insoluble particles of the feed (Cone *et al.*, 1997). The lag time is (time from incubation to start of gas production) very important digestibility parameters. The shorter lag time period for alfalfa could be due to high whole structure carbohydrates content. Tifton hay had a longest lag time indicating that insoluble fraction in such plant is very high as observed from the chemical analyse. 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). The results of GPSF and GPNSF were in agreement with Cone *et al.* (1997) that gas production profiles could be divided into three phases, representing gas production caused by fermentation of the water-soluble fraction, the non-soluble fraction and microbial turnover. As in the current study, Miller, (1995) reported that the reduction in gas and methane in tifton hay would be due to the conversion of CO_2 and H_2 to acetate instead of CH_4. This process mainly occurs when low roughage diets containing high proportions of sugars and protein are fed (Leedle and Greening, 1988). Tavendale *et al.* (2005) stated that rapidly fermented feeds as observed with artichoke by-product are likely to produce a lower proportion of acetate, and a higher proportion of propionate and butyrate. Also, the depression of methane production in rich NDF substrate (Tifton hay) probably due to indirect effect via fibre digestion.

The low DMD and OMD in tifton hay, this is probably because of high lignifications of NDF while, the opposite was observed in artichoke by-product. Also, the lower of OMD in tifton hay where in accordance with of OM digestibility at 24 h *in vitro* incubation reported by Lovett *et al.* (2004) working with perennial ryegrass. Both Blümmel and Ørskov (1993) and Apori *et al.* (1998) observed a positive relationship between gas production *in vitro* and DM degradability in situ. These feeds are also likely to be associated with an increased ATP production *in vitro* and a shorter time to maximum gas production rate. The ammonia concentration in artichoke by-products and alfalfa was higher than in tifton hay, this may be due to high N solubility in alfalfa and artichoke. The ratio of milligram true digested organic matter (TDOM) to milliliter gas produced at 24h (partitioning factor (PF)) was regarded as an index of efficiency of microbial biomass synthesis (EMBS) *in vitro* Blummel *et al.* (1997). The PF reflects substrate-dependent variation in the *in vitro* partitioning of degraded substrate between short chain fatty acids, gases and microbial biomass. Further, it was observed that the PF of the mixed diets had a significant relationship with the microbial efficiency *in vivo*, indicating the possibility of using PF of the diet to influence EMBS *in vivo* (Blummel and Lebzien, 2001; Blummel *et al.*, 2003). The PF of feedstuffs can theoretically vary from 2.75 to 4.41 reflecting Y_{ATP} of 10 to 40 (Blummel *et al.*, 1997). The results of the PF in the current study were located at the normal range mentioned previously. Dijkstra *et al.* (2005) reported that the microbial efficiency using gas production technique, in combination with substrate degradation may be useful to rank feeds of interest but, for evaluation in a complete diet, rumen models are more appropriate. There was no significant difference between artichoke by-product and alfalfa hay in PF indicating that artichoke by-product is promising new alternative feed resource for ruminants. However, to evaluate the suitability of the ensiled crude by-product of artichoke (*Cynara scolymus L.*) as animal feed, various fermentative, chemical and phytosanitary parameters were investigated by Meneses *et al.* (2007). The by-product showed a good aptitude for ensilage, having a pleasant smell and good silage characteristics. Changes in chemical composition during silage were low; the CP content was acceptable (88 g kg^{-1} DM) and the products had a high NDF content (509 g kg^{-1}).

CONCLUSION

In conclusion, On the basis of chemical composition, kinetics of gas production, *in vitro* dry and organic matter digestibility, and fermentation activity of artichoke by-products proved to be excellent unconventional feedstuffs for ruminants, equivalent to

any conventional feeds like alfalfa or tifton hay. This study suggested that artichoke have potential fermentation efficiency and could be incorporated in feed mixtures to replace conventional roughage sources (e.g. hay, silage) in ruminant diets without major problem. However, further studies are required and animal feeding test should be carried out to assess palatability and to observe feed intake.

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