Nutritive Value Assessment of the Alternative Feed Resources by Gas Production and Rumen Fermentation In vitro

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Abstract: In vitro gas production and rumen fermentation characteristics were measured to evaluate some alternative feed resources e.g. rice straw, tropical shrubs (Artiplex semibacata, Artiplex halimus, Leucaena), Artichoke leaves and Artichoke stems in comparison with berseem hay. A gas test technique was performed using fistulated sheep rumen fluid. Cumulative gas production was recorded at 3, 6, 9, 12, 24, 48, 72 and 96 h of incubation and gas production constants (\(b, c, L\)) were described using the equation \(\text{Gas}(t)=b(1-\exp^{-ct})\). Ammonia-N and volatile fatty acids (VFA) concentration were determined at 0, 1, 3 and 6 hr. of incubation. The NDF, ADF and ADL were significantly different among roughages used in this study. The rice straw contain highest level of NDF and ADF, while Leucaena contain the highest level of ADL. The lowest fiber constitutes were observed in artichoke leaves or stems. The maximum gas volume \((b)\) was highest for Artichoke stems followed by artichoke leaves, bereem hay, rice straw, Atriplex semibacata and Leucaena and lowest for Atriplex halimus. The maximum rate of gas production \((c)\) was highest for both artichoke stems and leaves and berseem hay and lowest for rice straw. The fermentation end products either ammonia-N or total volatile fatty acids varied significantly among the roughages. There were significant (P<0.05) differences between forages in terms of metabolizable energy (ME), net energy (NE) (MJ/kg DM) and organic matter digestibility (OMD). The organic matter digestibility values ranged from 41.48-67.57% and the highest value was that of artichoke stems and the lowest value was that of rice straw. The leaves or stems of artichoke showed the highest (P<0.05) values for ME, NE and OMD than all of the other roughages used in this study. All tropical shrub plants and rice straw had lower in vitro fermentation characteristics, cumulative gas production and kinetics parameters than berseem hay used as standard hay. The in vitro gas production technique can be used to determine the nutritive value of the roughages and to identify differences among their potential digestibility and energy contents. This study concluded that artichoke was considered as high quality roughage in comparison with berseem hay according to nutritive quality and gas production parameters.

Key word: Nutritive value, roughages, gas production, fermentation, in vitro

INTRODUCTION

The appellation; Alternative feed resources; has become commonly used to design those local feeds, which could replace partially or totally conventional feedstuffs either grass forages or concentrate feeds without reducing livestock performance but should decrease the feeding cost.

Tropical plants and agricultural by products represent an important fodder reserve for livestocks in harsh conditions that can be used by grazing ruminant in periods of feed scarcity. Leucaena leucocephala is a leguminous plant and it has high content of protein, energy, carotens and minerals\[1\]. Atriplex species contain a moderate level of crude protein, high level of fiber fractions and ash. These forages should be salt tolerant or / and drought resistant to be adaptable for propagation under arid conditions and can considerably provide low-cost fodder for animals\[18\]. Use of these forages in animal diets could participate in reducing the shortage of animal feed resources and subsequently increase milk and meat production in Egypt. The knowledge about their potential feeding value is insufficient. The nutrient composition of feeds is commonly determined primarily by chemical analyses. However, this does not provide sufficient information to determine the feed’s true nutritive value. The efficiency by which an animal utilizes feed nutrients has a significant impact on its productive performance and waste production. In the search to improve and optimize this “trophic chain”, it is therefore crucial to further develop methods to evaluate fibrous feeds, so that ruminant production can be maximized. Therefore, in vitro methods of feed evaluation have numerous advantages over in vivo methods. They are less expensive, less time-consuming and allow incubation to be maintained more precisely than in vivo. In addition, in vitro techniques

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utilize small amounts of test feeds making them applicable to screening feeds that are not available in sufficient quantity for *in vivo* experiments. The *in vitro* methods of Tilley and Terry,[41] in sacco method of Mehrez and Ørskov,[30] and enzymatic method of Jones and Hayward[25] have all been widely used to predict digestibility of feeds, and used as a selection tool for screening feeds for nutritional quality.

The *in vitro* gas production system helps to better quantify nutrient utilization, and its accuracy in describing digestibility in animals has been validated in numerous experiments. Animal experiments will continue to add information to our understanding of nutrient metabolism. However, where applicable the *in vitro* gas production system can be used to predict animal performance at a much lower cost. 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.

The association between rumen fermentation and gas production has long been known, in an early attempt in 1939 was tried to record the gas production directly via the rumen cannula in sheep, the technique was too difficult to execute and of poor reproducibility.[9] In 1974 Menke and Ehrensverd (cited by Theodorou *et al.*[40]) studying the stoichiometry of rumen fermentation with a syringe closed system noticed a very reproducible gas production data when the same substrate was incubated in the same quantity in different runs. The main innovation in such method was that the gas production is recorded rather than degradation. The same postulate continues until today, even when the method had been simplified and improved. The kinetics of gas production during ruminal fermentation may provide valuable information about feeds that can be used to formulate rations and model animal responses.

Menke and Steingass[31] reported a strong correlation between metabolizable energy (ME) values measured *in vivo* and predicted from 24 h *in vitro* gas production and chemical composition of feeds. The *in vitro* gas production method has also been widely used to evaluate the energy value of several classes of feeds[15] particularly straws,[28] agro-industrial by-products,[31] compound feeds[32] and various tropical feeds[34]. The main objective of this study is assessing the nutritive value of tropical shrubs (Atriplex semibacata, Atriplex halimus, Leucaena leucocephala), Artichoke leaves, Artichoke stems, rice straw in comparison with berseem hay by chemical analysis, rumen fermentation characteristics and gas production technique *in vitro*.

MATERIALS AND METHODS

**Feedstuffs:** Rice straw, Atriplex semibacata, Atriplex halimus, Leucaena leucocephala, Artichoke stems, and berseem hay (*Cynara scolymus*) were ground in mills to pass a 1 mm sieve prior to chemical analyses, *in vitro* gas production measurements and rumen fermentation. The chemical composition of the roughages used for *in vitro* gas production and rumen fermentation are presented in Table 1. Only one sample of each feed was utilized, as feeds were selected to represent a range in fermentability, rather than to categorize the feeds.

### Table 1: Chemical composition and fiber fractionations of berseem hay, rice straw, Atriplex semibacata, Atriplex halimus, Leucaena, Artichoke leaves and Artichoke stems

<table>
<thead>
<tr>
<th>Item</th>
<th>Hay</th>
<th>Rice straw</th>
<th>Atriplex semibacata</th>
<th>Atriplex halimus</th>
<th>Leucaena</th>
<th>Artichoke leaves</th>
<th>Artichoke stems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>11.2</td>
<td>17.75</td>
<td>0.4321</td>
<td>23.2</td>
<td>8.59</td>
<td>7.91</td>
<td>11.71</td>
</tr>
<tr>
<td>Organic matter</td>
<td>88.8</td>
<td>82.25</td>
<td>78.67</td>
<td>76.8</td>
<td>91.41</td>
<td>92.09</td>
<td>88.29</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>29.82</td>
<td>36.51</td>
<td>15.32</td>
<td>18.02</td>
<td>11.06</td>
<td>22.09</td>
<td>16.5</td>
</tr>
<tr>
<td>Ether extract</td>
<td>1.03</td>
<td>0.47</td>
<td>1.28</td>
<td>1.9</td>
<td>0.97</td>
<td>0.95</td>
<td>1.35</td>
</tr>
<tr>
<td>Nitrogen free extract</td>
<td>42.63</td>
<td>40.42</td>
<td>47.69</td>
<td>44.81</td>
<td>59.45</td>
<td>52.43</td>
<td>56.1</td>
</tr>
<tr>
<td>Fiber fractionation (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NDF</td>
<td>54.92</td>
<td>77.5</td>
<td>53.91</td>
<td>44.07</td>
<td>42.21</td>
<td>43.88</td>
<td>33.28</td>
</tr>
<tr>
<td>ADF</td>
<td>38.31</td>
<td>47.48</td>
<td>20.58</td>
<td>20.7</td>
<td>21.63</td>
<td>28.57</td>
<td>21.32</td>
</tr>
<tr>
<td>ADL</td>
<td>12.27</td>
<td>12.75</td>
<td>9.05</td>
<td>8.33</td>
<td>15.74</td>
<td>8.94</td>
<td>6.21</td>
</tr>
<tr>
<td>Cellulose</td>
<td>26.04</td>
<td>34.73</td>
<td>11.53</td>
<td>12.37</td>
<td>5.89</td>
<td>19.63</td>
<td>15.11</td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>16.61</td>
<td>30.02</td>
<td>33.33</td>
<td>23.37</td>
<td>20.58</td>
<td>15.31</td>
<td>11.96</td>
</tr>
</tbody>
</table>
Chemical Analyses: All feedstuff samples were analyzed according to AOAC\textsuperscript{[4]} for crude protein (CP), Crude fat (CF), ash, Nitrogen free extract (NFE), organic matter (OM), crude fiber. Neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), cellulose and hemicellulose were determined according to Van Soest \textit{et al}\textsuperscript{[43]}.

\textbf{in vitro gas production and rumen fermentation:} \textit{in vitro} gas production was undertaken according to the procedure described by Menke and Steingass\textsuperscript{[33]}. Buffer and mineral solution are prepared and placed in a water bath at 39°C under continuous flushing with CO\textsubscript{2}. Rumen fluid is collected from fistulated sheep fed on berseem hay and commercial concentrate mixture diet into a pre-warmed thermos flask. The rumen fluid is filtered and flushed with CO\textsubscript{2}, and the mixed and CO\textsubscript{2} flushed rumen fluid is added to the buffered mineral solution (1:2 v/v), which is maintained in a water bath at 39°C, and combined.

Samples (200 ± 10mg) of the air-dry feedstuffs were accurately weighted into syringe fitted with plungers. Buffered rumen fluid (30 ml) is pipetted into each syringe, containing the feed samples, and the syringes are immediately placed into the water bath at 39°C\textsuperscript{[31]}. Three syringes with only buffered rumen fluid are incubated and considered as the blank. The syringes are gently shaken every 2 h, 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 96h of incubation. Total gas values are corrected for the blank incubation, and reported gas values are expressed per 200mg of DM. Another two bottles containing 300mg feedstuffs samples and 45ml Buffered rumen fluid were incubated for the determination volatile fatty acids (VFA) and ammonia concentration at 0, 1, 3 and 6h from incubation. Ammonia and VFA concentration were determined according to Gips and Wibbens-Alberts\textsuperscript{[46]} and Warner\textsuperscript{[46]} respectively.

Cumulative gas was expressed as milliliter of gas produced per 200mg of dry matter and corrected for blanks. Berseem hay was used as standard hay. Cumulative gas production GAS\textsubscript{(t)} at time t was fitted to the modified exponential model\textsuperscript{[11]}

\[
\text{Gas}(t) = b(1-\exp^{-ct}), \text{ with the exclusion of the intercept.}
\]

Where
- \(b\) = The gas production from the insoluble fraction (ml)
- \(c\) = The gas production rate constant for the insoluble fraction \((b)\)
- \(t\) = Incubation time(h)
- \(L\) = Lag time (h)

\textbf{Energy estimation:} The energy value of forages can be 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 \textit{in vitro} incubation of forages\textsuperscript{[33]}, Menke and Steingass\textsuperscript{[33]}.

\[
\text{ME(MJ/Kg DM)} = 2.2 + 0.136\text{Gp} + 0.057\text{CP}
\]

\[
\text{OMD (\%)} = 14.88 + 0.889\text{ Gp} + 0.45\text{CP} + 0.0651\text{ XA}
\]

Where
- ME is the metabolizable energy
- OMD is organic matter digestibility
- Gp is 24 h net gas production (ml/200DM)
- CP is crude protein (% of DM)
- XA is ash (% of DM)

\[
\text{NE(Mcal/lb)} = (2.2 + (0.0272*\text{Gas}) + (0.057*\text{CP}) + (0.149*\text{CF}) / 14.64
\]

Where
- Gas is 24 h net gas production (ml/gDM)
- CP is crude protein (% of DM)
- CF id crude fat (% of DM)

Then net energy unit converted to be MJ/Kg DM.

\textbf{Statistical analyses:} Data were subjected to analysis of variance (ANOVA) using the General Linear Model. Significant differences between individual means were identified using least significance difference (LSD) multiple range test\textsuperscript{[36]}.

\textbf{RESULTS AND DISCUSSION}

\textbf{Chemical composition and gas production:} The chemical composition and fiber fractionations of rice straw, Atriplex semibacata, Atriplex halimus, Leucaena, Artichoke leaves, Artichoke stems and berseem hay are presented in Table 1. Forages had variable organic matter content with lowest in A. halimus and semibacata and highest in artichoke and Leucaena. The crude protein content varied from 4.85% in rice straw to 19.93% in Leucaena. The ether extract content of forages was lowest in rice straw and it does not differ significantly among other forages. The fiber fractions differ significantly among forages. The highest value for NDF, ADF, ADL, cellulose and hemicellulose were observed in rice straw and the lowest values in artichoke stems. Leucaena had a higher ADL content and lower cellulose content than other roughages. Artichoke either leaves or stems had a lower ADL content.
Figure 1 showed the cumulative gas production profiles, corrected for blank fermentation, of the seven different roughage samples that were incubated in buffered rumen fluid from sheep fed the ration with berseem hay and concentrate. There was a fast initial gas production, without lag time, after which gas production diminished little but stayed at a high level. After 15 to 24 h of incubation, gas production decreased further but did not stop fully. Incubation of feedstuff with buffered rumen fluid in vitro, the carbohydrates are fermented to short chain fatty acids (SCFA), gases mainly CO₂ and CH₄ and microbial cells. Gas production is basically the result of fermentation of carbohydrates to acetate, propionate and butyrate⁴⁷. Gas production from protein fermentation is relatively small as compared to carbohydrate fermentation while, contribution of fat to gas production is negligible⁴⁷.

The fast initial gas production was highly significant (P<0.01) in Artichoke stems in comparison with other roughages. The highest cumulative gas production was observed in artichoke either stems or leaves which, was followed by sample of berseem hay and the lowest was obtained by the sample from A.halimus. This is due to high content of the artichoke from NFE which, have a positive correlation with gas production. On the other hand, Cell wall content (NDF and ADF) were negatively correlated with gas production at all incubation times and estimated parameters. This may tend to reduce the microbial activity through increasing the adverse environmental conditions as incubation time progress. Also, The relatively high level of ADL in rice straw and Leucaena as shown in Table 1 explains in part the limited in vitro degradation and therefore the lower amount of gas produced.

Gas production can be regarded as an indicator of carbohydrate degradation and the low gas production in Atriplex are explained by condensed tannin’s binding to the carbohydrate and then by the inhibition of enzymes or microorganisms⁴⁷, complexing with lignocellulose, and preventing the microbial digestion. Tropical feeds contain considerable amounts of phenolic compounds that reduced in vitro gas production. The correlation between
the change in gas production in the presence of tannin binding agent and phenolic contents of browse was consistent with those of Khazaal et al\textsuperscript{(21)} and Tolera et al\textsuperscript{(22)}. However, since gas production on incubation of feeds in buffered rumen fluid is associated with feed fermentation, the low gas production from rice straw, Artiplex semibacata, Artiplex halimus, Leucaena, could be related to low feeding value of these feeds. In addition, Leucaena contains toxin compounds eg. mimosine which, has a negative correlation with gas production. The variation in the in vitro gas production on incubation of these roughages were explained by the differences in total VFA production as observed in Fig. 3, which mainly comes from carbohydrate fermentation. These results are consistent with the finding of Kamalak et al\textsuperscript{(20)} and Abdulrazak et al\textsuperscript{(31)}.

Values for the estimated parameters obtained from the kinetics exponential model and cumulative gas production at 24 and 48 hr (GAS24 and GAS48) are given in Table 2. GAS 24 and GAS 48 ranged from 25.7 to 51.15 and from 30.59 to 54.8 ml/200mg DM, respectively. Estimated lag varied from –3.26h in Leucaena to 0.32h in A.semibacata. Estimated constant rate of gas production (c) differ significantly between roughages. The highest rate of gas production was observed with artichoke stems followed by artichoke leaves and berseem hay. The lowest rate was found with A.halimus which, did not differ significantly from rice straw, A.semibacata and Leucaena. There are similarity between observed gas production and predicted gas production by exponential model (data not shown). The gas yield of artichoke stems is higher than artichoke leaves. There is no significant difference between rice straw, A.halimus, A.semibacata and Leucaena in cumulative gas production.

The lag time is (time from incubation to start of gas production) very important digestibility parameters. The shorter lag time period for Leucaena could be due to high whole structure carbohydrates content. 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 (anonymous). Kinetics of fermentation of feedstuffs can be determined from fermentative gas and the gas released from buffering of the SCFAs. Kinetics of gas production is dependent on the relative proportions of soluble, insoluble particles of the feed. Mathematical descriptions of gas production profiles allows analysis of data, evaluation of substrate and media-related differences, and fermentability of soluble and slowly fermentable components of feeds. Various models have been used to describe gas production profiles. The exponential model\textsuperscript{(31)} is widely used in ruminant feed evaluation to describe degradation kinetics as measured with the nylon bag.
Table 2: Accumulative gas production (Gas24h, Gas 48h) and estimated kinetic parameters for variety of roughages incubated with rumen fluid in vitro.

<table>
<thead>
<tr>
<th>Roughage</th>
<th>Gas 24h (ml/200mgDM)</th>
<th>Gas 48h (ml/200mgDM)</th>
<th>b (ml/200mgDM)</th>
<th>c (percentage of b per hour)</th>
<th>Lag(t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay</td>
<td>35.69</td>
<td>44.58</td>
<td>45.04^c</td>
<td>0.070^c</td>
<td>-0.34^c</td>
</tr>
<tr>
<td>Rice straw</td>
<td>26.16</td>
<td>36.13</td>
<td>40.43^a</td>
<td>0.040^a</td>
<td>-0.89^a</td>
</tr>
<tr>
<td>A. semibacata</td>
<td>25.71</td>
<td>33.89</td>
<td>37.01^a</td>
<td>0.052^a</td>
<td>0.32</td>
</tr>
<tr>
<td>A. halimus</td>
<td>26.31</td>
<td>30.59</td>
<td>33.04^a</td>
<td>0.065^w</td>
<td>-0.36</td>
</tr>
<tr>
<td>Leucaena</td>
<td>27.34</td>
<td>34.12</td>
<td>35.10^a</td>
<td>0.050^a</td>
<td>-3.26</td>
</tr>
<tr>
<td>Artichoke leaves</td>
<td>39.77</td>
<td>46.07</td>
<td>47.07^c</td>
<td>0.075^c</td>
<td>-0.96^c</td>
</tr>
<tr>
<td>Artichoke stems</td>
<td>51.15</td>
<td>54.81</td>
<td>54.97^c</td>
<td>0.101^f</td>
<td>-1.34^f</td>
</tr>
</tbody>
</table>

a, b and c means within same column with differing superscript are significantly different (P<0.05).

Table 3: Metabolizable energy (ME MJ/KgDM), net energy (NE MJ/KgDM) and organic matter digestibility (OMD) prediction for different roughages in vitro.

<table>
<thead>
<tr>
<th>Roughage</th>
<th>ME MJ/KgDM</th>
<th>NE MJ/KgDM</th>
<th>OMD %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay</td>
<td>7.94^a</td>
<td>5.19^a</td>
<td>54.34</td>
</tr>
<tr>
<td>Rice straw</td>
<td>6.03^b</td>
<td>3.92^a</td>
<td>41.48</td>
</tr>
<tr>
<td>A. semibacata</td>
<td>6.50^a</td>
<td>4.30^a</td>
<td>45.57</td>
</tr>
<tr>
<td>A. halimus</td>
<td>6.47^a</td>
<td>4.34^a</td>
<td>45.20</td>
</tr>
<tr>
<td>Leucaena</td>
<td>6.78^a</td>
<td>4.45^a</td>
<td>46.89</td>
</tr>
<tr>
<td>Artichoke leaves</td>
<td>8.56b</td>
<td>5.59^b</td>
<td>58.24</td>
</tr>
<tr>
<td>Artichoke stems</td>
<td>9.99^a</td>
<td>6.54^b</td>
<td>67.57</td>
</tr>
</tbody>
</table>

a, b and c means within same column with differing superscript are significantly different (P<0.05).
ME and NE profile are similar in seven forages and varied mixtures to replace conventional roughage sources and berseem hay are presented in Table 3. The predicted and therefore, artichoke could be incorporated in feed microorganisms. Doane fermentability of carbohydrates available to volume improved precision of prediction of A. semibacata, A. halimus or Leucaena. The variation in Romney between rice straw and all of other roughages. There is no chemical constituents measurements as compared to Figure 2. VFA produced varied significantly (P<0.05) prediction of ME is more accurate when based on gas and leaves, Artichoke stem and berseem hay are presented in and chemical constituents and concluded that the ME content of feed by production. calculated from a significant correlation between SCFA and gas production together with CP and fat content with metabolizable energy value of conventional feeds measured in vivo.

The organic matter digestibility (OMD)% was higher (P<0.05) in artichoke stems and leaves and lowest in rice straw. The OMD differs significantly among artichoke leaves and stems and berseem hay in comparison with rice straw, A. halimus, A. semibacata, and Leucaena. The OMD of artichoke stems is significantly higher than berseem hay but it was not significant with artichoke leaves. There are no significant differences between berseem hay, rice straw, A. halimus, A. semibacata, or Leucaena in OMD. However, the tropical feeds contained considerable amounts of secondary plant metabolites, particularly tannins which, is associated with reduction in OMD. Using the in vitro gas measurement and chemical composition in multiple regression equation, Menke et al., McLeod and Minson and Van Soest showed that there was no significant difference among A. semibacata, A. halimus or Leucaena in OMD. This may be due to high N solubility in berseem hay and artichoke. The profile of NH₃-N concentration is similar and there is no significant difference (P<0.05) among A. semibacata, A. halimus or Leucaena. The reduction of NH₃-N concentration in Atriplex species may be attributed to anti-nutritional factors like condensed tannins which form a complex compound with protein which adversely affect N digestion.

Total volatile fatty acids (TVFA, mM) concentration profile at 0, 1, 3 and 6 hr of incubation in vitro for rice straw, A. semibacata, A. halimus, Leucaena, Artichoke leaves, Artichoke stem and berseem hay are presented in Figure 2. VFA produced varied significantly (P<0.05) between rice straw and all of other roughages. There is no significant difference in VFA production among A. semibacata, A. halimus or Leucaena but the VFA concentration in Artichoke leaves or stems and berseem hay was significantly higher (P<0.05) in comparison with A. semibacata, A. halimus or Leucaena. The variation in VFA production among the roughages used in this study may be due to the differences in amount, nature and fermentability of carbohydrates available to microorganisms. Doane et al. and Kamalak et al. found a significant correlation between SCFA and gas production.

Energy contents and organic matter digestibility: The predicted metabolizable energy (ME, MJ/kgDM), net energy (NE, MJ/kgDM) and organic matter digestibility (OMD) from gas production for rice straw, A. semibacata, A. halimus, Leucaena, Artichoke leaves, Artichoke stems and berseem hay are presented in Table 3. The predicted ME and NE profile are similar in seven forages and varied widely being particularly high in artichoke stems, leaves and berseem hay. While the other four forages had significantly lower values of ME and NE. The data showed that there was no significant difference among rice straw, A. semibacata, A. halimus, Leucaena, or berseem hay. The artichoke stems and leaves had the higher content of ME and NE in comparison with berseem.. There was a positive correlation between metabolizable energy calculated from in vitro gas production together with CP and fat content with metabolizable energy value of conventional feeds measured in vivo.

In conclusion, there are considerable differences in the fermentability of carbohydrates between different roughages. This study suggested that artichoke have a potential fermentation efficiency better than berseem hay and therefore, artichoke could be incorporated in feed mixtures to replace conventional roughage sources.
(e.g. berseem hay, silage) in ruminant diets. In addition, due to the high digestibility of artichoke, it can be incorporated into the diet without major problem.

REFERENCES


