International Journal of Agriculture Innovations and Research
Volume 4, Issue 2, ISSN (Online) 2319-1473
Manuscript Processing Details (dd/mm/yyyy) :
Received : 24/08/2015 | Accepted on : 31/08/2015 | Published : 08/09/2015

# Effects of Local Energy Sources on the "In Situ" Digestibility and Ruminal Kinetic of *Erythrina poeppigiana* Foliage in a Silvopastoral System

**Guillermo Jiménez-Ferrer**
El Colegio de la Frontera Sur (ECOSUR),
Carretera Panamericana y Periférico Sur s/n,,
San Cristóbal de Las Casas, Chiapas, México, CP 29290.
Email: gjimenez@ecosur.mx

**Lorena Soto-Pinto**
(ECOSUR), Carretera Panamericana y Periférico Sur s/n,
San Cristóbal de Las Casas, Chiapas, México, CP 29290

**Esaú Pérez Luna**
Universidad Autónoma de Chiapas (UACH),
Facultad de Agronomía, Villa Flores, Chiapas, México

**Juán Kú-Vera**
Universidad Autónoma de Yucatán, Lab. Cambio
Climático y Ganaderia FMVZMérida, Yucatán, México

*Abstract* – **This study evaluated the effect of sorghum grain (Sg), green banana (Gb), polished rice (Pr), and sugarcane molasses (Mo) on the"in situ" digestibility ruminal kinetic of Poró (*Erythrina poeppigiana*) foliage under silvopastoral conditions in Turrialba, Costa Rica.Four ruminally cannulated Romosinuano steerswith a mean live weight of 450 kg (SD 31) were used. The experiment was designed as a 4 x 4 Latin Square with one square and four periods. Steers grazed in twelve paddocks on pasture composed of African star-grass (*Cynodon niemfuensis*), ruzzy grass (*Brachiaria rusisiensis)*, and natural grasses (*Axonopus compresus* and *Paspalum conjugatum*), under a rotational grazing system. Energy sources were supplemented at 0.60 Mcal ME /100 kg (BW)/day. The steer were supplemented daily with fresh foliage (leaves, petioles, and stems) of Poróat 0.5 kg of DM/100 kg BW. Significant differences (P< 0.05) were found among the DM of energetic supplements for initial degradability, potential degradability and degradation rate. The effects of treatments on the degradability parameters of the DM of *Erythrina* and the grass blend as well as on N-NH$_3$ and pH content, were not significant (P < 0.05). In addition, there were no significant differences (P< 0.05) among treatments for total concentration of volatile fatty acids (VFA´s) (mmol): (Pr = 87.0, Gb = 95.0, Sg =96.0, Mo = 87.0); however, the proportion of acetic acid, propionic acid and butyric acid presented significant differences (P >0.05) due to the effect of the molasses. The fermentation pattern was typical of cattlegrazing diets under tropical conditions, with the molar proportion of acetic acid greater than 65%, between 13 and 16%for propionic acid and between 9 and 12% for butyric acid.**

*Keywords* – **Central America, Energy, Fodder Tree, Ruminal Fermentation.**

## I. Introduction

Tropical cattle's farming is still mainly based on pastures under an extensive grazing system[1]. In Latin America, silvopastoral systems have been widely promoted over recent years[2]; these agroforestry systems incorporate tree foliage and fodder shrubs to improve animal health, milk and meat production [3] [4] , in addition to promoting environmental services [5] . In this context, diverse holistic strategies for animal production that include the use of feed supplements to improve the production and consumption of foods of animal origin, have been implemented on a global scale[6 ].

There is a wide diversity of native fodder trees throughout Latin America [7]and the genus *Erythrina* has a distribution range that extends from Mexico to South America. In southeast Mexico, many species of *Erythrina*are used in agro forestry systems as live fences, windbreaks, shade for coffee and cocoa plants or support for other plants. They improve the soil while providing animal fodder, human food, medicine and timber products [8] .The species Poró (*Erythrina poeppigiana* (Walpers) O.F. Cook,is a multiple use tree that provides a cheap source of protein for animal feed. Its fodder potential is based on high nitrogen content and biomass production [9] .The leaves of *E. poeppigiana* possess high nutritious value (20-22% of dry matter), are high in crude protein (27-34%), and present a good range of in-vitro digestibility (49-57%). Furthermore, the presence of potentially toxic alkaloids in the leaves of *E. poeppigiana* has not affected cattle health [10].

The available nitrogen in Poró foliage and many other fodder trees is very soluble, quickly degradable in the rumen and attaches to the cellular wall of fibre; therefore, the incorporation of energy supplement is necessary in order to improve ruminal fermentation and animal response [ 11] [ 12]. However, easily fermentable substrates enhance the concentration of volatile fatty acids and lower pH in the rumen which may reduce both ruminal fibre and protein degradation as well as the efficiency of microbial protein synthesis[13].

The objective of this study was to evaluate the effect of four local energy sources (polished rice, molasses , green banana and sorghum grain )on digestibility, ruminal kineticand passage rate of foliage from the Poró tree (*Erythrina poeppigiana*) within a silvopastoral system.

## II. Material and Methods

### *Location*

The experiment was carried out at the Tropical Agricultural Research and Higher Education Center (CATIE) in Turrialba, Costa Rica. The silvopastoral area is located at 9º 58´ N and 83º 31´ W. Mean annual temperature and rainfall is 23 ºC and 2600 mm respectively.

### *Experimental design, treatments and management*

Fourruminally cannulated Romosinuano steers, from the CATIE farm herd, weighing an average of 450 kg (SD 31), were used in the experiment. The experiment was designed as a changeover 4 x 4 Latin Square [14], with one square and four periods (14 days adaptation and 7 days measurement). The steers were fed four treatments during the dry season (March – May): grain sorghum, green banana, polished rice, and sugarcane molasses. Energy sources were supplemented at 0.60 Mcal ME (metabolizable energy) /100 kg body weight (BW) per day. Each steer within each square was subjected to all treatments **(Table 1).**

Table 1: Experimental design

| Square | 1 |
|---|---|
| Animal | A B C D |
| Periods | |
| I | 1 2 3 4 |
| II | 2 1 4 3 |
| III | 3 4 1 2 |
| IV | 4 3 2 1 |

Treatments: 1 = polished rice, 2 = green Banana, 3 = sorghum grain, 4 = molasses

The animals were treated against external and internal parasites and were in a healthy condition before and during the experiment. Water and mineral salt were offered ad libitum. Steers grazed in twelve paddocks (each with an area of one $ha^{-1}$) composed of African star-grass (*Cynodon niemfuensis*), ruzzy grass (*Brachiaria rusisiensis*), and natural grasses (*Axonopus compresus* and *Paspalum conjugatum*), with a stocking rate of 2.5 UA/ha under a rotational grazing system (3 days occupation, 24 days resting intervals). The steers were daily supplemented with fresh foliage (leaves, petioles, and stems) of *Erythrina poeppigiana* at 0.5 kg of DM (dry matter) /100 kg BW. The *Erythrina* foliage was obtained from trees under a cut-and-carry system. Energy supplements and *Erythrina* foliage were offered in the morning (6.00a.m.). The green banana was chopped (5 cm), whereas the sorghum grain was ground (particle size 30 mm). During the collection, data on the time of each experimental period was recorded.

*"In situ" digestibility*

The "in situ" dry matter digestibility of *Erythrina* foliage and the grass mixture was determined by implementing thenylon bag technique[15] using10 x 15 cm nylon bags with 40 µm pores. Three grams of fodder sample were deposited in each bag. The incubation timeswithin the rumen for each fodder sample were 0,3,6,12,24,48 and 72 h. The samples were introducedseparately in reverse order of incubation time (72h first) and subsequently removed together[16].The incubated sample bags were extracted, washed and dried to determine the quantity of DM in the fodder samples. Dry matter degradability of the fodder samples, corresponding to each incubation time, wasanalysed using the [17] Orskov and McDonald (1979) model:

$$P = a + b\,(1 - e^{-ct})$$

P =degradation at time t (h),
a = soluble fraction,
b = insoluble but potentially degradable fraction,
a + b = potential degradation and
c = rate of degradation of b

At the end of each experimental period, 3 samples of rumen licor ( 100 ml each one) were collected from each animal before feeding and at 0, 3, 6 and 12 h after feeding to determine pH, Ammoniacal nitrogen ($NH_3$-N ) and volatile fatty acids (VFAs) [11 ] .Diet rate of passage was evaluated using the chromium oxide technique[18 ] [19] .One hundred grams of mordanted fibre was introduced into each animal and then dreg samples were taken at 0, 6, 12, 18,24, 36,48,72,96 and 120 h to determine the quantity of marker excreted.Feed samples were collected to determine dry matter, crude protein[20] (AOAC, 1997), and in vitro dry matter digestibility[21] (Tilley and Terry, 1963); NDF and ADF were determined by the procedures implemented by Van Soest [22]. Metabolizable energy from grasses, *Erythrina* foliage and energy sources was estimated from in vitro digestibility.

*Statistical analyses*

The data were analysed using the GLM procedure in SAS Software [23].The mathematic model used was the following: $Yijk = \mu + P_J + T_k + C_l + E_{ijk}$, with i = 1 , j = 1 , k = 1,2,3,4 and *l*=1..4, where µ was the overall mean, PJ the fixed effect of period, Tk the fixed effect of treatments, Cl the random effect of steer, and the E*ijkl* the random residual error. Differences were declared significant if $P < 0.05$.

## III. Results and Discussion

*Chemical composition of feeds*

The chemical compositions and "in vitro" digestibilityof dry matter (IVDM) of the feeds used in the treatments are presented in Table 2. As expected, *Erythrina* fodder presented higher crude protein (CP) content and lower neutral detergent fiber (NDF) concentrations compared to the grass mixture. The grasses presented low digestibility and amounts of proteinbut high NDF content and acid detergent fibre (ADF). The treatments contained intermediate CP, typical for sources of energy such as sorghum, polished rice and molasses. As shown in other studies in Latin America, our results demonstrated that grass nutritional values were low in protein and digestibility, which suggests the need for protein and energy supplements to meet requirements for milk and meat production. Several studies define low-quality forages as those forages with a CP less than 75- 100 g/kg DM and suggest supplementation of such forages with appropriate nutrients to achieve high levels of animal production[24] [25 ].Normally, CP content of fodder tree foliage in Latin America is above 150-200 g / kg DM. In this experiment, the mean CP concentration of *Erythrina* forage was higher than the 200–250 g/kg DM range reported by previous studies in Central America [12].Previous experiences using foliage from fodder trees as a cattle feed supplement have indicated that this resource could represent an important protein supplement for milk and meat production[ 3] [26 ] [ 2].The foliage of *Erythrina poeppigiana*and many other fodder trees present attractive nutritional properties for the improvement of cattle pasture agro-systems in the tropics [ 9].Similarly, the use of plant by-products to increase energy consumption in cattle systems could offer economic and ecologicalbenefits to the cattle farmer, increasing production efficiency in addition to providing an environmentally friendly alternative [1 ].

*pH, ammonia nitrogen ($NH_3$ – N ),passage rate and volatile fatty acids.*

The effect of the treatments on the parameters of pH, $NH_3$-N and passage rate are presented in Table 3. Significant differences were not detected among treatments with respect to pH values, with amean pH value of 6.6 for all treatments. Variationsaccording to the sample time intervals reveal that thehighest pH for each treatment was before offering the sources of energy. The pH values subsequently decreased, reaching minimums at 1.5h and then attaining pH levels equivalent to those at supplementation initiation (data not shown). The sorghum and molasses supplements presented the lowest pH values. This ruminal pH pattern coincides with that described

Table 2: The chemical composition and *in vitro* digestibility of feeds used in the experimental diets

| | Feeds | | | | | |
|---|---|---|---|---|---|---|
| **Constituents[a]** | **Sorghum** | **Polished Rice** | **Green Banana** | **Molasses** | **Poró** | **Grass[b]** |
| DM ($g/kg^{-1}$) | 920 | 921 | 270 | 707 | 232 | 195 |
| CP (g/ $kg^{-1}$ DM) | 70 | 120 | 44 | 30 | 320 | 85 |
| NDF (g/ $kg^{-1}$ DM) | 252 | 305 | 95 | *nd* | 534 | 567 |
| ADF (g/ $kg^{-1}$ DM) | 164 | 213 | 56 | *nd* | 315 | 413 |
| IVDMD (%) | 98.0 | 63.8 | 95.0 | *nd* | 56.6 | 51.3 |
| EM (*MJ* Kg-$^{1}$ DM)[c] | 14.6 | 13.3 | 3.8 | 9.2[d] | 7.5 | 7.11 |
| Number of sample | 6 | 6 | 6 | 6 | 6 | 6 |

Poró = *Erythrina poeppigiana* , DM: dry matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber; IVDMD: *in vitr*o dry matter digestion; *ME*: metabolizable energy. *nd* not determined.
[a] calculated in CATIE Laboratory Animal Nutrition, [b]*Mixture : Cynodon nlemufensis, brachiaria ruziziensis, Axonopus compressus, Paspalum conjugatum* ;[c] estimated from IVDMD, [d]Feddipedia, 2015

Table 3: Effect of the sources of energy on the ruminal parameters of *Erythrina poeppigiana*

| | Parameters | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatments | $NH_3$-N (Mg/100 ml) | pH | Rate of passage Rp (% h) | Tt (h) | AA (m/100 mol) | PA | BA | VFA (mmol) |
| Polished rice | 53.4 [a] | 6.6 [a] | 8.6 [a] | 55.3[a] | 72.0 [a] | 16.0 [a] | 11.0 [b] | 87.0 [a] |
| Green banana | 51.7 [a] | 6.7 [a] | 8.5 [a] | 53.8[a] | 70.0 [a] | 13.0 [ab] | 12.0 [b] | 95.0 [a] |
| Sorghum | 51.6 [a] | 6.6 [a] | 8.0 [a] | 54.3[a] | 71.0 [a] | 14.0 [b] | 11.0 [a] | 96.0 [a] |
| Molasses | 52.8 [a] | 6.5 [a] | 9.4 [b] | 49.4[b] | 66.0[a] | 13.0 [a] | 9.0 [a] | 87.0 [a] |

NH3-N: ammonia nitrogen; AA = acetic acid; PA= propionic acid; BA=butyric acid: VFA = volatile fatty acids: Rp = rate of passage ; Tt = time transitMeans with different superscript within column differ (p<0.05).

by Van Soest [27] and Leng, [28 ] who indicate that the ruminal pH dynamic tends to decrease after food intake and then increases again after a certain amount of time has lapsed. In general, all the treatments demonstrated conditions that were close to neutrality. Likewise, the inverse relationship between pH behaviour and the total AGV concentration was confirmed. The concentration of NH3 – N did not present statistically significant differences; however, the effect of sampling time was highly significant ($P < 0.001$). The highest values were observed 3 h after supplementation; the banana and polished rice sources of energy presented high NH3 – N values, molasses intermediate and sorghum low values. The reduction in ammoniacal concentration was stabilized for all treatments at 12 h, with the exception of sorghum. With respect to the passage rate of solids, significant differences were observed ( $p < 0.05$) among treatments with the molasses and sorghum supplements demonstrating the highest and lowest values respectively.

The use of local energy resources, such as molasses, banana´s, yucca (*Manihot esculenta*)and agroindustrial by-products in tropical zones, is an option which is rapidly available, low cost and that allows an improved and integral nutritional balance in cattle grazing systems [29]. Carbohydrates are the most important source of energy for rumen fauna and therefore play an essential role in the synthesis of microbial protein[30]. Nevertheless, ruminal behaviour varies greatly according to the quantity and source of available carbohydrates; therefore, diet composition, particularly the concentration and type of nitrogenated and energy sources, is one of the most influential factors in the ruminal environment[31].Another important aspect is the manner in which supplements are offered in the diet, determining microorganism efficiency and conditioning animal production.

Table 3 showsthat the sources of energy did not affect the total concentration of VFA; however, there was a tendency for the molasses supplement to result in a decrease in the concentration of acetic and butyric acid. Sutton [32], in cattle milk production experiments, mentions that the fodder fermentation rate and the molar proportion of produced VFA differed widely with different substrates of fermented carbohydrates in the rumen. The consumption of rapidly fermentable matter, such as molasses, should produce increases in the production of AGV which results in acidification of the ruminal environment.

Although there were no differences in ruminal pH, the effect of the molasses could have resulted in a more acidic pH value; however, the presence of antiqualitive factors in the foliage of *Erythrina* and banana could have produced a depressor effect on ruminal fermentation[33 ] [34 ].Similarly, Sutton[35] reports important changes associated with supplementation with starch and banana, resulting in a decrease in ruminal pH and increases in the molar proportions of propionic acid at the expense of acetic acid. Pérez [36 ],found that ruminal pH decreased lineally with an increase in the consumption of green banana in milking cows (0.0, 0.4, 0.8, 1.2, 1.6 and 2.0 kg (DM)/I00 kg /BW/day)and VFAin the ruminal liquid did not vary; however, the proportion of butyric acid increased as there was a consequent decrease in acetic acid.

During the current experiment, it was observed that the concentration of total VFA attained maximum values 3 h subsequent to supplementation. The treatments with polished rice and sorghum reached maximum concentration, maintaining a slower decrease over time (data not shown). Supplementation with banana and molasses presented a rapid decrease in VFA concentration. The observed tendencies agree with Noceck [37]who indicate that VFA levels increase after supplementation and then decrease throughout the day. This process is directly related to ruminal pH behaviour, which is associated with the type and quality of the diet [27 ] (Van Soest, 1982)

*"In situ" degradability of DM*

Table 4: "*In situ*" degradability parameters of DM of the energy sources and their effects on the basal diet of *Erythrina poeppigiana* and grasses mixture

| Treatments | a % | P % | *c* $h^{-1}$ | T/2 h |
|---|---|---|---|---|
| **Parameters *** | | | | |
| Polished rice | 23.18 $^{a}$ | 60.64 $^{a}$ | 0.06 $^{a}$ | 10.10 $^{a}$ |
| Green banana | 16.25 $^{b}$ | 93.26 $^{b}$ | 0.05 $^{b}$ | 12.16 $^{b}$ |
| Sorghum | 4.50 $^{c}$ | 99.50 $^{c}$ | 0.04 $^{c}$ | 16.11 $^{c}$ |
| ***Erythrina poeppigiana*** | | | | |
| Polished rice | 27.0$^{a}$ | 49.9$^{a}$ | 0.08$^{a}$ | 8.6$^{a}$ |
| Green banana | 28.8$^{a}$ | 54.9$^{a}$ | 0.07$^{a}$ | 12.2$^{a}$ |
| Sorghum | 28.7$^{a}$ | 51.3$^{a}$ | 0.07$^{a}$ | 9.6$^{a}$ |
| Molasses | 25.2$^{a}$ | 50.0a | 0.08$^{a}$ | 8.4$^{a}$ |
| **Grasses Mixture** | | | | |
| Polished rice | 19.1$^{a}$ | 54.3$^{a}$ | 0.04$^{a}$ | 15.4$^{a}$ |
| Green banana | 13.6$^{a}$ | 51.7$^{a}$ | 0.06$^{a}$ | 10.1$^{a}$ |
| Sorghum | 15.8$^{a}$ | 53.5$^{a}$ | 0.04$^{a}$ | 16.0$^{a}$ |
| Molasses | 17.2$^{a}$ | 53.0$^{a}$ | 0.43$^{a}$ | 15.9$^{a}$ |

*According to the model Orskov and McDonald (1979). $P = a + b(1 - e^{ct})$
a = initial degradability; P = potential degradability; T/2 = average degradation time; *c* = degradation rate.
Means with different superscript within column differ (p<0.05).

Table 4 presents the "In Situ" degradability parameters of the DM of the sources of energy used in this experiment. As expected, there were clear differences between initial degradability, potential degradability and rate of degradation values (P < 0.05), due to the specific characteristics of each energy supplement. Parra [38],in a study on the degradability of diverse tropical raw materials, report that DM degradation of ground grain sorghum was 13 % and 73 % with respect to a mean degradation time of 139 and 15 h respectively. Beauchemin [39 ],mention that DM degradability of grains progressively increases as the size of particles to be degraded is reduced. In this experiment, there were no significant effects of treatments (P< 0.05) on the degradability parameters of *Erythrina* and the grass mixture. Various tests in Central America using foliage from *Erythrina* [12 ] reports degradability values for Poró foliage of 34.7, 59.5 and 6.5 h for initialdegradability, potential degradability and degradation time respectively, slightly above those found in this study. This could have been due to the characteristics of the Poró tree used in this experiment, since it had a regrowth age of 6 months, greater than the specimen used in the cited study.

## IV. Conclusion

The local sources of energy used in this study (green banana, molasses, polished rice and ground sorghum(0.60 Mcal ME /100 kg/ BW/day)did not have any significant effect on the concentration of NH3 - N,pH and total VFAin the rumen of grazing cattle that were supplemented with foliage of *Erythrina poeppigiana.* A typical fermentation pattern for grazing diets under tropical conditions was demonstrated, where the molar proportion of acetic acid was greater than 65 %, between 13 and 16 % for propionic acid and between 9 and 12 % for butyric acid. The values for initial degradability, potential degradability, and rate of degradation of the dry matter of the energy sources presented clear differences, due to the characteristics of each energy supplement. The energy sources had no effect on the degradation parameters of the staple diet of grass and foliage of *Erythrina.*

## ACKNOWLEDGEMENTS

Thanks are extended to the staff of Tropical Livestock of CATIE (Turrialba, Costa Rica), and especially to Dra. Maria L. Kass (r.i.p.).

## REFERENCES

[1] Graesser J., Mitchell A., Grau R., Ramankutty, N. Cropland/ pastureland dynamics and the slowdown of deforestation in Latin America. Environmental Research Letter, 10: 1 -10. 2015

[2] Ibrahim, M.A., Villanueva, C., M, C.. Traditional and improved silvopastoral systems and their importance in sustainability of livestock farms. In: M. Mosquera-Losada, R. Rigueiro-Rodríguez and A. McAdam, (eds), Silvopastoralism and sustainable land management. CABI (UK), 13-18.2005

[3] Jiménez-Ferrer G., Mendoza G., Alayón A., Soto-Pinto L. Evaluation of local energy sources in milk production in a tropical silvopastoral system with Erythrina poeppigiana. Tropical Animal Health and Production. 47:903–908. 2015.

[4] Sanchez, N.R. and Ledin, I. Effect of feeding different levels of foliage from Cratylia argentea to creole dairy cows on intake, digestibility, milk production and milk composition, Trop. Anim.Health Prod. 38 (4), 343–351. 2006

[5] Palmer, L.. A new climate for grazing livestock, Nature Climate Change, 4, 321–323. 2014

[6] Bocquier F. and González-García E. 2010. Sustainability of ruminant agriculture in the new context: feeding strategies and features of animal adaptability into the necessary holistic approach. Animal, 4 (7): 1258 – 1273.

[7] Murgueitio, E., Calle, Z., Uribea, F., Calle, A., Solorio, B. Native trees and shrubs for the productive rehabilitation of tropical cattle ranching lands, Forest Ecology and Management, 261, 1654–1663.2011.

[8] Jiménez-Ferrer G., López-Carmona M., Nahed-Toral J., Ochoa-Gaona S., de Jong B. Fodder trees and shrubs of the north-tzotzil region of Chiapas, México. Veterinaria (Mex), 39 (2) 199-213.2008

[9] Ibrahim, M.A., Holmann, F., Hernandez, M., and Camero, A. Contribution of Erythrina protein banks and rejected bananas for improving cattle production in the humid tropics, Agroforestry Systems, 49, 245–254.2000.

[10] Orwa C, A Mutua, Kindt R , Jamnadass R, S Anthony. Agroforestry Database: a tree reference and selection guide version 4.0, ICRAF, http://www.worldagroforestry.org/ sites/treedbs/treedatabases.asp (Accessed 17 March 2015).2009.

[11] Kass ML y Rodríguez G. Evaluación nutricional de alimentos In: M. Ruiz y A. Ruiz (eds), Nutrición de Rumiantes. Guía metodológica de investigación. ALPA-IICA, Costa Rica, 49 – 79. 1990.

[12] Camero, A., Ibrahim, M., and Kass, M.Improving rumen fermentation and milk production with legume-tree fodder in the tropics, Agroforestry Systems, 51, 157–166. 2001.

[13] Al-Asfoor, H., Schiborr, Sundrum, A., Schlecht, A. Particulate Rate of Passage and Faeces Quality of Water Buffalo Fed Diets Varying in Concentrations of Nitrogen and Structural and Non-structural Carbohydrates. Animal Nutrition and Feed Technology, 13: 165-180.2013.

[14] Lucas, H. L. Design and analysis of feeding experiments with milking dairy cattle. North Caroline State University, Raleigh, USA.1983.

[15] Orskov, E.R. Protein Nutrition in Ruminants. Academic Press, London.1982.

[16] Nocek E.J and Russel, J.B. Protein and energy as integrated system. Relationship of protein ruminal and carbohydrate availability to microbial synthesis and milk production. Journal of Dairy Science, 71: 2070 -2107.1988.

[17] Orskov, E.R. McDonald, L., The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. Journal of Agricultural Science, Cambridge, 92 (2), 499-503. 1979.

[18] Lascano C. y Quiroz R. Metodología para estimar la dinámica de la digestión en rumiantes. In: M. Ruiz y A. Ruiz (eds), Nutrición de Rumiantes. Guía metodológica de investigación. ALPA-IICA, Costa Rica, 89-104.1997.

[19] Gonzaga N,S., Lopes O:R. Heton, F.S. et al. Milk production, intake, digestion, blood parameters, and ingestive behavior of cows supplemented with by-products from the biodiesel industry. Tropical Animal Health and Production, 47: 1, 191-200. 2015.

[20] AOAC. Association of Official Analytical Chemists. Official Methods of Analysis, Washington, D.C., USA. 1997.

[21] Tilley, M.A. and Terry, R.A. A two-stage technique for the in vitro digestion of forage crops, Journal of the British Grassland Society, 18, 104–109.1963.

[22] Van-Soest, P., Robertson J., and Lewis B. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition, Journal of Dairy Science, 74, 3583–3597

[23] SAS, 2012. SAS/STAT. User´s Guide, (Sas Institute, Cary, NC, USA).1991.

[24] Garduza-Arias, G., Garcia-Bojalil, C.M. Mendoza, et al. Effect of supplementation with rumen undegradable protein on milk production and ovarian activity in double purpose cows. Journal of Applied Animal Research, 41:223-228.2013.

[25] López, S., Dijkistra, J., and France, J. Prediction of energy supply in ruminants, with emphasis on forages. In: D.I. Givens, R. Owen, R. Axford, and H. Omed, (eds), Forage Evaluation in Ruminant Nutrition, (CABI, Oxford UK), 63–94.2000.

[26] Mendieta-Araica, B., Spörndly, R., Reyes-Sánchez, N., and Spörndly, E. Moringa (Moringa oleifera) leaf meal as a source of protein in locally produced concentrates for dairy cows fed low protein diets in tropical areas, Livestock Science, 137, 10–17.2011

.[27] Van Soest P. Nutritional ecology of the ruminant. Corvallis, Oregon, 374 p.1982.

[28] Leng, R.A. Drought Feeding Strategies: Theory and Practice, (Pernambul Books, Armidale, Australia).1986.

[29] Feedipedia, Cereal grains and by-products. On line Animal Feed Resources Information System,Inra-Cirad-Afz-Fao,http://www. feedipedia.org/content/about-feedipedia (Accessed 07 Jul. 2015).

[30] Roque RL. Nutricion de Rumiantes : sistemas extensivos. Ed. Trillas, Mexico 3014 p.2003

[31] Dewrust R.J., Davies D.R. and Merry R.J. Microbial protein supply from the rumen. Animal Feed Science and Technology. 85: 1-21.2000.

[32] Sutton, J.D. Carbohydrates fermentation in the rumen – Variations of theme. Proc Nutr Soc (UK) , 38 (03), 275 – 281.1979.

[33] Brumby, V. D., Chaudhry, U. B., Haryono, S. U., Hendratno, N. The potential for tree forage supplements to manipulate rumen protozoa to enhance protein to energy ratios in ruminants fed on poor quality forages. In: RA Leng, and SH Bird, (eds) . Legumes trees and other trees as protein sources for livestock. Proceedings of the FAO-MA.1992.

[34] Atangana, A., Khasa, D., Chang, S., and Degrande, A. Ecological Interactions and Productivity in Agroforestry Systems. In:A. Atananga, S. Chang and A. Degrande (eds), Tropical Agroforestry. Dordrecht: Springer, 151-172 pp.2014.

[35] Sutton, J.D. Digestion and end-products formation in the rumenfrom production rations. In: Digestive physiology and metabolism in ruminants. Y. Ruckebush. and P. Thivend (eds). Westport, United States AVI. 271-290.1980.

[36] Perez, E., Ruiz M., Pezo, D. Suplementación de bovinos con banano verde. IV. Efectos sobre algunos parámetros de fermentación ruminal. Agronomía Costarricense (Costa Rica), 14(1): 67-72.1990.

[37] Nocek E.J and Russel, J.B. Protein and energy as integrated system. Relationship of protein ruminal and carbohydrate availability to microbial synthesis and milk production. J. Dairy Sci.71: 2070 -2107.1988.

[38] Parra, A., Combellas, R., Dixon R. Degradabilidad ruminal de algunas materias primas tropicales. Producción Animal tropical ( Rep. Dom. ), 9 : 208:211. 1984.

[39] Beauchemin, K., Yang, W.Z and Rode, L.M. Effects of barley grain processing on the site and extent of digestion of beef feedlot finishing diets. Journal of Animal Science, 79, 1925-1936.2001.

International Journal of Agriculture Innovations and Research
Volume 4, Issue 2, ISSN (Online) 2319-1473

## AUTHOR'S PROFILE

**Guillermo Jiménez –Ferrer**
*Contact Address:* ECOSUR Carretera Panamericana y Per. Sus s/n San Cristóbal de las Casas Chiapas México 29260
*Phone:* (+52) 9676749000 ext. 1410
*Place Birth*: Culiacán, Sinaloa México.
*Educational Background*: Ph D in Live (Animal Nutrition) in Universidad Autónoma de Yucatán, México. Msc. Tropical Livestock, CATIE, Turrialba Costa Rica. Ing. Agronomy (Universidad Autónoma Metropolitana, Xoch. México)
*Work Experience:* 25 years in silvopastoral Systems researcher and development in indigenous communities (Mayas-México) and consultant. Actuality leader of the Livestock and Climate Change Project of the southeast of México (Project SEP-CONACYT 242541)