Productive performance and net energy in rabbits fed increasing levels of Brosimum alicastrum fodder

Desempenho produtivo e energía líquida em coelhos alimentados níveis crecentes de forragem de Brosimum alicastrum

Desempeño productivo y energía neta en conejos alimentados con niveles crecientes de forraje de Brosimum alicastrum

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ABSTRACT

Twenty-four Californian rabbits breed with initial body weight of 1.36 ± 0.019 were used in a completely randomized design to evaluate the performance and calculate the net energy contribution of a commercial diet supplemented with foliage of *Brosimum alicastrum*, as well as the efficiency of utilization of metabolizable energy for maintenance, production and maintenance + production (km, kp and kmp). Animals were fed to cover consumption of 7% of body weight in dry matter. There were four diets: control (commercial feed) and three levels of *Brosimum alicastrum* inclusion (20, 40 and 60% fodder). Differences were found (P<0.05) in daily weight gain 25.20g**,** 17.80g**,** 12.50g, 16.24g and ±5.44**,** feed conversion 5.06, 6.85**,** 7.74 and 9.95± 2.02 and energy conversion (EC) 20.30**,** 27.92,32.11and42.19 ± 9.12Mcal/kg gain for control diet and 20**,** 40**,** and 60% of *Brosimum alicastrum* inclusion, respectively. Net energy value calculated was1.32Mcal/kg DM for the control dietand0.769Mcal/kg DM for *Brosimum alicastrum* fodder**.**

Keywords: efficiency, growth, production, retention, Ramón, tropical

RESUMO

Vinte quatro coelhos da raça california com peso inicial de 1,36 ± 0,019 kg foram usados em um delineamento inteiramente cazualizado, para avaliar o desempenho e calcular a contribuição de energia líquida de uma dieta comercial suplementada com folhagem de Brosimum alicastrum, bem como a eficiência de utilização da energia metabolizável para manutenção e produção (km, kp e KMP). Os animais foram alimentados se adequando o fornecimento de alimentos a 7% do peso corporal em matéria seca. Utilizaram-se quatro dietas: controle (ração comercial) e três níveis de *Brosimum alicastrum* (20, 40 e 60% de forrajem). Foram encontradas diferenças (P <0,05) no ganho de peso diário 25.20g, 17.80g, 12.50g, 16.24g e ± 5.44, conversão alimentar 5.06, 6.85, 7.74 e 9.95 ± 2.02 e a energia de conversão (CE) 20.30, 27.92, 32.11 e 42.19 ± 9.12 Mcal / kg de rendimento para o controle da dieta e 20, 40 e 60% de *Brosimum alicastrum* de inclusão, respectivamente. O valor energético líquido calculado foi de 1,32 Mcal / kg de MS da dieta de controle e 0,769 Mcal / kg de MS de forrajem *Brosimum alicastrum*.

Palavras-chave: crescimento, eficiência, produção, Ramón, retenção, tropical

RESUMEN

Veinticuatro conejos de raza California con peso corporal inicial de 1,36 ± 0,019 kg fueron utilizados en un diseño completamente aleatorizado para evaluar el desempeño y calcular la contribución de energía neta de una dieta comercial complementado con follaje de Brosimum alicastrum, así como la eficiencia de utilización de la energía metabolizable para mantenimiento, producción y mantenimiento + producción (km, kp y kmp). Los animales fueron alimentados para cubrir el consumo del 7% del peso corporal en materia seca. Se utilizaron cuatro dietas: control (alimento comercial) y tres niveles de inclusión de *Brosimum alicastrum* (20, 40 y 60% de forraje). Se encontraron diferencias (P <0.05) en la ganancia diaria de peso 25.20g, 17.80g, 12.50g 16.24g y ± 5,44, conversión alimenticia 5,06, 6,85, 7,74 y 9,95 ± 2,02 y la conversión energética (CE) 20.30, 27.92, 32.11 y 42.19 ± 9,12 Mcal / kg de ganancia para la dieta control y 20, 40, y 60% de Brosimum alicastrum inclusión, respectivamente. El valor calculado de energia neta fue de 1,32 Mcal / kg de MS de la dieta de control y 0.769 Mcal / kg de MS de forraje Ramón.

Palabras clave: crecimiento, eficiencia, producción, ramón, retención, tropical

Introduction

Rabbit's physiological characteristics (e.g. caecotrophy) allow them to integrate in a wide range of productive systems, through the utilization of non-conventional inputs as feed (Lukefahr, 2008). In the tropics, is particularly important to conduct systematic assessments of alternative sources of forage for animal feeding. *Brosimum alicastrum* is a tree species commonly used in the Mexican tropic in animal feeding. *Brosimum alicastrum* fodder presents high nutritional potential for different animal species including rabbits. However, information on its nutritional value in rabbits' feeding is limited. Martinez (2010) reported that including *Brosimum alicastrum* in rabbits' diet increased dry matter consumption (DM) and produced acceptable digestibility values for different components of the ration (DM, PC), its inclusion up 25%, produces a similar response such as concentrate-based feeding. Rojas (2008) reported that the metabolizable energy content (ME) of *Brosimum alicastrum* forage is similar for sheep and rabbits and the inclusion of this fodder into a diet based on commercial feeding did not have negative effects on digestibility and gross energy (GE) metabolism in rabbits. There is no previous work on net energy (NE) determination of *Brosimum alicastrum* forage in rabbits. Generation of knowledge about this value is important so to achieve an efficient utilization of this resource, and to explain adequately the performance obtained and appropriate comparisons with other substrates. Therefore, the objective of this study was to evaluate the productive performance of rabbits fed *Brosimum alicastrum* forage, and calculate net energy concentration in *Brosimum alicastrum* forage.

Materials and Methods

Study area location

The study was carried out in Yucatan State. Weather conditions classified as tropical with rainfall season in summer (AW0) (940mm per year) and an average of 26ºC. Relative humidity varies from 65% to 85% (Flores, 1994).

Animals

Twenty four male California breed rabbits 30 days old were used with an initial body weight (LW) of 1.36kg ± 0,109 during 49 days. Animals were housed in individual cages 40 x 80 cm, equipped with plastic feeders and drinkers. Previously to the experiment the animals were dewormed (ivermectin 400 µg/kg live weight) according to Birchard and Sherding (1996).

Experimental diets

In each treatment six animals were used. Experimental treatments were: control diet (commercial rabbit concentrate), T2 (80% commercial+ 20% Ramón), T3 (60% commercial + 40% Ramón); T4 (40% commercial + 60% Ramón). Ramón forage was sampled on day 1 and day 72 of the experiment, for the corresponding chemical analysis (Ramon forage included leaves and stems not bigger than 3mm thick, belonging to the same trees during the whole experiment). Feeding offered was equivalent to 7% of body weight in DM, and it was weekly adjusted according to the animals body weight. Feed was offered once daily at 10 am in separate containers (one for commercial feed and another for *Brosimum alicastrum* fodder). Animals received clean and fresh water *ad libitum*. Experimental diets were analyzed for chemical composition for dry matter (DM), crude protein (CP) (N*6.25) and ash. Neutral detergent fiber (aNDF) was analyzed with sulfate and without amylase, ash inclusive, acid detergent fiber (ADF) were also determined according to AOAC (1980).

Variables

Consumption

Fresh forage consumption was measured as a result of the difference between fresh matter offered and daily rejection, this value was multiplied by the DM content of commercial feed and *Brosimum alicastrum* fodder to calculate the DM intake.

Nutrient and energy consumption

Nutrient consumption was calculated based on proximal analyses of the substrates and DM content. The gross energy consumption (GE) was calculated based on DM intake multiplied by GE value of commercial feed and *Brosimum alicastrum* fodder. The metabolizable energy (ME) was calculated based on DM intake multiplied by ME value estimated by Rojas (2008) for *Brosimum alicastrum* in rabbits and sheep.

Daily weight gain

The animals were weighed weekly, prior to the feed offering. Body weight gain (WG) was determined by the difference in weight between the weighing. Daily weight gain (DWG) value was calculated by dividing the weight between 7 days.

Slaughter

Animals were slaughtered at 2.5kg LW without fasting, using sodium pentobarbital (63 mg/kg LW); the largest and smallest animal of each group were discarded for statistical analysis.

Net energy

The energy retention was calculated by the comparative sacrifice technique described by McDonald (2002). At the beginning of the experiment a group of 4 animals of the same breed with a LW of 1.5 kg were sacrificed to determine the energy content of the whole body. At the end of the experiment, the sacrificed animals were frozen and sectioned in four parts, in order to be freeze-dried in a Labconco Freezone lyophiliser (model 1000). Freeze drying process lasted 4 days; after that intestinal content was removed and then samples were grounded in a hammer mill (Crompton brand) with a screen size of 3mm. The gross energy content was determined in a calorimeter bomb (Parr model 115 / 5). Energy retention was calculated as follows:

Retained energy (RE) = final GE – initial GE

Where final GE content was the energy content in the animals at the end of the trial. Initial GE value was estimated multiplying average of energy in the first group sacrificed (a priori) by initial weight of the animals. Net energy (NE) value in feed and Ramon forage was calculated using the formula:

$$Net\ Energy(NE) = \left(\frac{Animal\ total\ GE}{GE\ consume} * \frac{GE}{Kg\ feed\ consumed}\right)$$

After obtaining the GE value retained in the animals, NE value was calculated for commercial feed. To calculate NE from Ramon forage, the calculated value for commercial feeding was considered through this value, NE was calculated for each level of inclusion in treatments in the experimental diets. The difference between the value of commercial feed ration and feed energy value of commercial treatments represented the value of NE for the forage inclusion rate. Additionally the efficiency of use for NE was calculated according the formula proposed by McDonald (2002).

$$Kmp = (NEm + NEp)/\left(\frac{NEm}{km} + \frac{NEp}{Kp}\right)$$

Where:

NEm: net energy for maintenance.

NEp: net energy production.

Km: coefficient of ME use for maintenance.

Kp= coefficient of utilization of ME for production.

Kmp= coefficient of ME use for maintenance and production.

To calculate the values for Km, Kp and Kmp, the SOLVER function in Microsoft Excel was used. For the variables DWG, DM consumption, FC and energy retention, the ANOVA analysis were performed according to a complete randomized design with six repetitions per treatment, using the statistical software package Statgraphics 5.1. The measurements were compared using the least significant difference procedure of Fisher (LSD); in addition linear regression analysis was used to examine the relation of DWG, energy conversion and NE of Ramón with the consumption of total ADF, NDF and lignin.

Results and discussion

Nutritional composition of experimental diets

Chemical composition of diets is presented in the following table.

Table1. Chemical composition of experimental diets.

	Control	T2	T3	T4
Dry Matter (%)	87.73	78.71	69.70	60.68
Crude Protein (%)	20.59	19.72	18.85	17.98
Neutral Detergent fiber (%)	38.95	38.85	38.76	38.66
Acid Detergent fiber (%)	21.89	23.29	24.69	26.09
Lignin (%)	4.67	5.05	5.44	5.83
Ash (%)	12.22	11.82	11.43	11.03
Gross Energy (Mcal/kg DM)	4.01	4.09	4.17	4.25
Metabolizable Energy (Mcal/kg DM)	2.30	2.21	2.11	2.02

Productive performance and nutrient consumption

Inverse relationship between daily weight gain and feeding conversion according to the level of *Brosimum alicastrum* consumed (P <0.05) was found. Increasing levels of *Brosimum alicastrum* forage in diets increased animals intake of DM, CP, ADF, NDF, lignin, EB and energy conversion (P <0.05).

Table 2. Productive performance and nutrient consumption in growing rabbits fed with increasing levels of *Brosimum alicastrum*

Variable	Treatment				MSE	P-value
	Control	T2	T3	T4		
DWG (g)	25.25a	17.78b	16.24c	12.50c	1.4473	0.0004
Total DM intake (kg)	5.27^{a}	7.5b	8.53c	8.56c	0.2456	0.0000
Commercial Feed DM intake (kg)	5.27^{a}	6.24b	5.55^{a}	3.6c	0.1778	0.0000
Brosimum alicastrum DM intake (kg)	0.00	1.26^{a}	2.97b	4.95c	0.1507	0.0000
Feed Conversion Ratio	5.06	6.84	7.73	9.94	0.5218	0.0002
Total CP intake (kg)	1.08a	1.49b	1.63b	1.54b	0.0465	0.0000
Total ADF intake(kg)	1.15a	1.73b	2.08c	2.22d	0.0599	0.0000

Total NDF intake (kg)	2.05a	2.91b	3.31c	3.3c	0.0953	0.0000
Total Lignin total intake (g)	240.00a	370.00b	450.00c	490.00c	0.0130	0.0000
Total GE total intake (Mcal)	21.17a	30.6b	35.42c	36.3c	1.0225	0.0000
Total ME total intake (Mcal)	12.2a	16.58b	17.99c	17.29c	2.6076	0.0000
Retained Energy (Mcal/kg)	2.435a	2.072b	2.079b	1.668d	0.1770	0.0656
Energy Conversion (Mcal/kg weight gain)	20.30	27.92	32.11	42.19	2.1730	0.0001
NE_{mp} Diet (Mcal/kg MS)	1.32	1.19	1.08	1.03	0.2700	0.0000
NE_{mp} Brosimum alicastrum (Mcal/kg MS)	NA	0.662	0.783	0.863	0.7490	0.0000

n = 4; [abc] Value in the same line with different letter are statistically different, MSE mean standard error.; NA: not apply.

Productive performance

In the present study, the productive performance was affected with the inclusion of *Brosimum alicastrum* fodder. Animals showed a decrease in DWG as *Brosimum alicastrum* inclusion and diet fibrous components increased (P <0.001) (Table 2). According to Debray et al (2000) and Nagadi (2008) when rabbits fed with high fiber diets, a significant decline in DWG had been found. Wen Shyg – Chiou et al (1998) mentions that when using fodder in rabbits feeding, dietary lignin is more related to the decline in productive performance. In the present study all the components of the fibrous fraction (ADF, NDF and lignin) of the diet were related to a decrease in DWG while forage inclusion increased (P<0.001)(Table 3). DWG in present study are lower than values reported by Lebas et al. (1986) in growing rabbits fed high fiber diets (>11.7%). It was found that the fraction of dietary lignin was more related to the reduction of DWG compared with the NDF or ADF. Relationships among DWG and fibrous fraction of the diet have been studied by Wen-Shyg Chiou et al (1998), who found that lignin (compared to cellulose or pectin) produced the lowest production performance. Nevertheless weight gains reported in this study are consistent with those reported by Hongthong et al. (2004) in rabbits fed forage-concentrate diets (5 – 20 g/day); Iyeghe-Erakpotobot (2006) using stylosanthes and concentrate combinations and higher compared to 8.70 – 9.91g/day reported by Iyeghe-Erakpotobot et al. (2012) for growing rabbits offered 15, 30 and 45 % groundnut forage meal diets; Iyeghe-Erakpotobot (2014) in rabbits fed 50% concentrate plus 50 % groundnut forage meal, 50 % concentrate plus 50 % lablab forage meal and 50 % concentrate plus 25 % groundnut forage and 25% lablab forage meal. Relationship between productive and *Brossimum alicastrum* fodder inclusion level related to fibrous fraction of diet consumption are described in linear regression equations (table 3). It can be appreciated that the consumption of fiber components had a direct impact on DWG and consequently increased feed conversion ratio (Table 2). Yao et al. (2015) reported high feed conversion ratio using mixture of forages with concentrate diets (6.97 – 7.72); Furthermore Iyeghe-Erakpotobor (2007) reported high feed intake (102 – 105 g/day) and low feed conversion efficiency (0.02 – 0.12) in rabbit fed combination of forage – concentrate.

Dry matter intake was increased as the inclusion level of forage increased, probably due to the energy density of diet decreasing. Inclusion of medium to high levels of fiber in the ration and consequently lower energy density of the diet, produced changes in the productive performance of animals with higher nutritional needs, so an increase in feeding consumption and feeding conversion can be observed (Fraga, 1989; Gidenne et al., 2000, 2004). Differences observed between treatments in DMI are related the increase in the concentration of ligno-cellulose in diets with increasing levels of *Brosimum alicastrum*, and the lower energetic density of diets. Increasing in the voluntary intake has been associated with consumption regulation in order to meet the nutritional requirements according to genetic potential. In a study carried out by Paul and Lallo (2014) the results showed that rabbits fed commercial concentrate with different forages adjusted dry matter intake in order to meet nutrient requirements. This is consistent with Yao et al. (2015) who mentioned that high feed intake of rabbits might be as a result in order to meet their nutritional requirements when using forage and concentrate diets. DMI obtained in this study are higher than DMI values reported by Paul and Lallo (2014). Meanwhile Iyeghe-Erakpotobor and Muhammad (2008) stated high feed intake ranged from 90 – 198 g/day when using diets based on mixture of forage with a concentrate supplement. According to Pinheiro et al. (2009) the main limitation to the consumption is the digestive tract capacity.

Table 3. Linear regression equations of productive performance and net energy of rabbits fed with increasing levels of *Brosimum alicastrum*.

Variable	Equations	r^2	P-value
DWG (kg)			
	36.46 (3.41) - 10.30 (1.84)*ADFTOT	68.97	0.0001
	40.65 (4.61) - 7.83 (1.56)*NDFTOT	64.15	0.0002
	35.60 (3.25) - 44.87 (8.02)*LIGTOT	69.07	0.0001
Energy conversion			
	1029.87 (6119.97)+ 16472.2 (3314.64)*ADFTOT	63.82	0.0002
	-3454.16 (8844.08)+ 11760.2 (3000.32)*NDFTOT	52.32	0.0015
	2109.21 (5736.98)+ 72429.7 (14142.2)*LIGTOT	65.20	0.0002
Net Energy $_{mp}$ Diet			
	1691.74 (60.89)- 283.74 (32.98) *FDATOT	84.09	0.0000
	-3454.16 (8844.08) + 11760.2 (3000.32)*FDNTOT	52.32	0.0015
	2109.21 (5736.98) + 72429.7 (14142.2)*LIGTOT	65.20	0.0002
Net Energy $_{mp}$ Brosimum alicastrum			
	-809.455 (226.737) + 790.894 (122.803)*FDATOT	74.76	0.0000
	-1215.97 (275.69) + 630.634 (93.52)*FDNTOT	76.45	0.0000
	-741.572 (217.42) + 3436.84 (535.98)*LIGTOT	74.59	0.0000

Y = a + b x, where a = intercept and b = slope; ADFTOT = total consumption ADF (kg); NDFTOT = total consumption NDF (kg); LIG TOT = total consumption of lignin (kg).

Efficiency of utilization of energy

Net energy efficiency of utilization showed a higher value in control diet and similar values between treatments with *Brosimum alicastrum* fodder. Efficiency values are presented in table 4.

Table 4. Estimate of the efficiency of ME use in rabbits fed with increasing levels of Ramon.

	Treatment					
Variable	Control	T2	T3	T4	MSE	P-value
K_{mp}	0.58a	0.54b	0.54b	0.53b	0.0125	0.0453
K_m	0.60a	0.55b	0.55b	0.54b	0.0129	0.0164
K_p	0.55a	0.50b	0.50b	0.49b	0.0129	0.0164

K_{mp}= ME efficiency utilization; Km = Maintenance NE efficiency utilization; Kp = Production NE efficiency utilization; [abc] Value in the same line with different letter are statistically different, MSE: mean standard error.

Net energy, energy conversion and energy retention

Information about NE in rabbits fed fodder is limited; in this study, dietary NE value decreased as *Brosimum alicastrum* fodder inclusion was increased, with an average value of 1.11 Mcal/kg DM for the commercial feed. The lowest NE concentration corresponded to the highest level of fiber (P<0.05), which resulted in an increase in the time required to reach the sacrifice weight and higher feed conversion ratio (Table 3), since a greater amount of energy was destined to the maintenance functions of the organism. As a result, a decrease in energy retention and consequently lower DWG by a lower availability of nutrients to be used in muscle accretion was observed (Gidenne et al., 1998; De Blas et al., 1999; Gutierrez et al, 2002;). In a study carried out by El – Badawi et al. (2015) rabbits fed 0 to 0.45 % of *moringa oleifera* leaves showed significantly lower body weight and energy content than those fed 0.15 to 0.30 % (P<0.05). In the same study net energy was calculated showing that rabbits fed 0.15 to 0.30 % moringa oleifera leaves supplemented diets had significantly (P<0.05) higher net energy than 0 and 0.45 % moringa oleifera leaves. Retained energy values obtained in the present study with 0 (2.4), 0.20 (2.07), 0.40 (2.07) and 0.60 (1.6) % Brosimum alicastrum fodder are consistent with retained energy reported by El-Badawi et al (2015) including 0

(1.88), 0.15 (2.6), 0.30 (2.7) and 0.45 (1.7) % of moringa oleifera leaves in rabbits. The contribution of energy from forage in the diet might decrease due to a lower digestibility of diets including high *Brosimum alicastrum* fodder level; this led to an increase in energy conversion as *Brosimum alicastrum* fodder inclusion increased in diets. The relationship between the energy cost of gain and the components of the fibrous fraction was highly significant (Table 3). Increases in dietary fiber promote a decrease in the efficiency of digestible energy retention in growing animals, which is explained by higher losses of fermentation. In the present study, a decrease in efficiency of ME utilization (kmp) was observed as *Brosimum alicastrum* fodder increased in diet without significant effect (P>0.05); nevertheless efficiency of ME utilization for maintenance (km) and production (Kp) decreased significantly (P<0.05) as *Brosimum alicastrum* fodder increased in diet. According to Gutierrez et al, (2002); De Blas et al., (1999); Gidenne et al., (1998) decrease in efficiency is greater when the fiber is provided with pectin-rich substrates, compared to less digestible substrates such as alfalfa hay. Gidenne et al. (2010) and De Blas et al. (2012) stated that current recommendation in rabbit feed establishes a high minimal content of fiber in order to attain high levels of feed intake and also to minimize digestive disorders. De Blas (2013) points that in practice, this restriction leads to combined feeding of fibrous by-products with concentrate feeds that provide nutrients required for highly producing animals. The high fiber and lignin content also implies low DE estimation in fibrous by-products and fodder with respect to current recommendations (De Blas et al. 2015). In this sense Iyeghe – Erakpotobor and Nwagu (2014) mention that the proportion of digestible energy intake required for growth increased as lablab forage meal increased in diet.

Conclusion

High levels of Brosimum alicastrum fodder in rabbits feeding allow to cover maintenance requirements, but increase the total energy cost to reach slaughter weight, increasing fattening period due to a lower NE value and consequently lower daily weight gain.

Brosimum alicastrum fodder inclusion did not present negative effects on dietary energy utilization.

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