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Tropical forages as a dietary alternative in fattening rabbits (*Oryctolagus cuniculus* L.)

Forrajes tropicales como alternativa alimenticia en conejos de engorde (*Oryctolagus cuniculus* L.)

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Abstract

The aim of this study was to evaluate the potential of the tropical forages morera (*Morus alba* L.), caraca (*Erythrina poeppigiana* (Walp.) O.F.Cook and gold button (*Tithonia diversifolia* (Hemsl.) A.Gray) as an alternative food source for fattening rabbits (*Oryctolagus cuniculus* L.) and its effect on their productive behavior. The experiment was carried out in the minor species program of Universidad Técnica Estatal de Quevedo, Ecuador. In this study was evaluated New Zealand male rabbits of 35 days of age and with an average weight of 475.47 ± 74.23 g, distributed in four treatments with six replicates in a complete block design. Treatments evaluated were as follows: T1: commercial concentrate *ad libitum* (control); T2: commercial concentrate 50 g + morera *ad libitum*; T3: commercial concentrate 50 g + caraca *ad libitum,* and T4: commercial concentrate 50 g + gold button *ad libitum*. To identify significant difference among treatments, an analysis of variance and a Tukey's multiple range test (P≤0.05) were carried out to compare the mean values of treatments. Variables measured were as follows: feed intake (FI); growth rate (GR); feed conversion rate (FCR); weight to channel (WC), performance to channel (PC) and profitability. Results show that the highest FI was recorded by T1, T2 and T4 (83.92 ± 4.31, 83.90 ± 1.08 and 81.72 ± 2.85 g dry matter.d^{-1}, respectively); highest GR was found in T1 (28.81 ± 2.55 g); most efficient FCR was T1, T2 and T3 (2.93 ± 0.27, 3.34 ± 0.28 and 3.23 ± 0.19, respectively); and most efficient PC was T3 (56.00 ± 1.11 %) being also the most profitable (53 %).

Keywords: *Morus alba, Erythrina poeppigiana, Tithonia diversifolia*, cuniculture, nutrition, New Zealand breed

Resumen

El objetivo de este estudio fue evaluar el potencial de los forrajes tropicales (*Morus alba* L.), caraca (*Erythrina poeppigiana* (Walp.) O.F.Cook y mirasol o botón dorado (*Tithonia diversifolia* (Hemsl.) A.Gray) como fuente de alimento alternativo engorde de conejos, y su efecto sobre su comportamiento productivo. El experimento se realizó en el programa de especies menores de la Universidad Técnica Estatal de Quevedo, Ecuador. En este estudio se evaluaron conejos machos de la raza Nueva Zelanda de 35 días de edad y con un promedio de peso de 74,23 ± 75,47 g, distribuidos en cuatro tratamientos con seis réplicas en un diseño de bloque completo. Los tratamientos evaluados fueron los siguientes: T1: concentrado comercial a voluntad (control); T2: concentrado comercial 50 g + morera a voluntad; T3: concentrado comercial 50 g + caraca a voluntad, y T4: concentrado comercial 50 g + botón de oro a voluntad. Para identificar diferencias significativas entre tratamientos, se aplicó el análisis de varianza y se utilizó la prueba de rango múltiple de Tukey (P≤0.05) para comparar los valores medios de los tratamientos. Las variables medidas fueron las siguientes: ingesta de alimento (FI); tasa de crecimiento (GR); tasa de conversión de alimento (FCR); peso a canal (WC), rendimiento a canal (PC) y rentabilidad. Los resultados muestran que la FI más alta se registró con T1, T2 y T4 (83,92 ± 4,31, 83,90 ± 1,08 y 81,72 ± 2,85 g de materia seca.d^{-1}, respectivamente); el GR más alto se encontró en T1 (28.81 ± 2.55 g); la FCR más eficiente fue T1, T2 y T3 (2.93 ± 0.27, 3.34 ± 0.28 y 3.23 ± 0.19, respectivamente); y la PC más eficiente fue T3 (56.00 ± 1.11%) siendo también la más rentable (53%).

Palabras clave: *Morus alba, Erythrina poeppigiana, Tithonia diversifolia*, cunicultura, nutrición, raza Nueva Zelanda.

Introduction

Using intensive animal systems with a short generation interval is a way to minimize animal protein deficit in developing countries (Isikwenu, 2013). In this sense, cuniculture stands out as a promising economic activity (Iyeghe-Erakpotobor & Esievo, 2010). The high cost associated with production of these animals has been a setback in the livestock industry. However, growing interest in rabbit (*Oryctolagus cuniculus* L.) production has stimulated the search for high-quality alternative protein sources which is expected not to compete with human food (Adedeji *et al.*, 2013; Quintero de Vallejo, 1993).

In recent years, tropical forages have been highlighted as a less expensive and locally available source in the tropics. Moreover, potential of tree fodder in diet is determined by its excellent nutritional composition and digestive utilization ability of animals (Medugu, Mohammed, Raji, Barwa & Zhinma, 2012.). This situation has stimulated the search for local food alternatives, using the existing infrastructure to materialize the exploitation of new raw materials as food sources and generate production patterns adjusted to the current social and economic reality of any environment (Esminger, Oldfield & Heinermann, 1990).

In this sense, tropical forages can improve the quality of diets traditionally used in animals. Crude protein content of these species is generally higher compared to various pastures (CATIE, 1985). Therefore, the aim of this study was to evaluate effect of tropical forages as morera (*Morus alba* L.), cacara (*Erythrina poeppigiana* (Walp.), O.F.Cook), and gold button or mirasol (*Tithonia diversifolia* (Hemsl.) A. Gray) included in an alternative diet on the fattening performance of rabbits.

Material and methods

The research was carried out in the experimental farm "La María", belonging to the Faculty of Animal Sciences of Universidad Tecnica Estatal de Quevedo (UTEQ), province of Los Ríos-Ecuador. The farm is located at a latitude of 01° 06' S and 79° 29' of longitude W, at an altitude of 73 m.a.s.l., in the tropical humid forest (THF) ecological zone.

As the aim of this study was to assess the effects of dietary fat in growing rabbits based on tropical forages, 48 male New Zealand rabbits of 35 days of age were considered, with an average weight of 475.47 ± 74.23 g of dry matter.d^{-1}. Rabbits were allocated in collective cages (two rabbits per experimental unit) of 0.50 m x 0.50 m x 0.40 m distributed in four treatments and six replicates in a completely randomized design. To identify significant difference among treatments and statistical significance for all comparisons was made at $p < .05$, and the fattening trial was analyzed using the GLM procedure using the Statistical Analysis Systems (SAS™) software (SAS, 2004).

In this sense, the evaluated treatments were as follows: T1: commercial concentrate *ad libitum* (control); T2: commercial concentrate 50 g + Morera *ad libitum*; T3: commercial concentrate 50 g + Caraca *ad libitum,* and T4: commercial concentrate 50 g + gold button *ad libitum*.

Variables measured were: forage intake (FI); balanced intake (BI); intake feed in g of dry matter (IFDM); final weight (FW); growth rate (GR) of fattening rabbits; feed conversion rate (FCR); weight to channel (PC), performance to channel (PC) and profitability.

In addition, animals were weighed and feed intake was measured weekly during the experimental stage to determine forage intake (FI); balanced intake (BI); feed intake in g of dry matter (FI); final weight (FW); weight gain (WG); feed conversion rate (FCR); weight to channel (WC), performance to channel (PC) and profitability, respectively.

Subsequently, rabbits were sacrificed with an average weight of 3067 ± 258 g, but they were fasted 20 h before sacrifice; however, transportation time was not considered since they were sacrificed and trials were subjected to approval by the Animal Protocol Review Committee of UTEQ, following the procedures of meat hygiene manual. Likewise, total mortality during fattening period was calculated considering all animals.

Nonetheless, three shrub forages were verified according to the forage bank established at the minor species program of UTEQ. In fact, an equalization cut was made allowing to maintain a supply and harvest for 30 days after, i.e. from the initial cut, shoots were used until the end of the experiment. In addition, each feed cut lasted for 12 hours. Nevertheless, fattening rabbits received water *ad libitum* through automatic drinking troughs. Alternatively, rabbits were dewormed at the start of the experiment and after 21 days, with Panacur (0.5 cc.$animal^{-1}$); furthermore, Sulfavit (2.0 g.L^{-1} of water) was also supplied every 14 days to inhibit coccidian development. In fact, at the end of the 56 days the research lasted, 100% of the animals were sacrificed to establish the performance to channel variable measure.

It is important to note that bromatological analysis of green foliage was performed on dried samples in a forced air oven at 65°C for 48 hours, and proximal composition were respectively determined by duplicate according to AOAC (1990), following procedures No. 934.01 and 973.49, respectively.

Conversely, algebraic expressions based on the economic theories of Krugman & Wells (2006), and Samuelson & Nordhaus (2009), were considered as follows: Total cost, total income and utility for profitability were used to establish profitability. Total cost was obtained by multiplying the activity or input by the respective price, followed by equation 1 as follows:

Equation 1: $PC = Px\ X$

Where:

PC = Production cost

Px = Input or X activity price

X = Input or activity

Total income was obtained by multiplying yield (kg of meat) by its market price. The algebraic expression is followed by equation 2 as follows:

Equation 2: $IT = P_Y Y$

Where:

TIT= Total income ($\$.kg^{-1}$)

Py= Market price ($\$.kg^{-1}$)

Y= Yield ($kg.ha^{-1}$)

Profitability was obtained by subtracting total costs from total income using equation 3 as follows:

Equation 3: *Profitability=TI-PC*

While profitability was obtained with equation 4:

Equation 4:

$$R\ (\%) = \frac{Profitability}{Costs} \times 100$$

Results

Chemical composition of fresh foliage

Chemical analysis of fresh foliage of tropical shrub tree species assessed is shown in Table 1. In addition, dry matter (DM) and organic matter (OM) showed their best proportions, in order: *M. alba* (26.2 %; 92 %), *E. poeppigiana* (22.1 %; 89 %) and *T. diversifolia* (14 %; 87 %).

Table 1. Chemical composition of fresh foliage of *M. alba, E. poeppigiana* and *T. Diversifolia* harvested at thirty days

Tropical forages	DM	OM	Carbon	Protein	Fiber
M. alba	26.2	92.0	8.0	22.0	15.2
E. poeppigiana	22.1	89.0	11.0	24.2	32.1
T. diversifolia	14.0	87.0	13.0	15.85	4.5

DM: dry matter; OM: organic matter

Source: Results of laboratory tests carried out in Agrolab in 2016.

Protein values had a moderate variation, whereas *E. poeppigiana* and *M. alba* showed values above 20% protein, while fiber was twice as high for *E. poeppigiana* (32.1%), with a slight reduction in forage intake. Nonetheless, *M. alba* with 15.2 % fiber had higher acceptance in consumption followed by *T. diversifolia* (Table 2). However, these shrubs were acceptable and no problems were reported by supplying these foliages in fresh form.

Productive parameters

The highest dry matter (balanced and forage) consumption was similar among diets T1: control, T2: inclusion of *M. alba,* and T4: inclusion of *T. diversifolia* (83.92 ± 4.31, 83.90 ± 1.08, 81.72 ± 2.85 g $DM.animal^{-1}.day^{-1}$) over ($p < .05$), T3: inclusion of *E. poeppigiana* (75.99 ± 1.58 g $DM.animal^{-1}.day^{-1}$). However, it was possible to obtain differences ($p < .05$) in weight gain between the control treatment (28.81 ± 2.55 g) compared to T2, T3 and T4 (25.24 ± 1.98, 23.55 ± 1.03 and 20.18 ± 1.70 g, respectively). Relative gains were found when using unconventional diets for fattening rabbits in tropical environments (Table 2). In addition, feed conversion rate (FCR) (Table 2) had a similar trend in treatments T1: concentrate, T2: inclusion of *M. alba* and T3: inclusion of *E. poeppigiana* (2.93 ± 0.27; 3.34 ± 0.28 and 3.23 ± 0.19).

Table 2. Productive parameters in fattening rabbits with tropical forages

Variables (Mean ± SD)	Treatments			
	T1 (control)	T2 50 g balanced + *M. alba* *ad libitum*	T3 50 g balanced + *E. poeppigiana* *ad libitum*	T4 50 g balanced + *T. diversifolia* *ad libitum*
BC (g)	83.92 ± 4.31a1	44.07 ± 0.00b	44.07 ± 0.00b	44.07 ± 0.00b
TFC (g)	0.0 c	39.83 ± 1.08a	31.92 ± 1.58b	37.65 ± 2.85a
FI (g)	83.92 ± 4.31a	83.90 ± 1.08a	75.99 ± 1.58b	81.72 ± 2.85a
FW (g)	2101.4 ± 166.27a	1844.8 ± 96.09b	1782.2 ± 104.81b	1648.8 ± 110.10b
WG (g)	28.81 ± 2.55a	25.24 ± 1.98b	23.55 ± 1.03b	20.18 ± 1.70c
FCR	2.93 ± 0.27a	3.34 ± 0.28a	3.23 ± 0.19a	4.08 ± 0.45b
WC (g)	1201.2 ± 98.89a	988.2 ± 53.54b	997.8 ± 58.80b	817.9 ± 51.95c
PC (%)	57.15 ± 0.61a	53.56 ± 0.30b	56.00 ± 1.11a	49.62 ± 0.64c

[1]Means in a row not sharing superscripts significantly differ at $P < .05$.

BC: Balanced consumption. TFC: Tropical forages consumption. FI: Feed intake. FW: Final weight. WG: Weight gain. FCR: feed conversion rate. WC: Weight to channel. PC: Performance to channel.

Likewise, performance to channel (PC) in T1: control and T3: inclusion of *E. poeppigiana* (57.15 ± 0.61; 56.0 ± 1.11 %) was not affected by the inclusion of green foliage of *E. poeppigiana* (Table 1), which have allowed to obtain satisfactory results when fattening rabbits fed with tropical forages.

Economic analysis

Treatment T3: Balanced + *E. poeppigiana* presented the lowest production cost (58.79 USD); the highest income was reported in T1 followed by T3 and T2 (108.5, 89.80 and 88.95 USD, respectively), and the highest utility was found in T1 (36.32) followed by T3 (31.02) (Table 3).

Table 3. Expenses, income and utility ($USD) in fattening rabbits with tropical forages

Items	Balanced (control)	Balanced + *M. alba*	Balanced + *E. poeppigiana*	Balanced + *T. diversifolia*
Expenses	72.18	61.62	58.79	60.63
Fixed costs ($USD)	43.98	43.98	43.98	43.98
Variable costs ($USD)	28.2	17.64	14.81	16.65
Incomes	108.5	88.95	89.80	73.61
Meat production (kg)	14.42	11.86	11.97	9.81
Utility ($USD)	36.32	27.33	31.01	12.98
Profitability (%)	50.32	44.35	52.75	21.41

Sale Price in January 2017 = 7.5 $USD.

Furthermore, T3 diet, which included green foliage of *E. poeppigiana*, showed a higher yield (52.75 %) compared to the control T1 (50.32 %), followed slightly by T2 (44.35 %), which should be related with the higher meat production of does recorded with T3 diet (Figure 1).

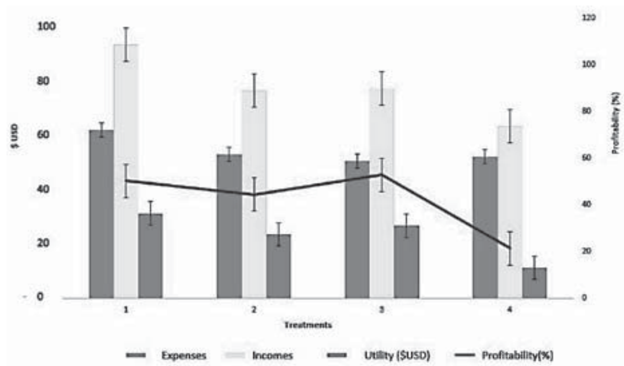

Figure 1. Expenses, income, utility and profitability ($USD) in fattening rabbits with tropical forages.

Discussion

Chemical analysis of fresh foliage of tropical shrub tree species assessed show that their nutritional contents are higher than what is found in pastures.

Moreover, ash results are related to OM content, and conversely, when higher MO content is found, a lower mineral content is also found (Herrera, Fortes, García, Cruz and Romero, 2008).

Results are comparable in variability to what Carmona (2007) reported when studying the effect of forage trees and shrubs species used, showing the chemical composition of *M. alba* with 25 % DM, 15 % and 28 % protein, 15 % fiber. In addition, *E. poeppigiana* showed values of 23-35 % DM, 15-25 % protein, 16-38 % fiber, and values for *T. diversifolia*, were DM 24-35%, protein 15-28 % and fiber 16-38 %.

However, the DM intakes reported by Nieves, López and Cadena (2001) are higher when using diets with non-traditional products (flour) + 300 g of fresh forage of *Trichanthera gigantea* (105.10 ± 4.88 and 106.14 ± 3.72 $g.dia^{-1}$). This higher consumption may be due to low polyphenols and tannins contents in the foliage of *Trichantera* according to some authors. Despite this, weight gains do not exceed (19.01 ± 5.24 and 19.79 ± 2.97 g), i.e. compared to those reported in the present study. Therefore, consumption results of DM obtained by Nieves, Terán, Cruz, Mena & Gutiérrez (2011) when using diets including foliage of *T. gigantea* (115.30, 118.57 and

113.77 g dia^{-1}), occurs because of high contents of digestible nutrients, but do not increase significantly daily weight gain (18.17, 18.15 and 20.93 g, respectively).

Some literature citations on the influence of alternative food sources in fattening rabbits are described by Quintero, García and Peláez (2007) and Montejo, López & Lamela (2010), where they have included up to 30 % *T. diversifolia* flour and 30 % lebbeck tree (*Albizia lebbeck* (L.) Benth.) flour obtaining weight gains of 20.3 and 16.3 g, respectively. In fact, in a previous work by Rodríguez & Bazó (1997), the authors noticed a weight gain of 21.3 g when fattening rabbits when using 50% of commercial concentrate + 50% of green leucaena (*Leucaena leucocephala* (Lam.) de Wit). Moreover, in another experiment with these same diets, Martín, Noda & Pentón (2007), demonstrated that it is possible to substitute up to 50 % of commercial concentrate for pelleted leaf of *M. alba*, without significant differences in weight gain (22 g and 25 g). Moreover, several authors have found that daily feed intake and daily weight gain when fattening rabbits seem to be affected by the inclusion of green foliage in a conventional diet (concentrate), which has allowed proposing its use for fattening rabbits.

Furthermore, feed conversion rate had a similar trend in treatments T1, T2, and T3; these results exceed those reported by Nieves *et al.* (2001), who obtained weight gains by dietary inclusion levels of non-traditional products as follows: (flour) + 300 g of fresh forage of *T. gigantea* in the diet for rabbits. Similarly, Quintero *et al.* (2007), with three levels of *T. diversifolia* flour (15, 30 and 45%, respectively) in the diet (4.8, 4.2 and 4.4), and according to Nieves, Rojas & Terán (2005), found that this type of dietary fat, influenced the process of nutrient utilization and biological efficiency (WG and FCR) due to digestibility changes of ingested nutrients.

Additionally, performance to channel in T1 and T3 was not affected by the inclusion of green foliage of *E. poeppigiana* green foliage, which have allowed to obtain satisfactory results when fattening rabbits fed with tropical forages. Consequently, the combination of tropical forage resources is a safe alternative for subsistence of cunicular exploitation with less dependence on commercial concentrated feed (Nieves, Rojas & Terán, 2005; Rodríguez & Bazó, 1997).

On the other hand, T3 diet, which included green foliage of *E. poeppigiana*, showed a higher yield compared to the control T1, followed slightly by T2; this should be related with the higher meat production of does recorded with T3 diet. In this sense, the use of tropical forages offers economic advantages and represents a potential alternative to fattening rabbits in tropical rural conditions.

Conclusion

Results found in this study indicate that the use of green foliage of tropical forage species such as *E. poeppigiana* and *M. alba* in the New Zealand rabbits bred in the Ecuadorian littoral for fattening, is an alternative food option as an unconventional raw material to help improve the sustainability of these production systems; this leads in turn to lower food costs and maintains productive rates in conditions of the Ecuadorian humid tropics.

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