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Inclusion of Mulberry (*Morus alba*) in the Rabbit Fattening Diet *(Oryctolagus cuniculus)*

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ABSTRACT: The aim of the study was to evaluate the effects of the inclusion of mulberry foliage (*Morus alba*) in the diet on productive variables and carcass yield in fattening rabbits. An animal behavior test was performed by using a completely random design with 36 weaning rabbits. Four treatments were established to include mulberry in the daily diet in concentrated proportions: mulberry foliage, provided for 42 days to rabbits in the fattening phase: T1: 100:0, T2: 80:20, T3: 60:40, and T4: concentrate: mulberry ad libitum. Food consumption, weight gain, feed conversion and carcass yield were measured. Significant differences ($p < 0.01$) were found in mulberry consumption, final live weight and food conversion. Daily weight gain, carcass yield, digestive tract weight and cecum showed no differences between treatments ($p > 0.05$). In the ad libitum treatment rabbits consumed about 20% of mulberry, and their level of inclusion in the diet can be 20 and 40% without effect on the behavior of productive variables.

KEYWORDS: Forage, productive behavior, voluntary consumption, food conversion, carcass yield.

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1. INTRODUCTION

The rabbit (Oryctolagus cuniculus) is a herbivorous animal that requires in its diet forages with balanced levels of fiber and protein that promote digestibility processes (Mora, 2010). Protein and fiber in the rabbit tract promote cecotrophy. The fiber promotes cecal fermentation and the increase of microbial biomass and short-chain fatty acids (Gidenne et al., 2010), also stimulate the transit of food through the gastrointestinal tract and intervenes in the process of hard stool formation (Gutierrez et al. 2017). The ingested proteins are fermented by the cecal flora and converted into ammonia, a precursor compound of microbial protein synthesis whose importance is its contribution of amino acids such as lysine, threonine and sulfur amino acids (Gidenne et al., 2010).

The inclusion of more soluble fiber sources in diets promote an increase in the length of the intestinal villi, on the contrary, the inclusion of sources of lignified fiber can produce atrophy in the tissue structure and alter the normal functioning of the epithelial cells of the intestine responsible for breaking down various food molecules and transporting them inside the body (intestinal enterocytes) (Moreno and Riaño, 2020). Therefore, in recent years, the use of forage trees has generated increasing interest in rabbit feeding (Hafsa et al., 2016).

Mulberry forage (Morus alba) has been studied in various parts of the world in animal feed for its bromatological composition; protein greater than 20%, fiber and minerals (Mora, 2010). The high digestibility of mulberry makes its introduction into diets for rabbits and other animal species very promising. Mulberry denotes a potential to increase the consumption of a critical nutrient such as raw protein (Ramos et al., 2011). To maximize the inclusion of mulberry as a component of the diet, it is necessary to study the digestive environment of the species and evaluate previous experiences in the inclusion of this protein source to introduce it at correct levels minimizing unwanted effects by excess or lack of important nutritional fractions (Canul-Ku et al., 2013). Inclusion levels are reported between 25% to 80% in the feeding of rabbits from the use of fresh mulberry, offering the leaf, leaf and stem, dry leaf, and in flour or nutritional blocks which opens a very wide range that could limit in some way the standardization of comparative parameters (Nieves et al., 2009; Mora et al., 2012 and Ramos et al., 2011). The aim of this study was to evaluate the substitution of concentrated food by fresh mulberry during the fattening phase and its effect on the productive variables and the yield of the carcase.

2. MATERIALS AND METHOD

The work was carried out at the Livestock Unit at Universidad Politécnica de Francisco I. Madero located in Tepatepec, Hidalgo. The place is located at 1900 masl with a temperate climate with rains in summer (Cw).

The study used 36 hybrid male rabbits F1 (New Zealand x California) of 40 days of birth and with an average weight of 1.2 kg. The rabbits were randomly distributed in 9 cages, 3 rabbits per cage. Kamva mulberry leaves and a local brand pelletized commercial food were harvested for food. Bromatological analyses of mulberry forage and concentrate were performed to determine the energy and protein levels present in each study treatment. Four treatments were evaluated, with three repetitions and each repetition with 3 experimental units. For 42 days in the fattening phase 4 treatments with different proportions of concentrated food and mulberry forage were evaluated according to the following levels: T1: 100:0, T2: 80:20, T3: 60:40, and T4: concentrate: mulberry ad libitum. The consumption of concentrate in the morning and fresh fodder was recorded. The amount offered per treatment was determined based on the daily consumption of the animals and the value was adjusted per week. The variables of productive behavior in the study were: concentrate consumption, mulberry consumption, daily weight gain and food conversion. At the time of slaughter, variables of the carcass were determined: yield, digestive tract weight and cecum weight.

Statistical analysis

A completely random experimental design was employed:

$Yij = \mu + Di + \varepsilon ij$

Where:

Yij = Response variable to be evaluated in the first treatment of the j-th repetition.

μ = General average.

Di = Effect on the first experimental treatment (k = 1,..., 4).

$\varepsilon i\,j$ = Experimental error associated with the response of ij factors.

The data were analyzed with SAS parcels (2009), by GLM procedure, descriptive statistics were obtained by treatment and means were compared by the Tukey Lines test.

3. RESULTS

Food bromatology

The overall chemical composition of mulberry leaves in the experiment was 27.4% dry matter in the fresh plant, with a crude protein level of 20.3% of, and 9.3% crude fiber with 16.2% total ash (Table 1). The values found here are similar to those reported in previous studies by (Hurtado et al.,2012 and Zapatier et al., 2021). The concentrate Tepexpan (Rabbit Plus), has protein values of 16.5%, fiber 15% and 3% ash.

Table 1. Bromatology of mulberry leaves (Morus alba) and concentrate for rabbits (Rabbit Plus Tepexpan).

Component	Mulberry forage (Variety Kanva)	Concentrate Tepexpan® (Rabbit Plus)
Dry mater (%)	27.4	88
Raw protein (%)	20.3	16.5
Crude fibre (%)	9.3	15
Ethereal extract (%)	4.06	3
Ash (%)	16.2	9

The bromatological composition of the treatments according to the proportion of concentrated food and mulberry forage did not show significant differences ($p>0.01$) for the components of protein, ethereal extract and ash (Table 2). Only differences were found ($p<0.01$) for fiber levels, with the ratio of 60:40 being the highest value.

Table 2. Experimental diet bromatology for fattening rabbits with different levels of mulberry inclusion

	Experimental diets with different inclusion level of mulberry (mulberry concentrate-forage)			
	100:00	80:20	60:40:	*Ad libitum*
Raw protein (%)	16.2[a]	15.8[a]	14.9[a]	15.9[a]
Crude fibre (%)	14.8[c]	19.3[b]	24.3[a]	18.2[b]
Ethereal extrac (%)	3.0[a]	2.9[a]	2.8[a]	2.9[a]
Ash (%)	8.9[a]	9.0[a]	8.9[a]	9.0[a]

[abc] Different literals in the same row indicate significant differences between treatments ($p < 0.01$)

3.1 Productive performance

Significant differences were found by treatment for consumption of concentrate, consumption of mulberry foliage ($p<0.01$), initial live weight and food conversion. For final live weight and daily weight gain no significant difference was found (p 0.01). The consumption of the average concentrate during the period reported statistical differences between means, due to the interaction between the different levels of mulberry, however, numerically the highest consumption in the treatment of concentrate and diet ad libitum is appreciated (Table 3).

Table 3. Productive indicators of rabbits fed with different levels of mulberry inclusion.

	Experimental diets with different inclusion level of mulberry (mulberry concentrate-forage).			
	100:00	80:20	60:40:00	*Ad libitum*
Concentrated consumption (g/d)	152.51 (5.28)[a]	122.23 (6.43)[b]	97.35 (1.05)[c]	132.07 (9.08)[b]
Consumption Foliage of Mulberry (g/d)	0	30.56 (1.61)[b]	64.90 (0.7)[b]	24.41 (2.37)[c]
total consumption (g/d)	152.51 (5.28)[a]	152.78 (8.04)[a]	162.25 (1.75)[a]	156.48 (9.23)[a]
initial live weight (Kg)	1.29 (0.15)[ab]	1.47 (0.15)[a]	1.52 (0.13)[a]	1.13 (0.14)[b]
Final live weight (Kg)	2.66 (0.12)[a]	2.61 (0.14)[a]	2.56 (0.35)[a]	2.44 (0.15)[a]
daily weight gain (g/d)	32.51 (1.71)[a]	27.22 (1.63)[a]	24.84 (5.48)[a]	31.13 (3.03)[a]
feed conversion	4.70 (0.19)[b]	5.63 (0.46)[ab]	6.75 (1.30)[a]	5.06 (0.52)[b]

[abc] Different literals in the same row indicate significant differences between treatments ($p < 0.01$)

The highest consumption of mulberry was found at the inclusion level of 40% of mulberry foliage with 64.9 g per day. Rabbits fed ad libitum consumed 24.41 g of mulberry foliage. The highest weight gain was obtained in the group of rabbits that consumed 100% concentrate with 32. 51 g followed by rabbits offered ad libitum concentrate and mulberry foliage with 31.13 g. Feed conversion was similar among rabbits from 100 percent concentrate treatment and ad libitum feeding.

3.2 Performance in channel

The inclusion level of mulberry on carcass yield of rabbits, the weight of the digestive tract and visors had no significant effect (p 0.01). The best yield to the channel was 60.6% for rabbits fed with 20% blackberry foliage (Table 4).

Table 4. Performance and characteristics of the rabbit channel consuming diets with different.

	Experimental diets with different inclusion level of mulberry (mulberry concentrate-forage).			
Variable	100:00:	08:20	60:40	*Ad libitum concentrate: Mulberry foliage*
Final live weight (Kg)	2.66 (0.12)[a]	2.61(0.14)[a]	2.56 (0.35)[a]	2.44(1.36)[a]
Carcass weight (kg)	1.55 (0.1)[a]	1.59 (0.10)[a]	1.48 (0.26)[a]	1.43(0.78)[a]

Weight visors (kg)	0.50 (0.03) [a]	0.51 (0.05) [a]	0.52(0.05) [a]	0.48(0.27) [a]
Digestive Tract Weight (Kg)	0.25 (0.04) [a]	0.21 (0.07) [a]	0.24(0.03) [a]	0.24 (0.11)[a]
Blind weight (Kg)	0.140 (.01) [a]	0.15 (0.03) [a]	0.14 (0.03) [a]	0.16 (0.07)[a]
Channel yield (%)	58.35 (1.09) [a]	60.66 (0.77) [a]	57.57(2.93) [a]	58.53(33.10) [a]

[a]Different literals in the same row indicate significant differences between treatments ($p < 0.05$).

The weight of the cecum between treatments was between 0.14 and 0.16 kg. The weight of the viscera was similar between treatments (p 0.01), the lowest weight was found in rabbits fed ad libitum with 480 g while the highest weight was 520 g for rabbits fed with 40% mulberry foliage.

4. DISCUSSION

The rabbit is a mono gastric herbivore has a digestive system that allows the ingestion of large amounts of fibrous food and rapid transit thereof. The cecum microbiota can obtain energy from fibrous constituents. Adult rabbits can reach mulberry dry matter consumption of 68.5 g when offered as a single food (Mora, 2010) and gain weight corresponding to 40% compared to the use of concentrated food 100% (Bamikole et al. 2005). Other studies reported no significant difference between diets of 0, 25 and 50% including mulberry for dry matter consumption (Bamikole et al., 2005). The preference of fodder consumption in rabbits is influenced by dietary and environmental factors (Ozakwe and Ekwe, 2017). The presence of antinutritional factors in high concentrations can inhibit enzymes and form directly complexes with nutrients, making them indigestible by proteolytic enzymes (Hernández et al., 2017).

The addition of forages to the rabbit diet should consider their nutritional value and their effect on digestibility, to promote consumption and productive performance (Hafsa et al., 2016). The preference for forage consumption is affected by dietary and environmental factors, the trophic selection of rabbits is preferable to more nutritious plants (Bobadilla et al, 2020). In a study of inclusion of mulberry leaf flour as a concentrate substitute in rabbit fattening, lower consumption with inclusion level (40 %) of mulberry flour as a substitute for commercial concentrate was reported (Valoy et al., 2014). Sanguinés et al., (2006), proposed that to obtain 1 kg of rabbit meat it is necessary to supply 11 kg of fresh mulberry, when the commercial concentrate is offered at 75 % of the total consumption. Nieves et al., (2009), reports daily weight gains with inclusion levels of 10 to 30% from 25 to 26 g per day and dietary conversions of 5.2 to 5.4. The voluntary consumption of mulberry and the inclusion level for better acceptance by rabbits is below 20%, with a selective voluntary consumption of mulberry foliage of 24.41 g, which is greater than 10,01 g reported in a study of substitution of concentrate by mulberry (Ramos et al., 2011).

The yield to the channel of rabbits ranges between 50-65%, and is related to age, breed and feeding (Valoy et al., 2014). In an evaluation of different levels of Leucaena in the feeding of rabbits reported yields to the channel of 53 % (Castillo et al., 2022). Feeding schemes with high levels of cellulose tend to decrease the yield to the channel, however, it has been reported that inclusion levels of 20% of forages, does not affect the productive behavior, nor the characteristics of the carcass, nor the morphometry of the gastrointestinal tract of rabbits (Vivas et al., 2018). Comparative studies report that there is no effect of the inclusion of plants on carcass components and meat quality (Herrera et al., 2018 y Molina et al. 2018). The graduated levels of fodder in diets do not influence the weight of internal and external organs (Abubakar et al., 2015).

CONCLUSIONS

The inclusion of mulberry foliage in diets evaluated for the fattening of rabbits has a substitutive effect on the consumption of commercial concentrate without affecting the productive behavior of rabbits or the carcass yield, the weight of the digestive tract and the cecum. The group of rabbits fed ad libitum show that the voluntary consumption of mulberry foliage is close to 20% of the total consumption, which should be considered for the definition of inclusion levels. It is suggested to continue conducting assessments of mulberry use in rabbit feeding, in terms of establishing the factors intrinsic to the animal and extrinsic foliage affecting consumption.

Declaration of availability of data

The raw data supporting the conclusions of this article will be available by the authors, without undue reservations.

Declaration of Ethics

The study with animals was reviewed and approved by the internal committee of care and use of animals for animal science of the Universidad Politecnica de Francisco I. Madero.

Author contributions

JVM: Contributed to the planning and conduct of the study, data acquisition and statistical analysis, and wrote the manuscript. DMSS: contributed to the planning, realization of the study, writing and review of the manuscript. JNE: contributed to the study and interpretation of the data. SVL: contributed to manuscript review and data interpretation. RNA: contributed to manuscript review. All authors contributed to the article and approved the submitted version.

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Editor's note

All statements expressed in this article are the sole responsibility of the authors.

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