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Traditional Diet Based On Artisanal Moringa Oleifera Lam Pellets. And Opuntia Ficus-Indica (L.) Mill. On The Weight Gain Of Crossbred Male Rabbits

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ABSTRACT
The potential of using an artisanal pelleted feed based on Moringa oleifera and Opuntia ficus-indica for feeding weaned rabbits was investigated. A completely randomized experimental design was used with 12 rabbits and six replicates, where the growth of 60-day-old mixed-breed male rabbits (New Zealand white X Rex X Chinchilla) was evaluated for five weeks, which were subjected to two treatments (T1: commercial feed, T2: artisanal pellets based on Moringa oleifera Lam). Live body weight (LBW), Weight gain (WG), Feed intake (FI), Feed conversion ratio (FCR), production costs and economic efficiency of feed were analyzed with student's t-test and Pearson correlation. In general, no significant differences ($P < 0.05$) were found in FI, WG, FCR, LBW, EE and REE and EE. It is worth mentioning that the cost per kilogram of artisanal feed was $0.41, while the commercial one was $0.48. Also, A negative correlation was found between Price of weight gain and lower Body weight gain (R^2=-0.956), In conclusion, artisanal pellets could be an alternative to commercial feed, because the results were similar, but the price per kilogram of feed was $0.07 cheaper.

Keywords: Animal nutrition; Oryctolagus cuniculus; food alternative: sustainable development.

Introduction

The rabbit belongs to a small species production system with an average daily gain that can vary between 30 and 50 g/day, the main breeds used on Mexican farms are New Zealand, Chinchilla and Rex (González-Redondo et al., 2010; Olivares et al., 2009); while rabbit farming is an alternative activity to feed rural populations due to its high degree of protein for human consumption; however, feeding costs can reach up to 60% of total production costs, so it is necessary to substantially improve the current average feed conversion (Gidenne et al., 2017), with a healthy and sustainable diet (Khalid et al., 2020).

Moringa oleifera is a multi-purpose tree introduced in Mexico in the XIX century, its fresh leaves and pods are rich in carotene, ascorbic acid and amino acids (Velázquez-Zavala et al., 2016), it is an ideal food for livestock, due to its high content of protein, even its branches have been reported as acceptable for ruminants and other animals, and contains all the essential amino acids (Olson & Alvarado-Cárdenas, 2016). In addition, this plant has agronomic potential to be cultivated in arid and semi-arid regions, due to its high resistance to drought. Regarding their nutritional values, the leaves contain 31.68% DM, 8.78% CP, 2.23% EE, 6.41% CF, 14.88% ash, that is, with the daily supplementation of 0.30% of moringa leaves in New Zealand rabbits can have a total digestible nutrient intake of 103.8 and a Feed conversion of 5.27 (El-Badawi et al., 2014), but up to 150 g/kg can be included in the diets of growing rabbits, without any adverse effect on their growth performance (Hafsa et al., 2016), being an alternative for sustainable animal feeding in tropical countries (Safwat et al., 2014) and even as a substitute for alfalfa (Sun et al., 2018).

Opuntia ficus-indica is a plant widely distributed in the semi-arid regions and some tropical regions of Mexico and Mesoamerica, as a crop and in the wild, widely used in rural areas (López-Gutiérrez et al., 2015) for its extraordinary nutritional and pharmaceutical properties, with high antioxidant potential (Abdel-Hameed et al., 2014), it has approximately 92.24% DM, 5.63% CP and 2,347 kcal DE/kg and it has been recommended to include up to 30% in the diets of growing rabbits (Pascoal et al., 2020). In addition, other positive characteristics have been identified for instance: a significant decrease in lipids in blood plasma, an increase in the count of red and white blood cells, and hemoglobin, as well as a better immune response and a significant increase in the activity of intestinal amylase, lipase and protease in rabbits compared to controls (El-Neney et al., 2019). With all the above, the need arises to find alternatives for the poorest communities in Mexico, where plants from the region are used and production costs are reduced. Therefore, the aim was to analyze the productive and economic efficiency of an artisanal pelleted feed based on *Moringa oleifera* and *Opuntia ficus-indica* for feeding cross-bred male rabbits (New Zealand white X Rex X Chinchilla), which is the main genotype used in rural areas of southeastern Veracruz, Mexico.

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Methods
This study was carried out in the Sustainable Alternatives area of the Faculty of Engineering in Agricultural Production Systems of the Universidad Veracruzana located at 18°00'14.0 "N and 94°55'45.1" W, at 100 meters above sea level with warm subhumid climate with rains in summer, average annual temperature of 24-28 ºC and precipitation of 1400-1600 mm, characterized by hillsides and Vertisols or Luvisols soils (Pérez-Prieto et al., 2018). The protocol of this study was carried out in compliance with the Mexican regulations NOM-062-ZOO-1999 that establishes the technical specifications for the production, care and use of laboratory animals (DOF, 2001) and international protocols such as Directive 2010/63/EU of the European Parliament (DO, 2010).

Methodology
Elaboration of the ration under artisanal pelletizing: To obtain Moringa meal, a plantation of *Moringa oleifera* trees was established in the field in Vertisol soil without the use of pesticides. The plant was harvested when it reached a height of 110 cm, making uniform cuts of the tree foliage to guarantee the availability of tender shoots. The foliage was cut manually when the plants were 120 days old. Subsequently, the leaves were dried under shade for five days, turning three times a day to promote uniform drying. At the end of the process, the material was stored in cardboard boxes to avoid deterioration, later the leaves were ground in a corn mill and were stored in paper bags until use. In the elaboration of the pellets, fresh nopal leaves (in intermediate phenological stage) were used, which were previously liquefied until obtaining a liquid consistency, which was incorporated into the other ingredients (Table 1), to later bring this mixture to a meat mill used as a pelletizer, where steam was applied at 80ºC for 30 seconds to sanitize the feed (Boltz et al., 2019) forming pellets with a recommended diameter of 3.5 mm and 8 mm in length (Maertens, 2010), where the nature of the cactus mucilage allowed give structure and hardness to the pellet (Guadarrama-Lezama et al., 2018).

Table 1- Ingredients and chemical composition of the basal diet.

Ingredients	g/kg diet
Moringa meal	150
Yellow corn	650
Soybean meal	100
Fresh nopal leaf	94
Salt (NaCl)	6
Chemical analysis	(%)
Humidity	0.74
Crude protein	14.46
Crude fiber	4.29
Ether extract	3.83
Ash	4.24
Digestible energy (MJ/kg)	80.56

The commercial feed. Consisted of pellets with a moisture content of 12%, 14.50% protein, 2% fat, 1% calcium, 18% fiber, 10% ash and 0.45% phosphorus.

Test conditions. The weaned rabbits were kept individually in standard cages (50 cm × 61 cm × 45 cm), provided with automatic feeders and drinkers, at the rate of one animal per cage. The temperatures were between 16 and 26ºC, except in week 8 that the maximum temperatures were at 32ºC, while the relative humidity ranged between 70-80% throughout the experiment.

Experimental design. Before starting the experiment, the genotype New Zealand X Rex X Chinchilla was selected, this is the most used by farmers in the region, due to its potential for dual purpose (meat and fur). Twelve 60-day-old male rabbits (1636±0.01), which were in a period of adaptation to the diet for seven days. A completely randomized design was established with six replications per treatment. The animals were subjected to the experimental diet for a period of five weeks and the diet formulation was based on the nutritional requirements for fattening rabbits (De Blas & Wisewan, 2020), while the balance of the ration was carried out with MIXIT-WIN program (Agricultural Software Consultants, Inc., San Diego, California, USA).

Study variables. The following variables were obtained throughout the experiment:

Live body weight (g), LBW. The rabbits were weighed weekly before morning feeding.

Weight gain (g/week), WG. It is an index that represents the units of live weight that an animal increase expressed in g.
WG = Final weight (g) - Initial weight (g)

Feed intake (g/week), FI. Feed consumption was estimated by the conventional method, calculating the difference between the feed offered and the feed rejected, expressing it in grams per day. FI = Feed offered - feed rejected

Feed conversion ratio (FCR/week). It is an index that represents the ratio of each kilogram of feed consumed per kilogram of weight gain of the rabbit: FCR= *Feed intake (g/week)*/ *Weight gain (g/week).*

At the end of the experiment, the economic variables were analyzed: Total feed intake (TFI), price of diet, total feed cost, body weight gain, price of weight gain, total revenue, net revenue, economic efficiency (EE) and relative economic efficiency (REE).

Data Analysis
The variables were analyzed with the student's T test ($P \leq 0.05$). A linear Pearson correlation was performed with the average values of the variables: LBW, WG, FI, FCR, Total feed intake (TFI), EE and REE using JASP V. 0.13.1 software.

Results
In general, no significant differences ($P \geq 0.05$) were found in FI, WG, FCR and LBW. The price of the artisanal feed was much lower, considering the cost of the ingredients and preparation was \$0.41 per kilogram, whereas the commercial feed cost \$0.48 per kilogram.

However, this lower cost did not reflect the Total feed cost due to the Body weight gain was similar ($P \geq 0.05$), so we did not find significant differences with the economic variables: Total revenue, Net revenue, Economic efficiency, and Relative economic efficiency (Table 3). The artisan was similar to commercial feed.

It should be mentioned that a highly significant correlation was found ($P < 0.001$) between the economic variables EE and REE (R^2=0.997) (Table 4). A negative correlation was found between Price of weight gain and Body weight gain (R^2=-0.956), therefore, the cost of each kilo of rabbit meat gained will be higher if the weight gain is low.

Table 2- Means of weekly changes in growth performance of cross-bred male rabbits (New Zealand X Rex X Chinchilla) with T1: commercial feed, T2: artisanal pellets based on *Moringa oleifera* Lam.

Parameter	Treatment (T.)		
	Artisanal	Commercial	T. P-value
Live body weight (g)			
Week 5–6	1636.8	1636.7	0.999
Week 6–7	1842.3	1917.3	0.669
Week 7–8	2011.7	2020.3	0.966
Week 8–9	2098.3	2163.7	0.715
Week 9–10	2188.3	2286.8	0.610
Week 10–11	2316.3	2428.7	0.552
Weight gain (g/week)			
Week 5–6	205.5	280.7	
Week 6–7	169.3	103.0	0.334
Week 7–8	86.7	143.3	0.443
Week 8–9	90.0	123.2	0.179
Week 9–10	128.0	141.8	0.328
Week 10–11	205.5	280.7	0.648
Feed conversion ratio			
Week 6–7	0.3	0.8	0.327
Week 7–8	0.9	2.2	0.372
Week 8–9	0.5	1.4	0.777
Week 9–10	3.3	1.7	0.114
Week 10–11	2.2	1.4	0.324

Note. Student's t-test.

Table 3- Economic efficiency and prices at the experiment growing cross-bred male rabbits (New Zealand X Rex X Chinchilla) with T1: commercial feed, T2: artisanal pellets based on *Moringa oleifera* Lam.

Item	Treatment (T.)		T.
	Artisanal	Commercial	P-value
Total feed intake (g)	1553.9	1509.9	>0.05
Total feed cost ($/kg)	0.64	0.72	>0.05
Body weight gain (g)	679.50	792.0	0.107
Price of weight gain ($/kg)	2.36	1.92	0.061
Sale tanned rabbit fur ($)	2.6	2.6	>0.05
Total revenue ($)	17.42	16.52	0.379
Net revenue ($)	9.46	8.47	0.334
Economic efficiency	2.19	2.05	0.290
Relative economic efficiency (%)	53.80	50.96	0.331

Note. Student's t-test.

Table 4- Pearson's Correlations.

Variable	Total feed intake (g)		Total feed cost ($/kg)		Body weight gain (g)		Price of weight gain ($/kg)	Relative economic efficiency (%)		Economic efficiency
Total feed intake (g)	—									
Total feed cost ($/kg)	0.057		—							
Body weight gain (g)	0.119		0.587	*	—					
Price of weight gain ($/kg)	0.099		-0.554		-0.956	***	—			
Relative economic efficiency (%)	0.594	*	-0.050		0.273		-0.029	—		
Economic efficiency	0.582	*	-0.083		0.256		-0.012	0.997	***	—

* p < .05, ** p < .01, *** p< .001

Discussions

The tender shoots of *Moringa oleifera* provide 15.2% of dry matter and 22.6% of crude protein, these parameters being similar to those of alfalfa; although, it has a higher content of important amino acids such as Lysine (0.93), Methionine (0.31%), Arginine (0.99%), Leucine (1.51%), Glycine (0.9%), Alanine (1.09%) and glutamic acid (2.03%) (Valdivié-Navarro et al., 2020), the plant extract (250 mg / L) has even been used as a growth promoter in weaned rabbits (Hashem et al., 2019). In this regard, a daily increase of 74.8g has been found with 40% Moringa in the feed and with a FCR of 5.86 ± 0.05 and an EE of 2.3 (Santos-Ricalde et al., 2017), it has also been found that with 30% of *Leucaena leucocephala* and *Moringa oleifera* the EE was at a rate of 1.5-2 (Safwat et al., 2014); however, studies carried out with the substitution of 15% of the commercial feed for M. oleifera significantly increased weight gain and feed efficiency by 4.63 (Dougnon et al., 2012). Therefore, in this study, a feed with 15% *M. oleifera* and 9.4% *Opuntia ficus-indica* was provided, with an average FCR of 1.61 ± 0.64 (during the last week), this probably due to the potential of the *Moringa oleifera* leaf as an enhancer of intestinal health, because it allows to alleviate oxidative stress and the inflammatory response in the small intestine of hyperthermic rabbits, which has even reported an average daily gain of 14.1g (Khalid et al., 2020) with a digestibility of 55.89%, even in diets with 40% Moringa meal (Safwat et al., 2015), this inclusion in the diet can increase the REE from 112.56 to 120.20% with respect to a commercial feed (Sobhy et al., 2016).

For its part, *Opuntia ficus-indica* has proven to be a rich source of vitamin C (2.4, 2.8µg / 100g), vitamin E (25, 23µg / 100g) and vitamin A (10, 13µg / 100g) and 17.4% protein; in addition, recent studies show that they could be incorporated into growing rabbit diets by up to 50%, even obtaining a FCR of 2.05 and EE of 3.29 (Amer et al., 2019), in addition to its antioxidant and antimicrobial properties (Aruwa et al., 2018). It is worth mentioning that, as in this study, the selection of the nopal leaves must be in the intermediate phenological stage, where the average content of crude protein of 55.7%, EE of 15.5%, pectin of 180.1 g, hemicellulose has been reported 45.29 g, cellulose 119.4 g and Lignin 8.0g (Pessoa et al., 2020). Therefore, it is suggested in future studies to analyze the nutritional advantages this type of diet may have.

The non-existence of significant differences in FCR could be due to crossbreeding of rabbits, although the data found in that study show favorable FCR values and even lower than studies carried out in the tropics with values ranging from 10.69 ± 2.7 (Ewuola et al., 2012) to 3.16 ± 0.41(Etchu et al., 2018), even lower than average for feeder rabbits (Gidenne et al., 2017). Studies carried out in purebred New Zealand, Chinchilla and Rex did not find differences on carcass yield and meat quality, although the crosses of these three breeds are the most used in southeastern Mexico, they are not the most efficient, since it has been found that the New Zealand purebred litters consume less feed than the California and New Zealand crosses; but they accumulated less weight, this same response was found with Chinchilla, whose minimum potential of the breed is 1,488.05 kg at 20 days (Oke et al., 2011), the main problem of these crosses being the lower growth efficiency, which is lower than the standard of the pure breed, even with the supplementation of amino acids (Nasr et al., 2017), therefore some researchers recommend using genotypes that reflect higher carcass performance (Obasi et al., 2019). However, in dual-purpose specimens (meat and fur), it allows economic efficiency to remain above 1.21 and relative profitability to be higher than 17.1%, although the best economic response was reflected in group B. Although it is possible mention that the quality of the fur will depend on the genotype, diet and microclimate (Taha et al., 2017), to obtain a higher price, since under current conditions it is sold only as a by-product.

Conclusion
The use of an artisanal pelleted feed based on Moringa oleifera and *Opuntia ficus-indica* for feeding cross-bred rabbits did not show significant differences (P> 0.05) in the FI, FCR, LBW and economic efficiency. Therefore, it is concluded that artisan is similar to commercial feed, but considering the cost of the ingredients and preparation, artisanal pelleted was cheaper ($0.07), so it could be a nutritional alternative. However, it is suggested in future studies to analyze the nutritional advantages this type of diet may have.

Limitations and Future Studies
The efficiency of animal growth is conditioned by the interaction of genetic and nutritional factors, so this study was limited by the crossbred breed.

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