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PRODUCTIVE PERFORMANCE AND CARCASS QUALITY OF MEXICAN HAIRLESS PIG BREED CASTRATED MALES FED WITH *MORINGA OLEIFERA* AND *BROSIMUM ALICASTRUM*

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ABSTRACT

Twenty-four neutered male of Mexican Hairless Pig breed (MHP) were evaluated fed with four diets: control diet (C), 10% *Moringa oleifera* meal (MO), 10% *Brosimum alicastrum* (BA) and 5% MO + 5% BA (MB). The pigs were slaughtered when they achieved 50.10 ± 1.65 kg body weight. The pigs which consumed C and BA obtained the lowest value of food conversion ratio (FCR) ($P \leq 0.05$) in comparison with MB. The pigs fed with MO and BA presented greater protein conversion (CPC), energy conversion (EC), protein efficiency (CPE), and energy efficiency (EE) in meat, in contrast with the pigs fed with MB ($P \leq 0.05$). Meat weight in the carcass was higher for the pigs which consumed MO and BA, in comparison with the other treatments ($P \leq 0.05$). The weight of lean ham increased in pigs which consumed MO, in comparison with those fed with C and MB ($P \leq 0.05$). The results obtained indicate that the inclusion of *Moringa oleifera* and *Brosimum alicastrum* meals in the diet of the MHP breed increases carcass weight and meat weight in ham, and reduces rib fat.

Key words: forage trees; meat production; native breed; nutrition

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INTRODUCTION

At present, local swine breeds around the world are considered an invaluable genetic resource, as they are a genetic diversity pool and a feasible option of an environmental strategy; however, studies in this field are very scarce (Aparicio *et al*., 2018). In the Southeast of Mexico, there is a hairless pig breed which is endangered, despite playing a key role in the social economy, cultural and historical identity of the Mayan communities, besides being rustic and well adapted to the region (Ángel *et al*., 2020). This breed is considered a descendent from Iberian pigs which were brought to Mexico during the Spanish conquer in the XV Century (Cortes *et al*., 2016; Estupiñán-Véliz *et al*., 2020). This breed is of slow growth with low nitrogen retention and high fat accumulation (Santos-Ricalde *et al*., 2011), They are raised mainly by traditional systems in rural communities (Ángel *et al*., 2020), and should be considered as a strategy for social policies as they are a source of animal protein and contribute to the rural food security (Oliveira *et al*., 2018; Lemus *et al*., 2020).

Local swine breeds, when compared to genetically improved ones, are better adapted to the traditional production systems, are less affected by a reduction in protein and energy intake from the diet (Batorek *et al*., 2018).

Nieto *et al*. (2018) indicate that the ability of the Iberian breed to fix body protein is limited, compared to conventional swine breeds in similar growth stages. Also, the need for a sensibly reduced protein diet has been suggested due to the metabolic constraints of this breed.

In tropical regions such as the Yucatan Peninsula, in Mexico, grains and cereals produced for animal feed compete with the food supply for human consumption, therefore, small farmers usually replace these foods with plants high in protein (Kambashi *et al*., 2014).

In this sense, it has been suggested that the hairless pig breed from Mexico, can use non-conventional food resources, since its well adapted to feeding systems based on agricultural by-products and local plants, which justifies the use of locally produced plant resources as an alternative to reduce the import of protein from conventional sources (Abou-Elezz *et al*., 2012). Knowing the productive response of the hairless pig breed in Mexico to different nutritional regimes is valuable to define low-cost dietary programs (Rodriguez-Gonzalez *et al*., 2016).

However, the use of forages for swine feed has some drawbacks due to the high fiber content which is associated to a decrease in nutrient digestibility (Thacker and Haq, 2008). It has been suggested that heirloom pig breeds can digest fiber better than improved breeds (Urriola and Stein, 2012), this could be due to the larger gut size and more active microbiota.

Leaves from *Moringa oleifera* and *Brosimum alicastrum* are an alternative for the hairless pig feed in Mexico, due to their high protein content along with other nutrients. In addition, the use of both forages in swine feed have several advantages: the high availability of plant resources in the Southeast of Mexico and the high biomass yield (Castro-Gonzalez *et al*., 2008; Falowo *et al*., 2018). Little research has been done to clarify how the inclusion of tropical forages in the diet of the Mexican hairless pig can affect its productive performance, carcass quality and meat (Ortiz *et al*., 2015; Dzib-Cauich *et al*., 2016) therefore, this information can be useful for producers and the sustainable swine production in the tropics.

There is a commercial interest in evaluating the carcass quality and meat from the Mexican hairless pig, as the culinary value from Iberian swine descendants has been acknowledged due to its high fat accumulation trait which defines the meat quality and derived products, improving the meat's texture and flavor (Gonzalez *et al.*, 2018); these parameters are improved by the forage consumption, which has led to promoting the marketing of these pigs to specific markets.

Therefore, the objective of this study was to evaluate the effect of including *Moringa oleifera* and *Brosimum alicastrum* leaf meal in the diets of the Mexican hairless pig breed, on the productive performance and carcass quality.

MATERIALS AND METHODS

Location of Experimental Facilities. This study was conducted in the facilities of the Agricultural and Livestock Production and Research Unit at Conkal Technological Institute, Yucatan, Mexico, located at 21° 05′ N and 89° 32′ W. The climate of the region is tropical sub-humid with rains in summer (AW_0), altitude is 8 mamsl, average annual rainfall of 1105 mm (400-1300 mm), relative humidity close to 78% and an average annual temperature of 25.8 °C (24-28 °C) (Flores-Guido and Espejel-Carvajal, 1994).

Animal Management and Experimental Design. Twenty-four neutered male MHP breed were assigned randomly to four treatments, with initial an average weight of 21.84 ± 2.28 kg, according to a completely randomly design; the main factor was experimental diet with four levels (six repetitions per feeding group).

The treatments were four experimental feeding regimens, corresponding to: Control diet (C), 10% of *Moringa oleifera* (MO), 10% of *Brosimum alicastrum* (BA) and a mix 5% MO/5% BA (MB).

Table 1. Composition of the experimental diets.

	Diets			
	C	**MB**	**MO**	**BA**
Diet Formulation %				
Corn	35.96	37.55	38.37	37.95
Soybean meal (48%)	11.52	11.35	11.28	11.73
Bran	48.07	37.00	35.91	36.50
Sunflower oil	2.00	2.00	2.00	2.00
Moringa olifera meal	0.00	5.00	10.00	0.00
Brosimum alicastrum meal	0.00	5.00	0.00	10.00
Calcium phosphate	1.08	1.11	1.13	1.11
Calcium carbonate	0.75	0.34	0.72	0.00
Vitamin Premix[a]	0.05	0.05	0.05	0.05
Mineral Premix[b]	0.10	0.10	0.10	0.10
Lysine 98	0.22	0.22	0.16	0.28
Methionine 98	0.00	0.03	0.03	0.03
Sodium chloride	0.25	0.25	0.25	0.25
Nutrient composition % (calculated values)				
CP	16.00	16.00	16.00	16.00
ME (Mcal kg^{-1} of feed)	2.91	2.86	2.86	2.88
Fat content	5.67	5.66	5.62	5.69
NDF	24.71	23.53	22.9	23.63
ADF	7.88	9.03	8.95	8.95

Table 1 shows the ingredients and chemical composition of the experimental diets, which were formulated according to N.R.C. (1998) for pigs between 20-50 kg.

Content in one kg: Vitamin A, 8 000 000 UI; Vitamin D3, 500.000 UI; Vitamin E, 35 000 UI; Vitamin K3, 1.250 g; Thiamin, 0.500 g, Riboflavin, 2.000 g; Pyridoxine, 0.500 g, Niacin, 10.000 g, pantothenic acid, 5.000 g, Antioxidant, 125.000 g, Vitamin B12, 7.500 mg, Biotin, 25.000 mg, [b] Content in one kg: Iron, 100.000 g; Manganese, 100.000 g; Zinc, 100.000 g; Copper, 10.000 g; Iodine, 0.300 g; Selenium, 0.200 g; Cobalt, 0.100 g, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF).

The pigs were individually penned and provided with a feeder and automatic drinker, were the animals always had feed and water *ad libitum*. The pigs were also fed at 07:00 h and 14:00 h. The quantity of feed administered to the pigs was adjusted daily according to the quantity rejected the previous day. In this way, the dry matter (DM) of the feed offered and rejected was determined in order to obtain the correct intake (Abou-Elezz *et al*., 2012).

The MHP breed management was conducted according to the guidelines and regulations for animal experimentation of the Conkal Technological Institute.

Experimental Procedures. The experimental period lasted 82 d with a seven-day period of adaptation to the experimental diet. The feed consumption was recorded daily and the animals were weighed weekly with 12 h of fasting. The information obtained was used to determinate the average daily gain (ADG), feed conversion ratio (FCR) and average daily feed intake (ADFI). In order to calculate the protein efficiency (CPE) and energy efficiency (EE), the equation proposed by McDonald *et al*. (1999) was used. The other efficiency parameters were conducted considering the same approach as the previous equation. The total carcass gains (based on the weight of the cold carcass) was calculated according to Clarke *et al*. (2018).

Slaughter of Animals. The pigs were slaughter humanely when reached 50.1 ± 1.65 kg of body weight, according the Official Mexican Standard (NOM-033-ZOO-1995). Before slaughter, the pigs were subjected to a fasting period of 12 h. Subsequently, the carcass was cooled down to 4°C over a period of 24 h and the primal cuts were obtained and weighed according the guidelines of the Official Mexican Standard (NMX-FF-081-SCFI 2003). Backfat thickness was measured at the tenth rib using a Whitworth digital Vernier (Mitutoyo and model 500-173).

It is important to emphasize that the HMP is considered an endangered local breed, for this reason, only 24 animals were slaughtered for the present study.

Statistical Analysis. Data from productive performance and carcass quality variables, were analyzed by two-way analysis of variance (ANOVA), fitting a linear model using GLM procedure of the SAS ver. 9.0 statistical package (Statistical Analysis Systems Institute, 2004).

The linear model was: $\mathbf{Y_{ij} = \mu + T_i + \varepsilon_{ij}}$; were: $\mathbf{Y_{ij}}$= response variable (productive performance and carcass quality variables), μ= general mean, $\mathbf{T_i}$= treatment effect (four experimental diets: C, MO, BA, MB) and $\mathbf{\varepsilon_{ij}}$= random error.

Results were expressed as least-square means and standard error of the mean (EEM). The means comparison was performed with Bonferroni test (P≤0.05, is considered statistically significant). Also, in order to determine the relationships between the characteristics of productive performance and those of carcass quality, a correlation Pearson analysis was conducted.

RESULTS

The average values of each variable in relation to the productive performance of the MHP breed using four experimental diets are shown in Table 2. According to the results, the inclusion of tropical forage in pig MPH breed feed, did not significantly affect ADG, carcass WG and ADFI (P>0.05). The values reported for total feed intake and CP were lower for the animals fed with MO compared to the animals fed with MB (P≤0.05). The value of total energy intake was greater for the pigs fed with MB and C, compared to the pigs from the MO treatment (P≤0.05). Moreover, the FCR value was higher on the pigs fed with MB compared to those fed with C and BA (P≤0.05).

Table 2. Average values of the productive performance of the MHP breed fed with tropical forage.

Variables	Diets				
	C	MB	MO	BA	EEM
ADG (kg)	0.360	0.350	0.380	0.360	0.02
Carcass WG (kg)	19.44	19.077	19.88	19.25	0.28
Total feed intake (kg DM)	123.30[ab]	126.42[a]	118.09[b]	121.87[ab]	1.43
ADFI (kg/animal/d)	1.46	1.60	1.59	1.50	0.10
Total CP intake (kg)	19.73[ab]	20.23[a]	18.89[b]	19.50[ab]	0.23
Total energy intake (Mcal kg^{-1} of feed)	359.90[a]	362.21[a]	338.32[b]	350.99[ab]	4.13
FCR (ADFI/ADG)	4.03[b]	4.50[a]	4.16[ab]	4.13[b]	0.11

[ab] Different letters in the same line differ at ($P \leq 0.05$), average daily gain (ADG), Weight gain (WG), average daily feed intake (ADFI), crude protein (CP), feed conversion ratio (FCR).

Table 3 reports the average values of the protein and energy efficiency rates. The pigs fed with MB were less efficient in the use of protein and energy compared to the animals fed with C; thus, these animals obtained the highest and lowest values of CPC and CPE in weight gain, respectively (P≤0.05).

The values of EE in weight gain indicate that the pigs fed with MB were less efficient, in comparison with the other treatments (P≤0.05). Regarding the values of CPC, EC, CPE and EE in meat, these indicate that the pigs fed with MO and BA were more efficient in the use of protein and energy when compared to those that consumed MB. Finally, the values found for CPC and EC in Fat were not affected by the treatments (P>0.05).

Some characteristics of the carcass quality were affected by the inclusion of forage in the MHP breed feed

(Table 4). In this work, no treatment effects were observed in the weight of the carcass. Between the treatments MB and C, the carcass yield (%) was superior for MHP breed fed with MB. Of all the treatments, the value of total meat on the carcass was greater for the MHP breed which consumed BA and MO.

Table 3. Feed conversion and crude protein and energy efficiency of experimental diets in MHP breed.

Variables	Diets				
	C	MB	MO	BA	EEM
CPC in weight gain (daily CP intake/ADG/100)	0.65[b]	0.72[a]	0.67[ab]	0.66[ab]	0.02
CPC in meat (total intake of CP/WG of meat)	2.23[ab]	2.52[a]	2.20[b]	2.14[b]	0.18
CPC in fat (total intake of CP/WG of fat)	2.59	3.02	3.19	2.97	0.40
EC in meat (energy intake/WG of meat)	40.78[ab]	45.25[a]	39.52[b]	38.64[b]	3.30
EC in fat (energy intake /WG of fat)	47.31	54.23	57.16	53.61	7.27
CPE in weight gain (ADG/ADFI*CP of diet)	1.55[a]	1.40[b]	1.51[ab]	1.52[ab]	0.04
CPE in meat (WG of meat /Total intake of CP)	0.44[ab]	0.40[b]	0.45[a]	0.47[a]	0.01
EE in weight gain (ADG/ADFI*ME of diet)	0.085[a]	0.078[b]	0.085[a]	0.085[a]	0.01
EE in meat (WG of meat/total intake of energy)	0.025[ab]	0.022[b]	0.026[a]	0.026[a]	0.01

[ab] Different letters in the same line differ at ($P \leq 0.05$), protein conversion (CPC), energy conversion (EC), protein efficiency (CPE), energy efficiency (EE).

Table 4. Quality Characteristics of the MHP breed carcass.

Variables	Diets				
	C	MB	MO	BA	EEM
Carcass weight (kg)	33.07	33.54	34.07	33.21	0.22
Carcass yield (%)	64.20[b]	66.34[a]	65.76[ab]	65.07[ab]	0.26
Total meat on the carcass (kg)	14.90[c]	14.46[c]	16.05[a]	15.87[b]	0.22
Total bone on the carcass (kg)	5.26	6.83	6.76	5.79	0.25
Total fat on the carcass (kg)	12.90	12.25	11.26	11.54	0.30
Ratio meat/fat (kg)	1.19	1.19	1.44	1.42	0.09
Backfat at 10th rib (cm)	2.76	2.58	2.28	2.43	0.20

[abc] Different letters in the same line differ at ($P \leq 0.05$)

The inclusion of forage studied in the feed of MHP breed only affected the values of lean ham (without bone) and backfat (Table 5). It is also reported that the pigs which consumed MO increased the weight of lean ham compared to the animals fed with C and MB. Moreover, of the treatments evaluated, the MO and BA allowed a significant reduction in the weight of backfat of MHP breed.

In accordance with Figures 1 and 2, a positive correlation is suggested between efficiency of protein in weight gain or efficiency of energy in weight gain and weight gain of the carcass.

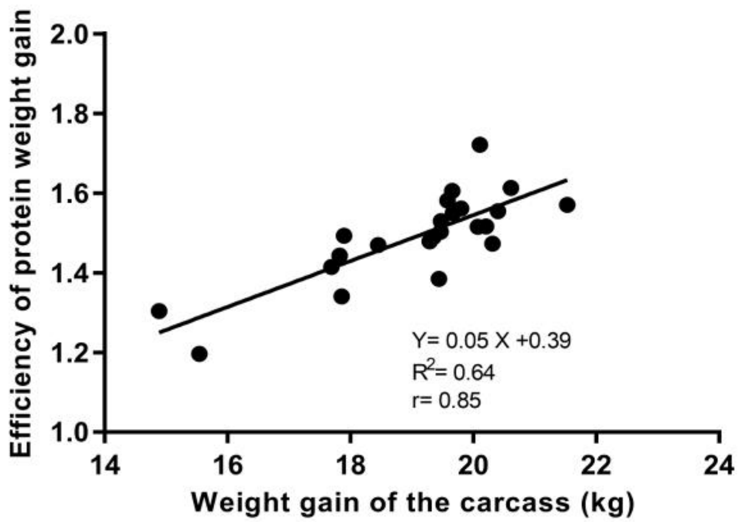

Figure 1. Correlation between protein weight gain efficiency and carcass weight gain

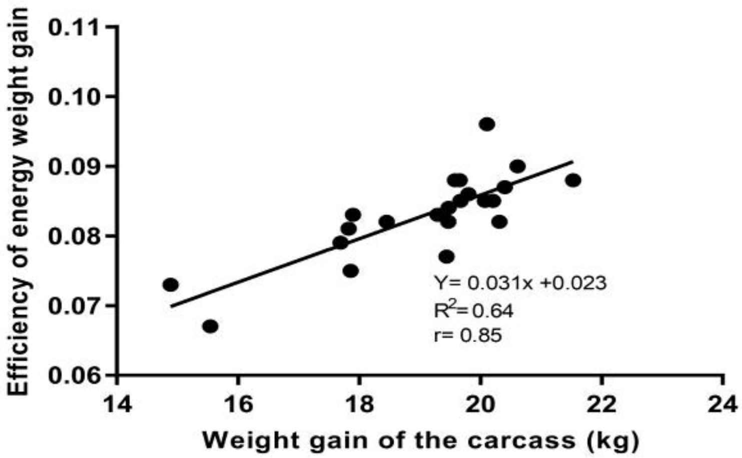

Figure 2. Correlation between weight gain energy efficiency and carcass weight gain

Table 5. Meat yield of the MHP breed of the prime cuts.

Variables	Diets				
	C	MB	MO	BA	EEM
Lean ham without bone (kg)	4.95^{b}	4.91^{b}	5.39^{a}	5.11^{ab}	0.06
Ham fat (kg)	2.93	2.68	2.66	2.65	0.08
Lean shoulder without bone (kg)	4.20	3.68	4.33	4.21	0.10
Shoulder Fat (kg)	2.53	2.34	2.26	2.35	0.07
Whole loin (kg)	3.46	3.60	3.81	4.00	0.09
Loin external fat (kg)	3.55	3.29	3.06	3.04	0.11
Lean rib (kg)	1.97	2.29	2.19	2.22	0.06
Rib fat (kg)	1.08^{a}	1.19^{a}	0.93^{b}	0.90^{b}	0.06

^{ab} Different letters in the same line differ at ($P \leq 0.05$)

DISCUSSION

The chemical composition among experimental diets were similar, and this could provide a partial explanation of not differences among the values of ADG (P>0.05). However, the values found were inferior to those reported by Nieto *et al*. (2018), where the maximum ADG of the pure Iberian pigs (pigs fed 129 g CP/kg DM at 0.95 × *ad libitum*) was 0.559 kg.

The value reported for FCR was higher in the pigs fed with MB, in comparison with the pigs fed with C and BA; this fact was also observed by Xandé *et al*. (2009) and Batorek *et al*. (2018), for Muyoka creole pigs and Krškopolje pigs, respectively, which were fed with fiber diets, a situation which can be explained by the fact that the fibrous feed provokes a reduction in the digestibility of the proteins and ileal amino acids which are associated with an increase in the loss of nitrogen, as well as endogenous and exogenous amino acids, with a concomitant reduction in the pig's growth rate (Agyekum and Nyachoti, 2017). In addition, the growth rate of the creole pigs is associated with their low capacity for nitrogen retention (Santos-Ricalde *et al*., 2011).

The low efficiency in the utilization of CPC and CPE in weight gain of the pigs fed with MB, with respect to diet C; could be explained by an effect in the reduction of amino acid proportions or a reduction in their bioavailability when the forages under study are mixed (5%MO/5%BA). In fact, the chemical composition of the diet is an indication of its nutrient content but not of its availability for the animal. Moreover, the composition of diet C contained a greater proportion of wheat bran and the reports indicate that the inclusion of this ingredient in the diet does not affect the digestible energy (Zhao *et al*., 2018).

In the present research, the values obtained for CPC, EC, CPE and EE in meat indicate that the pigs fed with MO and BA were able to utilize the protein and energy in order to convert it into meat, when compared to animals which consumed BM. The greater efficiency of protein and energy can be attributed to the good ileal digestibility of *Moringa oleifera* and *Brosimum alicastrum,* given that a large part of the nitrogen is not linked to the cell wall (Yáñez *et al*., 2010; Ly *et al*., 2016). The fact that the treatments did not affect the value of CPC and EC in fat can be attributed to the type of animal breed. In this context, González *et al*. (2018) have reported that genetic Iberian pig line affect more markedly yield and quality of fresh loin than feeding with oleic acid enriched diets.

Previous studies have demonstrated that the MHP is a breed which, due to the genetics, tends to deposit fat in the carcass regardless of the type of feed (Rodríguez-González *et al*., 2016).

Carcass yield is one of the main parameters of quality in the pig and an increase in the weight of lean meat improves the economic income of the producers. In the present study, the greater weight of total meat on the carcass (kg) of the animals fed with MO and BA in comparison with the other treatments, can be explained by the weight increase in lean ham without bone (kg), attributed to the efficiency in the exploitation of the protein and energy presented by these pigs. In another result, the fat reduction in the rib could be explained by the presence of bioactive compounds (phenolic compounds) in the *Moringa oleifera* leaves. Recent reports indicated that the ethanol extracts of *Moringa oleifera* leaves contain bioactive compounds which reduce body weight in obese rats, by the reduction of mRNA expression of the leptin gene, the increase in the mRNA expression of adiponectin; which is inversely related with the body mass index and the percentage of body fat (Metwally *et al*., 2017). However, further studies are required in MHP breed in order to confirm this effect.

In this study it was found that the weight gain value of the carcass presented a lineal relationship with the protein and energy efficiency in weight gain, which can be attributed to the intake of protein and energy or the combination of both. These results concur with the findings obtained by Nieto *et al*. (2018) due to the fact that, in the Iberian pig, the quantity of protein required for the formation of lean meat varies, regardless of the animal´s weight. The results of the present study confirm that the energy efficiency increases with the animal's weight, as previously reported in the Iberian pig (Nieto *et al*., 2007; Garcia-Valverde *et al*., 2008).

In accordance with the results obtained, the inclusion of *Moringa oleifera* and *Brosimum alicastrum* meal, is suggested as an alternative forage for MHP breed, given that it allowed a weight increase in the meat of the carcass and leg, as well as a reduction in rib fat. The protein and energy efficiency for weight gain in the meat was not affected by diets of MO and BA. However, by mixing both of these forages together these response variables were affected.

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