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EFFECT OF MORINGA OLEÍFERA MEAL INCLUSION ON MEAT QUALITY FROM THE MEXICAN HAIRLESS PIG

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ABSTRACT

The aim of this study was to evaluate the physico-chemical characteristics and fatty acid profile of the meat and subcutaneous fat of the Mexican Hairless Pig (MHP) fed with Moringa oleifera meal (MOM). Fifteen pigs of the genotype MHP were used, nine castrated males and six females, which were randomly distributed into three groups. The first group received a control diet (0% MOM), while the second and third groups received a diet containing 20% and 40% of MOM, respectively. Diet and the sex of the animal had no influence on physico-chemical parameters of the meat. Both diet and sex affected the composition of fatty acids of the meat and subcutaneous fat. The results suggest the inclusion of MOM as a source of fatty acids for the diet of the MHP, given its contribution to the production of meat and subcutaneous fat rich in Monounsaturated Fatty Acids (MUFA).

Keywords: mexican hairless pig; moringa oleifera; meat quality; fatty acids.

1. INTRODUCTION

In Mexico, the Mexican Hairless Pig (MHP) is a genotype reported to be in danger of extinction (FAO, 1993), thus the importance of conserving its genetic variability. Since 1999, the Mexican Association Specializing in Creole pigs has successfully implemented a rescue program and genetic preservation of MHP. The MHP feeds on natural resources of plant origin with high values of proteins and has a slow growth rate, accumulating large quantities of fat in its carcass and meat (Delgado *et al*., 2002). Most of the research to date has focused on evaluating the effect of the inclusion of meal from tropical forages on the animal´s productive parameters (Santos *et al.*, 2011); however, very few reports are available on the influence of MHP feeds on meat quality, more specifically, on fatty acid synthesis in intramuscular and subcutaneous fat of MHP.

The quality aspects of pork are increasingly important from both a technological and nutritional points of view. The consumer, for health reasons, demands meat with a higher content of Polyunsaturated Fatty Acids (PUFA), a tendency which can be attributed to a diversity of studies indicating that the consumption of fatty acids Ω 9, 3 and 6 can prevent cardiovascular diseases, cancer and arteriosclerosis; these fatty acids also present anti-inflammatory properties (Mitchaothai *et al*., 2007).

Research carried out on commercial pigs has mainly focused on the effect of including levels of vegetable or animal oils as a source of fatty acids Ω 3 and Ω 6, with which the fatty acid profile of the Longissimus dorsi muscle and subcutaneous fat of pork can be modified (Alonso *et al*., 2012); however, the sources of PUFA of vegetable origin such as, olive, canola, and sunflower are expensive, therefore, other alternatives must be considered. One option is the use of Moringa oleifera (MO) leaves as a source of fatty acids and other components such as, proteins, vitamins, minerals and compounds with antioxidant properties (Syariati, 2011). The MO leaf contains 3.49% of lipids, of which 66.7% corresponds to α-linolenic acid (C18:3 n-3), the predominant fatty acid in MO (Soliva *et al*., 2005).

In general, pork is characterized by its high value in protein, fat, minerals and vitamins. In this sense, the meat of the MHP represents a food source for the low-income, rural communities of the Yucatan Peninsula, Mexico where the animals are fed with local grains and forages in a traditional "back-yard" model. However, to date, there have been no studies carried out on the effect of the inclusion of MOM on meat quality. Thus, the objective of the present work was to evaluate the proximal composition, physico-chemical characteristics and fatty acid profile of the meat and subcutaneous fat of the MHP fed with Moringa oleifera meal (MOM).

2. MATERIALS AND METHODS

2.1. Study location

The study was carried out in the research facilities of the animal husbandry center of the Technological Institute of Conkal, located in the municipality of Conkal, Yucatan, Mexico, coordinates 20°29'N and 89°39'W, at a height of 8 m, with an Aw type climate, sub-humid warm, a rainfall of 850 mm and an average annual temperature of 25.5°C.

2.2. Plant material and elaboration of meal

Leaves and stems of MO were collected in a forage bank, cut after 55 days of re-growth from

September 2013 to January 2014. The leaves were separated from the stems and both plant materials were placed in a convection oven (Terlab, TE-H80DM, USA) at 65 ºC for 24 h. After drying, leaves and stems were ground in an IKA MF-10 grinder with a sieve size of 3 mm. The MOM obtained was stored at room temperature in hermetically sealed glass containers until use. The chemical composition of the meal obtained from Moringa oleifera is shown in Table-1.

Table-1. Chemical composition of the *Moringa oleifera* meal on a dry basis.

Parameters	%
Proteins	18.19
Neutral detergent fiber (NDF)	30.92
Acid detergent fiber (ADF)	25.95
Moisture	5.23
Dry material	94.77
Ash	17.13
Total calcium*	0.31
Total phosphorus**	0.06
Lipids	3.5
Fatty acids***	
C16:0	48.70
C16:1 (n-7)	2.43
C18:0	7.81
C18:1 (n-9)	4.03
C18:2 (n-6)	6.45
C18:3 (n-3)	18.70

* Sodium molybdate p-aminophenol sulphate
** Acid digestion and atomic absorption.
***Percentage of total fatty acids identified.

2.3 Animals and sampling

The experiment was approved by the Animal Protocol Review Committee of the Technological Institute of Conkal.

Fifteen pigs of the genotype MHP were used, nine castrated males and six females, all of which had an average initial weight of 20.50 ± 1.06 kg. A completely randomized design was used, with three treatments corresponding to the animals' diets (Table-2). Each group consisted of three males and two females. The first group was assigned a control diet (0 % MOM) and the other groups were given a diet with 20 and 40% of MOM, respectively. Pigs were slaughtered by electrical stunning and exsanguination at a local slaughterhouse from Zootechnical Research Center of the Technological Institute of Conkal, with a live weight of approximately 44.84 ± 0.615 kg, after which the carcasses were placed in cold storage at 4°C for 24 h. The Longissimus dorsi muscle was taken from the left side of the carcass of each animal. For the evaluation of muscle quality, the ribs and vertebras were used as reference; the sixth rib to determine the pH, seventh rib for water activity (a_w), eighth rib for the color of the meat and subcutaneous fat, ninth rib for the fatty acids profile and lastly, the eleventh to the last rib were used to determine the chemical composition. Cooking loss and drip loss were measured from the first to the fourth vertebra and between the fifth and eighth vertebras of the Longissimus lumborum, respectively. Samples for the determination of the fatty acid profile and chemical composition were vacuum packed (Torrey, EVD4, USA) and frozen at -20°C until analysis.

Table-2. Composition and chemical analysis of the experimental diets.

	Treatments		
	Control	**20-HMO**	**40-HMO**
Ingredient %			
Corn grain	55.82	49.7	43.96
Soybean meal without hulla	15.53	13.43	10.68
Bran	8.00	11.68	0.00
Alfalfa dehydrated	16.00	0.00	0.00
Beef fat	3.00	3.00	3.00
Moringa meal	0.00	20.00	40.00
Calcium phosphate (monocalcium)	0.60	0.75	1.3338
Calcium carbonate	0.46	0.89	0.5162
Mineral premixture *	0.10	0.10	0.10
Vitamin premixture **	0.05	0.05	0.05
Lysine 98	0.19	0.10	0.00
Methionine 98	0.00	0.05	0.11
Sodium chloride	0.25	0.25	0.25
Total	**100**	**100**	**100**
Chemical composition on a dry basis %			
MS	91.74	91.82	92.68
PC	15.70	15.30	16.30
EM (Mcal/kg)	3178.61	3065.64	2743.07
Lipids	5.45	5.73	6.13
FDN	23.82	18.83	23.38
FDA	11.62	10.96	15.02
Ca	7.26	9.86	13.60
P	4.31	4.88	6.29
Ash	5.34	5.80	6.67
Fatty acids***			
C11:0	0.68	3.99	0.43
C12:0	0.62	0.83	0.14
C14:0	12.85	7.85	7.47
C16:0	32.74	26.92	21.03
C16:1 (n-7)	0.20	0.74	1.01
C18:0	7.30	7.82	6.61
C18:1 (n-9)	15.07	16.59	23.72
C18:2 (n-6)	0.23	1.82	2.46
C18:3 (n-3)	3.34	4.46	6.71
∑SFA	54.97	49.42	37.16
∑ MUFA	15.27	17.27	24.72
∑ PUFA	3.57	6.27	9.16

*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. ** Content in one kg: Vitamin A, 8 000 000 IU; Vitamin D3, 500.000 IU; Vitamin E, 35 000 IU; K3, 1.250 g; Thiamine, 0.500 g, Riboflavin, 2.000 g; Piridoxin, 0.500 g, Niacin, 10.000 g, pantoteneic acid, 5.000 g, Antioxidant, 125.000 g, Vitamin B12, 7.500 mg, Biotin, 25.000 mg. ***** Percentage of total fatty acids identified.

2.4 pH measurement

The pH reading was carried out within the first 45 min and 24 h post-mortem, using a potentiometer (Consort, C931, USA); the electrode was calibrated using known pH buffers. To obtain the measurement, 10 g of meat were weighed out and mixed with 40 mL of distilled water using a blender (Osterizer®). An electrode was introduced into the mixture and the pH values were registered. Each value was the mean of three measurements.

2.5 Instrumental color measurement

Color was measured using a colorimeter (X-rite, SP60, USA) which was previously calibrated with the black and white standard. Measurement of meat and subcutaneous fat color was performed in the coordinates: L* (Luminosity), a*(Red-Green) and b*(Yellow-Blue) at 24 h post-mortem. The meat sample was exposed for 1 h at 3°C according to the method of Boccard *et al.* (1981). Chroma (C*) and hue angle (H°) of the samples were calculated by means of the following formulas:

$C^* = (a^{*2} + b^{*2})^{1/2}$

$H° = \arctan(b^*/a^*)$

Each value was the mean of six measurements of the same sample.

2.6 Water activity

Water activity was measured at 24 h post-mortem with a dew point hygrometer (Aqualab, CX-2, USA). Approximately 10 g of meat was placed in cells which were deposited in the equipment and the a_w values were registered. Each value was the mean of three measurements.

2.7 Cooking loss and drip loss

Cooking loss and drip loss from the Longissimus lumborum muscle were evaluated using the method described by Honikel (1998). The results of both measurements were expressed as percentage of weight with respect to the initial weight of the sample. Each value was the mean of three measurements.

2.8 Proximal composition

The proximal composition of the Longissimus dorsi muscle (protein, lipid, moisture and ash), was determined in triplicate using the techniques proposed by the AOAC (2002).

2.9 Analysis of fatty acids in meat and subcutaneous fat

Extraction of lipids from the meat and subcutaneous fat was carried out following the methodology of Hanson and Olley (1963). 1 mL of lipids extracted from the meat or subcutaneous fat was deposited in screw-capped test tubes and mixed with 1 mL of potassium hydroxide (0.5 N KOH, in methanol) and 1 mL of boron trifluoride in methanol for the formation of methyl esters, following the methodology proposed by Morrison and Smith (1964). The methyl esters of fatty acids were analyzed in a gas chromatograph (Perkin-Elmer Autosystem) equipped with a flame ionization detector (FID); an EC-Wax capillary column (30 m long, 0.25 mm internal diameter, and 0.25 µm phase thickness; Alltech Associates Australia, Baulkham Hills, NSW, Australia) was employed. The detector and injector temperatures were 250 °C and 280 °C, respectively, the carrier gas flow (N_2) was 2.3 mL/min. Oven temperature programming was as follows: initial temperature of 100 °C with an increase of 5 ºC/ min until 180 ºC was reached, followed by a gradient of 0.8 ºC/min up to 230 ºC, the total running time of the samples was 90 min. Injection volume was 1 µl of each sample in triplicate, in Split mode. Fatty acid methyl esters (FAMES) peaks were identified by comparison of retention times to Supelco FAME standard mixtures (GLC-10, GLC-20, GLC-40, and GLC-80; Sigma, St Louis, MO, USA).

The peak areas were computed, and percentages of FAME were obtained as area percentages by direct normalization. Data are expressed as normalized peak area percent of all identified FAME.

2.10 Statistical analysis

Dependent variables were analyzed by means of a General Linear Model (GLM) tool which considered the effects of the diets and sex. Analysis of variance was carried out using the statistical package SAS version 9.1, the Tukey Test of comparison of means was applied in significant variables.

The following statistical model was used: $Y_{ijk} = \mu + \alpha i + \beta j + (\alpha\beta ik) + e_{ij}$

Where Y corresponds to the variables under study, µ is the general mean of the samples, αi is effect of the diet, βj is effect of the sex, (αβik) is interaction of the diet with the sex and e_{ijk} experimental error.

3. RESULTS AND DISCUSSIONS

There were no sex x diet interactions (P>0.05) for any of the parameters measured; therefore, only the main effects (sex and diet) expressed as means values are reported in the tables.

The measurement of pH and water activity (a_w) is related to the meat quality of pork. The present work shows the effect of diet and sex on the values of pH and a_w of the meat from the Longissimus dorsi muscle of the MHP (Table-3). When the pH was measured at 45 min post-mortem, similar values were obtained (P>0.05) from the meat of the Longissimus dorsi muscle of the MHP for the control diet, 20-MOM and 40-MOM. The pH values reported in this work are similar to those obtained from the Longissimus dorsi muscle of crossbreed Duroc males and Iberian females (Ramírez and Cava, 2007). However, the pH values found in this work are lower in comparison with those of pigs such as the Chatos Murcianos (Poto *et al.*, 2007) and Cinta Senese (Pugliese *et al.,* 2013).

The pH of the Longissimus dorsi muscle at 24 h post-mortem was not affected by the diet or the sex (P>0.05) and the pH values found in the present work are similar to those reported for the same muscle in pigs Chato Murciano (Peinado *et al.,* 2004) and for the terminal line of Duroc males x F1 females (Bertol *et al.*, 2013).

Kauffman et al. (1993) proposed that with a pH value (at 45 min post-mortem) lower than 5.8, the meat is considered to be PSE (pale, soft and exudative), whereas, with a pH value above 6.0 obtained at 24 h it is considered to be DFD (dark, firm and dry). Based on these criteria, the pH values obtained in this work indicate that the Longissimus dorsi muscle of the MHP does not classify as PSE or DFD meat, and is therefore fit for fresh consumption and industrialization.

Table-3. Quality characteristics evaluated in MHP.

	Diets						**Sex**
	Control	**20-HMO**	**40-HMO**	**Sign**	**Males**	**Females**	**Sign**
Longissimus dorsi pH45min	5.84±0.077	5.95±0.077	6.01±0.077	ns	5.92±0.056	5.94±0.693	ns
pH24h	5.59±0.077	5.65±0.077	5.61±0.077	ns	5.65±0.045	5.58±0.055	ns
a_w	0.93±0.004	0.92±0.004	0.93±0.004	ns	0.93±0.003	0.93±0.004	ns
Longissimus Lumborum (%) Drip loss 24h	1.42±0.188	1.79±0.188	1.05±0.188	ns	1.4±0.137	1.37±0.168	ns
Drip loss 48h	2.17±0.277	2.66±0.277	1.63±0.188	ns	2.2±0.202	2.0±0.248	ns
Cooking loss	11.09±0.912	12.61±0.912	10.21±0.912	ns	12.01±0.666	10.60±0.816	ns
Longissimus dorsi							
L*	57.32±1.293	57.77±1.293	56.58±1.293	ns	58.90±0.944	55.55±1.156	ns
a*	4.7±0.892	4.91±0.892	2.48±0.892	ns	4.09±0.651	3.97±0.797	ns
b*	12.82±0.672	13.05±0.672	11.62±0.672	ns	12.81±0.490	12.18±0.601	ns
Chrome	13.75±0.802	14.00±0.802	11.92±0.802	ns	13.58±0.586	12.87±0.718	ns
Hue	70.19±3.155	69.56±3.155	78.09±3.155	ns	72.99±2.304	72.24±2.822	ns
Subcutaneous fat							
L*	82.45±0.542	82.33±0.542	81.35±0.542	ns	82.26±0.398	81.83±0.487	ns
a*	-1.34±0.23	-1.45±0.23	-0.92±0.23	ns	-1.39±0.168	-1.08±0.206	ns
b*	8.05±0.531	8.06±0.531	7.96±0.531	ns	7.88±0.388	8.16±0.475	ns
Chrome	8.21±0.509	8.20±0.509	8.020±0.509	ns	8.01±0.372	8.27±0.456	ns
Hue	100.26±1.882	100.18±1.882	96.61±1.882	ns	100.11±1.375	97.92±1.685	ns
Longissimus dorsi (%)							
Moisture	69.32±0.256	69.54±0.256	69.25±0.256	ns	68.69^{a}±0.229	70.14^{b}±0.187	**
Protein	21.56^{a} ±0.170	21.48^{b}±0.170	21.43^{b}±0.170	*	21.14^{a}±0.124	21.84^{b}±0.152	*
Fat	5.60±0.238	5.19±0.238	5.30±0.238	ns	6.60^{a}±0.174	$4.13±0.213^{b}$	**
Ash	3.50±0.142	3.66±0.142	3.99±0.142	ns	3.64±0.104	3.80±0.127	ns

Sign= significance
ns= not significant
Different letters indicate significant differences *($p<0.05$), ** ($p<0.001$)
20-MOM= 20% of Moringa oleifera meal in the diet
40-MOM= 40% of Moringa oleifera meal in the diet
$a_{w=}$ Water activity

Water activity (a_w), measured at 24 h post mortem in the Longissimus dorsi muscle of the MHP, was not affected by the diet or sex of the animal ($P>0.05$). The values of a_w reported in this work are typical for fresh meat, which is considered as a highly perishable food (Badui, 2006).

One variable of quality which affects the weight and economic value of meat for commercialization is water holding capacity (WHC). This can be measured in two ways; by determining drip loss and cooking loss. The present work reports the effect of the diet and the sex of the animal on drip loss at 24 and 48 h post-mortem and cooking loss at 24 h (Table-3). Drip loss and cooking loss were found to be higher, without statistical difference, ($P>0.05$) in the meat from the Longissimus lumborum muscle of the animals fed with the control diet and 20-

MOM when compared to the meat from animals fed with 40-MOM diet. In another result, the meat of the male pigs was found to lose more water in comparison with that of the females; however, no significant differences were observed (P>0.05) and this result could be attributed to the similar pH values found in the meat of all the treatments.

The cooking loss and drip loss results obtained in this work were lower than those reported by Suzuki *et al*. (2003) for pork from the pure bred Berkshire, characterized by its high WHC and resulting of good quality. This result indicates that the meat of the MHP loses less water and therefore presents less weight loss and greater yield; allowing it to be considered a good quality meat.

The color of pork is influenced by pigment content, the chemical form of this pigment and meat structure (Lindahl *et al*., 2001). With respect to the color evaluated (Table 3) in the meat from the Longissimus dorsi muscle of the MHP, the diet and the sex of the animal were found to have no effect (P>0.05) on the coordinate L* (luminosity), a* (red) and b* (yellow). The values of a* y b*, chroma and hue angle reported in this work demonstrate that the color of the meat is pale red. In a study carried out by Renaudeau and Mourot (2007), it was also reported that the sex of the animal had no influence on the color of meat from Creole pigs of the French Antilles.

Similarly, the color of the subcutaneous fat of the MHP was not affected by the diet or the sex of the animal. The values found in the coordinate L* were similar to those reported by Pugliese et al. (2013) in pigs of the Cinta Senese breed. According to the values of L*, a*, b*, chroma and hue angle found, a white color with a slight yellow coloring was obtained in the fat of the MHP.

Very little information is available regarding the proximal composition of the Longissimus dorsi muscle of the MHP to facilitate the evaluation of its quality. In this work, the results of the proximal composition analysis (Table 3) can be found within the range of those reported by authors who have studied other breeds of pigs (Corino et al., 2002; Estévez *et al,* 2003). The moisture percentage of the meat in this work was found to be similar to those reported by Muriel et al. (2004) in the Longissimus dorsi muscle of Iberian pigs and in the Longissimus lumborum muscle of Cinta Senese pigs (Pugliese *et al*., 2013).

The diet and the sex of the animal had an influence on the protein content of the meat from the MHP (P<0.05); however, these protein levels are within the range of values reported for crossbreeds of Duroc x Large with Landrace White fed with by-products of animal origin and beef fat (Morel *et al*., 2013).

On the other hand, only the sex of the MHP had an effect (P<0.001) on the lipids content of the meat, with the males showing higher lipids values in comparison with the females, an effect which was probably the result of the castration of the males which influences lipid deposition (Peinado *et al*., 2008). The percentage of lipids obtained for the meat of the males was lower than that of the meat from the crossbreed of Landrace x Large White (Fiego et al., 2005) and from Chato Murciano (Poto *et al*., 2007), while the percentage of lipids in the meat of the females was similar to those reported for the crossbreed of Yorkshire x Chester White (Lim *et al*., 2014).

In this work, the diet and sex of the MHP did not influence the percentage of ashes, however, these values concur with those found in pig carcasses of Duroc x Landrace females fed with different fat sources (Realini *et al*., 2010). In contrast, the levels of ashes found herein do not concur with the value found in Longissimus dorsi muscle of reciprocal crossbreeds of Iberian males with Duroc females and Duroc males with Iberian females (Ramírez and Cava, 2007).

The composition of fatty acids of the Longissimus dorsi muscle is shown in Table-4.

Table-4. Composition of fatty acids (%) of the intramuscular fat of the Longissimus dorsi muscle.

	Diets				Sex		
	Control	**20-MOM**	**40-MOM**	**Sign**	**Males**	**Females**	**Sign**
C9:0	1.26±0.289	0.66±0.289	0.83±0.289	ns	0.98±0.211	0.85±0.258	ns
C11:0	1.42^{a}±0.103	1.08^{a}±0.103	0.007^{b}±0.103	**	0.95±0.075	0.71±0.092	ns
C12:0	1.07±0.268	1.39±0.268	1.34±0.268	ns	1.35±0.196	1.18±0.240	ns
C14:0	6.88±1.420	5.42±1.420	2.18±1.420	ns	5.39±1.037	4.27±1.270	ns
C16:0	29.79±2.363	27.81±2.363	27.98±2.363	ns	26.98±1.725	30.07±2.113	ns
C16:1 (n-7)	1.42±0.121	1.64±0.121	1.80±0.121	ns	1.44^{a}±0.088	1.81^{b}±1.441	*
C18:0	15.56±3.482	15.70±3.482	19.79±3.482	ns	15.25±2.543	18.78±3.114	ns
C18:1 (n-9)	24.07^{a}±1.744	28.37^{ab}±1.744	32.99^{b}±1.744	*	30.44±1.273	26.52±1.560	ns
C18:2 (n-6)	1.33±0.360	1.51±0.360	1.73±0.360	ns	1.50±0.263	1.55±0.322	ns
C18:3 (n-3)	1.56^{a}±0.226	2.11^{b}±0.226	2.14^{b}±0.226	*	1.50^{a}±0.165	2.10^{b}±0.202	*
C20:4 (n-6)	1.19^{a}±0.301	1.74^{ab}±0.301	2.44^{b}±0.301	*	1.68±0.220	1.92±0.269	ns
∑SFA	56.01±3.210	52.08±3.210	52.15±3.210	ns	50.94±2.344	55.89±2.871	ns
∑ MUFA	25.50^{a}±1.752	30.07^{ab}±1.752	34.80^{b}±1.752	*	31.88±1.280	28.33±1.567	ns
∑ PUFA	2.49±0.516	3.62±0.516	3.87±0.516	ns	3.00±0.377	3.66±0.462	ns
∑ P/S	0.04±0.014	0.06±0.014	0.07±0.014	ns	0.06±0.012	0.06±0.010	ns
∑ n-6	2.55±0.504	3.25±0.504	4.20±0.504	ns	3.18±0.368	3.48±0.451	ns
∑ n-3	1.56^{a}±0.226	2.11^{b}±0.226	2.14^{b}±0.226	*	1.50^{a}±0.165	2.10^{b}±0.202	*
∑ n-6 /n-3	2.12±0.231	1.54±0.231	2.13±0.231	ns	2.00±0.168	1.86±0.206	ns
∑h	26.56^{a}±1.783	32.00^{ab}±1.783	36.87^{b}±1.783	*	33.44±1.302	30.18±1.544	ns
∑H	37.76±2.823	34.62±2.823	31.51±2.823	ns	33.74±2.062	35.53±2.525	ns
h/H	0.78±0.130	0.92±0.130	1.23±0.130	ns	1.05±0.095	0.86±0.116	ns

Different letters indicate significant differences *($p<0.05$), ** ($p<0.001$), ∑h= hypocholesterolemia (Total of C18:1 (n-9), C18:2 (n-6), C18:3 (n-3)), ∑H=Hypercholesterolemia (Total of C12:0, C14:0, C16:0).

In this work, 11 fatty acids were identified in the lipid fraction of the Longissimus dorsi muscle, of which five were unsaturated fatty acids. Among the saturated fatty acids, the most common were myristic (C14:0), palmitic (C16:0) and stearic (C18:0), while oleic acid (C18:1 n-9) was the most abundant unsaturated fatty acid.

The content of some saturated fatty acids (SFA) showed a tendency to diminish in response to the increase in the level of MOM inclusion. The saturated fatty acid (SFA) values found in this study do not concur with those reported for Large White pigs fed with different sources of energy (animal fat, corn oil or canola oil) (Corino *et al*., 2002) and for the Iberian pigs lines fed with grass in a natural outdoor production system (Estévez et al., 2003).

The total amount of monounsaturated fatty acids (MUFA) of the meat was 25.5, 30.0 and 34.80% for the control diet, 20-MOM and 40-MOM, respectively. This result indicates that the MUFA content of the meat was affected by the diet of the MHP ($P<0.05$). This effect is partially explained by the influence of the fatty acid composition of the diet on the activity of the Δ9 desaturase enzyme (Table-2) (Tejerina *et al*., 2012). It is known that the Δ9 desaturase catalyzes the synthesis of MUFA from the palmitic and stearic acids (Siebert *et al*., 2003).

Corino *et al*. (2002) stated that the presence of MUFA acids confers a high nutritional value to the pork for human consumption. These results coincide with those reported for females of the crossbreed Landrace x Large White fed either sunflower oil or linseed oil (Botsoglou *et al*., 2014).

The levels obtained in this work for the total amount of polyunsaturated fatty acids (PUFA) were not significantly influenced by the diet or sex of the MHP. The values of PUFA obtained herein differ from those reported by Rey *et al*. (1997), in which a higher content of PUFA was indicated in Iberian pigs of the Torbiscal line fed with acorns in the last fattening stage (4.85% of PUFA). In this work, the inclusion of MOM in the diet of the MHP was found to significantly reduce undecanoic acid (C11:0) in the meat ($P<0.001$). Moreover, a significant increase ($P<0.05$) was found in the percentage of oleic acid (C18:1 n-9) in the meat due to diet. It has been reported that the percentage of oleic acid (C18:1 n-9) of the meat largely depends on the content of this fatty acid in the diets (Rey

et al., 1997; Bertol *et al.,* 2013); an effect that was observed in the present work. The importance of the presence of oleic acid in the meat is in relation to the quality and taste of meat products (Rey *et al*., 1997); furthermore, there is evidence that oleic acid has certain health benefits, by reducing cholesterol levels (Estévez *et al*., 2003).

The level of palmitoleic acid (C16:1 n-7) was found to be higher in the females in a comparison with the males; however, it was lower than those reported in females of the Rattlerow Seghers hybrid lines (Ntawubizi et al., 2009).

Linolenic (C18:3 n-3) and arachidonic acids (C20:4 n-6) of the Longissimus dorsi muscle was affected by the diet ($P<0.05$) and the increase in the first fatty acid can be attributed to the consumption of MOM, as it is considered to be a source of α-linolenic acid (C18:3 n-3). The levels of α-linolenic acid were higher in meat from MHP fed with 20-HMO and 40-HMO in comparison with those obtained for the control diet. In previous studies, α-linolenic and arachidonic acids were not identified in the intramuscular fat of the MHP fed with commercial feed until a slaughter weight was reached at 115 days (Delgado et al., 2002). Another result in the meat of MHP showed that the sex of the animal had a significant influence ($P<0.05$) on the α-linolenic acid content, with the females obtaining higher values in comparison with the males. This could be attributed to the possibility of a high activity of Δ6 and Δ5 desaturases in female pigs (Hallenstvedt *et al*., 2012).

The ratios of PUFA/SFA, n-6/n-3 and h/H (hypocholesterolemia/hypercholesterolemia) are commonly used to evaluate the nutritional value and healthy consumption of meat fat (Orellana et al., 2009). According to the literature, in order to avoid the risk of cardiovascular diseases, the recommended ratio for polyunsaturates and saturates (P/S) and the ratio of n-6/n-3 of the meat for human consumption are 0.45 and below 4.0, respectively (Wood *et al.*, 2004). In this sense, the values found for P/S in this work were lower than the recommended, while the ratio n-6/n-3 was within the recommended range.

The values of h/H obtained in the meat of the MHP varied between 0.78 and 1.23 and were not affected by the diet or the sex of the animal; however, they were lower than the recommended levels (British Department of Health, 1994).

The composition of fatty acids in the subcutaneous fat of the MHP is shown in Table 5. With respect to the percentage of each SFA, no significant effect was observed as a result of the diet or the sex of the animal; however, the total amount of SFA decreased significantly ($P<0.05$) as the dietary amount of MOM was increased. The SFA values found are high in comparison with those reported for the dorsal fat of the Cinta Senense pigs fed with a commercial concentrate (Pugliese *et al*., 2005).

The subcutaneous fat of the animals fed with 40-HMO showed higher levels of palmitoleic (C16:1 n-7), arachidonic (C20:4 n-6) ($P<0.01$) and α-linolenic acids (C18:3 n-3), and consequently, a greater content of MUFA ($P<0.05$) when compared to the control diet and 20-HMO. The sex of the animal also affected the levels of palmitoleic, α-linolenic and araquidonic acids as well as PUFA ($P<0.05$) of the subcutaneous fat, with the females obtaining higher values of these fatty acids in comparison with those obtained by the males. This is partially explained by the activity of the enzymes Δ9, Δ5 and Δ6 desaturases (Siebert *et al*., 2003; Hallenstvedt *et al*., 2012). The values found in this work for the ratio P/S for subcutaneous fat of the MHP are lower than the recommended; in contrast, the ratio n-6/n-3 was within the adequate dietary ratio (Wood *et al*., 2004).

The diet and sex of the MHP did not affect the h/H values of the subcutaneous fat; these values were inferior when compared to those obtained from the meat of the MHP and this difference can be attributed to the higher quantity of saturated fatty acids found in the subcutaneous fat of the MHP.

Table-5. Composition of fatty acids (%) of the subcutaneous fat.

	Diets			Sex			
	Control	**20-MOM**	**40-MOM**	**Sign**	**M**	**H**	**sign**
C11:0	0.31±0.063	0.34±0.063	0.32±0.063	Sn	0.34±0.046	0.30±0.056	sn
C12:0	2.96±0.643	2.92±0.643	2.33±0.643	Sn	2.92±0.467	2.55±0.572	sn
C14:0	21.43±4.874	18.39±4.874	16.38±4.874	Sn	17.63±3.560	19.84±4.360	sn
C16:0	25.50±1.438	24.89±1.438	22.06±1.438	Sn	22.37±1.050	25.93±1.286	sn
C16:1 (n-7)	0.23^{a}±0.086	1.21^{b}±0.086	1.93^{c}±0.086	**	0.92^{a}±0.063	1.33^{b}±0.077	*
C18:0	17.52±2.614	15.28±2.614	11.85±2.614	Sn	14.58±1.909	15.18±2.338	sn
C18:1 (n-9)	15.99±2.767	20.44±2.767	24.91±2.767	sn	22.52±2.021	18.37±2.475	sn
C18:2 (n-6)	1.51±0.238	1.35±0.238	2.01±0.238	sn	1.54±0.174	1.70±0.213	sn
C18:3 (n-3)	2.16^{a}±0.286	2.46^{ab}±0.286	3.43^{b}±0.286	*	2.15^{a}±0.209	3.22^{b}±0.256	*
C20:4 (n-6)	1.36^{a}±0.156	1.47^{a}±0.156	3.99^{b}±0.156	**	2.01^{a}±0.114	2.54^{b}±0.140	*
∑SFA	67.74^{a}±2.518	61.85^{ab}±2.518	52.96^{b}±2.518	*	57.87±1.839	63.83±2.253	sn
∑ MUFA	17.21^{a}±2.873	23.13^{ab}±2.873	30.85^{b}±2.873	*	25.46±2.098	22.00±2.569	sn
∑ PUFA	4.06±0.484	3.81±0.484	5.45±0.484	sn	3.69^{a}±0.353	5.18^{b}±0.433	*
∑ P/S	0.05^{a}±0.010	0.06^{ab}±0.010	0.10^{b}±0.010	*	0.06±0.009	0.08±0.009	sn
∑ n-6	2.87^{a}±0.327	2.82^{a}±0.327	6.01^{b}±0.327	**	3.55±0.239	4.25±0.292	sn
∑ n-3	2.16^{a}±0.286	2.46^{b}±0.286	3.43^{b}±0.286	*	2.15^{a}±0.209	3.22^{b}±0.256	*
∑ n-6/n-3	1.44±0.171	1.22±0.171	1.77±0.171	sn	1.63±0.125	1.32±0.153	sn
∑h	19.67±2.964	24.26±2.964	30.36±2.964	sn	26.22±2.164	23.31±2.651	sn
∑H	49.91±4.455	46.22±4.455	40.78±4.455	sn	42.93±3.985	48.34±3.253	sn
h/H	0.40±0.127	0.59±0.127	0.77±0.127	sn	0.64±0.092	0.54±0.113	sn

Different letters indicate significant differences *($p<0.05$), ** ($p<0.001$), ∑h= hypocholesterolemia (Total of C18:1 (n-9), C18:2 (n-6), C18:3 (n-3)), ∑H=Hypercholesterolemia (Total of C12:0, C14:0, C16:0).

4. CONCLUSIONS

In general, the inclusion of MOM in the diet of the MHP did not affect the physico-chemical characteristics of meat quality; however, the diet did have an effect on the MUFA content of the meat and also affected the SFA and MUFA content of subcutaneous fat. The sex of the MHP only had an influence on the PUFA content of subcutaneous fat.

From a nutritional point of view, it is possible to suggest that by increasing the consumption of MOM as a source of fatty acids for the diet of the MHP, unsaturated fatty acids can be increased in the meat and subcutaneous fat, contributing to the health of the consumer.

The characteristics of meat quality in the MHP fed with Moringa oleifera would suggest the convenience of its genetic conservation, exploitation, production and industrialization of the meat and meat products.

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