DOI: https://doi.org/10.52973/rcfcv-e32154 Revista Científica, FCV-LUZ / Vol. XXXII, rcfcv-e32154, 1 - 9

Trace elements, macro minerals and iron forms content, in meat of Pampa Rocha pig reared indoor and outdoor with pasture

Contenido de elementos traza, macro minerales y formas de hierro en carne de cerdo Pampa Rocha criado en confinamiento o al aire libre con pasturas

Cecilia Carballo[1], Nandy Espino[1,2], Ana Vodanovich[1], Marcelo Ferrando[3], Ali Saadoun[1,2] and María Cristina Cabrera[1,2]*

[1]*Universidad de la República, Facultad de Agronomía, Departamento de Producción Animal y Pasturas, Laboratorio de Calidad de Alimentos & Productos. Montevideo, Uruguay.* [2]*Universidad de la República, Facultad de Ciencias, Fisiología & Nutrición, Instituto de Biología. Montevideo, Uruguay.*
[3]*Universidad de la República, Facultad de Agronomía, Departamento de Suelos y Aguas. Montevideo, Uruguay.*
**email: ccarballo@fagro.edu.uy*

ABSTRACT

Pampa Rocha pig (PRp) is a local breed present and produced in Uruguay. Twenty-three pigs were used housed indoor (I) and outdoor with pasture (O), live weight 94.5 and 91.5 kilograms (kg), respectively. Animals were fed with concentrate in both systems, but pasture access was granted to the animals in the O. After slaughtering, the *Longissimus dorsi* (LD), *Psoas major* (PM), *Gluteus medius* (GM), *Semitendinosus* (ST), *Biceps femoral* (BF), and *Quadriceps femoris* (QF) were sampled to be analyzed. In O, the growth of pigs was lower, and improved the concentrate intake:live weight gain. The content of heme iron and the ratio Fe Heme/Fe Total were higher in outdoor. The LD muscle showed lower total and heme iron content. For ham, QF showed the highest values of heme iron. No differences were observed between systems or muscles in the content of Ca, Mg, and K. The Na content was similar in both systems, and higher in PM. No differences were observed between production systems for trace elements content. According to the results obtained, it is possible to produce PRp meat with interesting mineral content, in two alternative systems to the classic confinement. This breed produces healthier meat in O. It could be interesting to exploit some differences founded between LD and PM muscles, which are normally consumed as fresh meat, and are adapted to the different demands of human nutrition. Rearing in O that include pastures is a good way to promote and add nutritional value to this local breed.

Key words: Pampa Rocha pig; macro mineral; trace element; heme iron; outdoor production system

RESUMEN

El cerdo Pampa Rocha (PRp) es una raza criolla uruguaya. Se utilizaron 23 cerdos alojados en dos sistemas: cama profunda (I), o al aire libre con pasturas (O), faenados a los 94,5 y 91,5 kg, respectivamente. En ambos sistemas se alimentaron con concentrado comercial, teniendo acceso a libre pastoreo en el sistema O. Inmediatamente luego de la faena, se tomaron muestras de los músculos para análisis: *Longissimus dorsi* (LD), *Psoas major* (PM), *Gluteus medius* (GM), *Semitendinosus* (ST), *Biceps femoral* (BF) y *Quadriceps femoris* (QF). Los cerdos criados en O mostraron un crecimiento más lento, pero mejoraron la conversión de concentrado. El contenido de hierro heme y la relación Fe Heme/ Fe total fue mayor en O. En el LD se observó menor contenido de hierro heme y total, pero en músculos del jamón, el QF mostró los valores más altos de hierro heme. No se observaron diferencias entre sistemas o músculos para los contenidos de Ca, Mg y K. El contenido de Na fue similar entre sistemas y mayor en PM. No se observaron diferencias entre sistemas para el contenido de elementos traza. Según los resultados obtenidos es posible producir carne de cerdo PRp con contenidos interesantes de minerales, en dos sistemas alternativos al confinamiento clásico, siendo más saludable desde el punto de vista nutricional aquella producida en O. Sería interesante aprovechar algunas diferencias encontradas entre los músculos LD y PM, que son consumidos normalmente como carne fresca, y que por sus valores se adaptan a las necesidades de la nutrición humana. La cría en O que incluya pasturas implica una alternativa de producción que adiciona valor nutricional y a su vez valoriza esta raza porcina local.

Palabras clave: Cerdo Pampa Rocha; macro minerales; elementos traza; hierro heme; sistema de producción al aire libre

Received: 13/05/2022 Accepted: 13/06/2022 Published: 26/08/2022

INTRODUCTION

Pampa Rocha pig (PRp) is a local genetic animal resource reared in Uruguay, mainly in Rocha, East region of the Country [9, 35], whose population is in danger-maintained condition [14], and its revaluation being important to recover it. In that region, family-scale producers work hardly to conserve that local pig (*Sus scrofa domesticus*) and look how it can be valued though its products, such as meat, in a first step for the local market and afterward in the international one.

Much remains to be done, and the producers need scientific information regarding the meat quality parameters of the PRp to help them to do their promotion campaigns. Two advantageous points could help this pig to grow as a meat product for local and regional consumers. The first one is that the pig meat is growing within the international meat market in comparison to others usual meat [29]. The second one is that consumers today ask for differential and local products [6].

By other side, pork is a traditional and valuable source of protein and micronutrients in many low-income countries, contributing with the physical and cognitive development of children and adolescents. In this sense, in Latin America, pork consumption has risen rapidly in recent years, particularly in Argentina, Brazil, México, and Uruguay, with this demand driven by higher domestic production, quality improvements, and favourable relative prices [29, 30]. Additionally, fertile lands with abundant pasture represent an opportunity to rear pigs with improved attributes that might influence consumer perception.

Globally, consumer demands are changing, and recent outbreaks of animal diseases have raised health and safety food concerns [13]. As previous studies have demonstrated that nutrients as mineral content can vary among animal species, diets, genetic types, muscles, ages, and processes [2, 4, 10, 31, 34] and some mineral, particularly Fe content can to best in outdoor systems and in the local breeds [27, 40]. The accurate determination of nutrient content in a new animal protein food is necessary to accomplish the nutritional value of the different cuts of meat in relation to their economic value [4, 37].

People increasingly prefer ecologically friendly or organic meat products that are antibiotic-free and produced in line with ethical and animal welfare standards [15]. Outdoor (O) production represents an opportunity to meet these new demands, and future systems should include creole local breeds and pastures to add value to meat products. On the other hand, the deep bed system is present in Uruguay and in the region as an alternative system to classic confined one. As main characteristics, the best animal welfare is mentioned because de litter (dry vegetable matter) enriches the environment, water is not used for cleaning and there is no management of excreta. Low-cost facilities can be used, making this system viable on family farms [12].

If PRp meat is valued and become a commercial product, so this genetic resource animal will be protected and preserved in its original ambient for the next generation of producers. This economic schema has been useful to protect and preserve other productive species in other countries. Probably the most illustrative example would be the Iberian pig, today produced in Spain and famous for its products as delicatessen, known worldwide [31]. PRp is far to be at the same level and status that the Iberian pig, but availability of nutritional information of this kind of animal could help it to grow as a differential product.

Thus, the objective of this investigation was to evaluate the nutritional value of fresh meat obtained from PRp produced in Uruguay in two alternative production systems to classic confined, outdoor with pastures and deep bed, both possible to be adopted by family producers. The present investigation has been focused on trace and macro minerals, as well as on heme and non-heme iron, zinc, copper, manganese, calcium, magnesium, sodium, and potassium contents in the *Longissimus dorsi*, *Psoas major*, and ham muscles, i.e., *Gluteus medius*, *Semitendinosus*, *Biceps femoral*, and *Quadriceps femoris*.

MATERIALS AND METHODS

Animals and feeding

The whole experiment was conducted with the approval of the animal ethical committee of the Faculty of Agronomy (Udelar-Uruguay, protocol N° 317, file N° 021130-001003-16). Twelve males (castrated) and eleven females PRp born in an O system, were weaned at 45 days of age (DA), live weight (LW) 14.5 ± 3.5 kg, and housed in group, both sex mixed, in a shed. The sides of the shed were fenced with wire mesh and the litter was made of wheat straw.

The animals remained in there until they reached the LW of 39.6 kg ± 2.8. Then 11 animals (6 males and 5 females) were kept in the same shed, providing 1.5 square meters (m^2) of floor per animal (Indoor, I). The other 12 animals (8 males and 4 females) were housed grouped in field facilities, next to the shed, fenced with wire mesh too (O with pasture). The animals of the O system have always access to a refuge and cultivated pastures, having an available grazing area of 300 m^2 per animal.

The criteria for composed the groups in each treatment was the similar weight when pigs were assigned to each production system, and presence of male and female pigs in both. Both housing systems had feeders for concentrate and automatic water sources with permanent access. The concentrate characteristics are showed in the TABLE I.

In the I system, feed offered was calculated according to LW, at rate of 100% of maximum voluntary intake (MVI) [28]. In the O system with access to pasture, diet intake was restricted by 15% of MVI, up to 67.50 ± 12.79 kg of LW; after that, there was a subsequent restriction of 25% until the sacrifice. This procedure was applied to favour pasture

TABLE I
Composition and nutrient level of concentrate (air-dry basis)

Ingredient %		Nutrient Content %	
Rice bran,defatted	20	Dry matter %	90.23
Rice bran, whole	10	DE ($Mcal \cdot kg^{-1}$)	2.79
Sorghum grain, ground	25	Crude Protein	14.49
Corn grain, ground	15	Crude ash	12.11
Wheat grain, ground	15	Ether extract	3.35
Soybean meal, 47 % CP	10	Crude Fiber	8.30
Calcium carbonate	2.5	Calcium	0.63
Salt	0.35	Available phosphorus	0.27
Premix[1]	2.15		

The premix[1] included: ROVIMIX® Pig CT 2 % , vitamin A, D3, E, K3, C, thiamine, riboflavin, pyridoxine, cyanocobalamin, folic acid, pantothenic acid, copper (as copper sulfate), selenium (as sodium selenite), zinc (as zinc oxide), iron (as iron sulfate), manganese (as manganese sulfate), iodine, lysine, threonine, and OXICAP® MS (antioxidant) and BioCholine® and MICOFIX® (mycotoxin binder), and ROVABIOTM (multienzyme complex).

intake [19]. The cultivated pasture was a mixture, in a dry matter (DM) basis, of *Cichorium intybus* (48.6%), *Trifolium pratense* (34.9%), *Lolium multiflorum* (12.3%), and undefined weed (4.2%). Pasture consumption was estimated for a period of 7 days (d) prior to slaughter, through the difference in forage availability at the entrance and exit of the animals to the grazing strip, applying the double sampling method [25]. At the end of the experiment, the animals (LW of 94.5 ± 3.6 and 91.5 ± 3.4 kg for I and O with pasture, respectively), were slaughtered in a commercial slaughterhouse. Immediately after sacrifice, *Longissimus dorsi* (LD) between the 10th and 12th ribs, *Psoas major* (PM), *Gluteus medius* (GM), *Semitendinosus* (ST), *Biceps femoral* (BF), and *Quadriceps femoris* (QF) were removed and transported to the laboratory in refrigerated isothermal boxes (Rubbermaid Incorporated, Huntersville, USA).

Productive and carcass parameters

Concentrate intake was estimated daily considering the offer and residual fed. The individual LW (kg) was registered every 14 d. At slaughtering, carcasses were individually identified and weighted on an electronic hanging scale (NQF, D5000, Uruguay). The dorsal fat thickness was measuring in three points of the each LD sample with caliber milimeters (mm, Kendo, XM2007006, China).

Mineral determinations

For each muscle, a 5 grames (g) sample, free of visible fat and connective tissue, were used. The samples were dried in a forced-air oven (105°C, Labotecgroup, BJPX-Juneau, Uruguay), until they reached a constant weight. Dried samples were then incinerated in a digital muffle furnace (Thermolyne, Cimarec 3, USA), at 580°C for 16 hours (h), using porcelain crucibles (SUP-68281) with caps (SUP-68223), both from Marienfeld (Superior, Laboratory Glassware, Germany), until whitish ashes were obtained. The ashes were then solubilized with 2 mililiters (mL) of HCl 6 Molar (M) (HCl, Merck a.g, analytical grade) and 2 mL of HNO_3 1 M ultrapure (HNO_3 65%, Merck, a.g. distilled by sub boiling), over a hot plate (< 80°C, Thermolyne, 48000 Furnace, USA).

The samples were filtered using Whatman ashless filter paper and up to 25 mL with deionized, 18 Megaohm·centimeters^{-1} (Mohm·cm^{-1}) water [34]. A blank containing only acid was included too. Total Fe, Zn, Cu, Mn, Ca, Mg, Na and K contents were determined by atomic absorption spectrometry (AAS, Perkin Elmer, Analyst 300, USA) with either flame or emission. This system was equipped with a hollow monoelement cathode lamp (Lumina Hollow Cathode Lamp, Perkin Elmer, USA) for Ca, Mg, Na, K, Fe, Zn, Cu, and Mn.

For each analyte, adequate standard solutions of Ca, Mg, Na, K, Fe, Zn, Cu, and Mn containing 1000 micrograms·mL^{-1} (µg·mL^{-1}) in 2% HCl from Perkin Elmer (TruQTM grade, USA) were used, and a blank was included for each analyte with 2% HCl. To avoid interference in the measurements of Ca and Na, solutions of La2O3 and Al-Cs, respectively, were dissolved in 2% HCl and used. An air-acetylene flame was used with a ratio of 10-2.5, L·minutes^{-1} (L·min^{-1}). The limit of detection (LOD) was calculated as 3 second·meters^{-1} (s·m^{-1}), where was the standard deviation of 20 blank measurements divided by the slope of the calibration curve. The limit of quantification (LOQ) was calculated as 10 s·m^{-1}.

Heme and non-heme Iron determination

For heme iron determination, Hornsey's procedure was followed [16] as adapted by Ramos *et al.* [34]. Briefly, fresh meat samples (2 g) were finely chopped and macerated in 9 mL of HCl-acidified acetone in glass test tubes (Pyrex, N°9820, USA). Total heme pigments in meat samples were determined as hemin after extraction with acidified acetone solution. Hemin was quantified by its absorption peak at 640 nanometers (nm) in a spectrophotometre (Thermo Corporation, California, USA). Heme iron content was calculated with the factor 0.0882 µg iron/µg hematin. Non-heme iron was determined as the difference between total iron and heme iron content.

Statistical analysis

Data are presented as mean ± SEM for each rearing system, muscle and sex studied (when differences were observed for sex). Main effects, namely I, O with pasture, muscle and sex, were analysed using an ANOVA with a GLM procedure and a *post hoc* Tukey-Kramer multiple comparison test, with a significance level set at $P<0.05$. The data were analysed using the software NCSS (NCSS, 329 North 1000 East, Kaysville, UT 84037, USA, Version 2009).

RESULTS AND DISCUSSION

Productive parameters

As seen in TABLE II, differences between production systems in age at slaughter, LW daily gain, and concentrate intake/live weight gain ratio were observed. The growth of pigs in O system with pasture was lower and age of slaughter significantly higher than pigs in I. Concentrate restriction applied to pigs could explain these results [32]. When concentrate is not restricted, growth of pigs reared O is higher than reared in I, as reported Juska *et al.* [20].

No differences in dorsal fat thickness or carcass yield between systems were observed (TABLE II). In general, pigs fed pastures have a lower performance, due to greater development and weight of gastrointestinal tract [22]. For other hand, local breeds have a high dorsal fat thickness (29-63mm) although this feature can be modified

TABLE II
Productive parameters and carcass characteristics from Pampa Rocha pigs reared in an Indoor or Outdoor with pasture production systems

Parameters	Systems		
	Indoor	**Outdoor**	***P*-value**
Age of slaughter (days)	171.0 ± 1.36	183.1 ± 1.30	0.001*
Live weight (kg)	94.55 ± 3.63	91.50 ± 3.38	ns
Live weight gain (g·day^{-1})	801.2 ± 33.00	686.3 ± 31.60	0.02*
Concentrate intake / live weight gain (kg/kg)	4.34 ± 0.16	3.85 ± 0.16	0.02*
Carcass weight (kg)	68.05 ± 0.68	66.30 ± 0.65	ns
Carcass yield (%)	72.00 ± 0.76	70.2 ± 0.72	ns
Dorsal fat thickness (mm)	28.45 ± 1.91	25.43 ± 1.83	ns

Values are mean ± SEM of n=11 (6 males, 5 females) for I and n=12 (8 males, 4 females) for O, for fattening period. Values of $P<0.05$ indicate significant differences between production systems by ANOVA GLM. As sex effect was no significant means represents male and female together through the feed and the production system [1, 32]. Pasture intake with a restricted concentrated diet improved the ratio of concentrated intake: LW gain. This is important for little and medium scale farmers that search lower production costs. No differences due to the effect of were observed for any of the variables studied.

Mineral composition in concentrate and in the cultivate pasture

Concentrate and pasture mineral composition is show in TABLE III. The botanical composition and the mineral content of the different species of pasture varied with the sampling date. The high contribution of Fe (mg·kg^{-1} DM) in comparison to the concentrate stands out, similarly to Mn. On the other hand, the concentrate had high levels of Cu, Zn, and Mg compared to the three plant species that made up the mixture. In general, the ryegrass showed lower contents of Fe, Mn, Cu, and Zn.

The contribution of Fe from *Trifolium pratense* was important with respect to the other plant species, as well as to the concentrate. Ramos *et al.* [33] reported higher Fe bioaccessibility in *Trifolium pratense* than in *Medicago sativa* and *Lotus corniculatus*. *Cichorium intybus* was observed in a higher percentage of the botanical composition. This plant species is more preferred by pigs than the other two [8]. Pasture intake (DM) represented 1.6% of LW in animals in the O system during the finishing period. Rivero *et al.* [35] in a review,

TABLE III

Trace elements and macro mineral contents in concentrate and *Trifolium pratense*, *Cichorium intybus*, and *Lolium multiflorum*, representing the botanical composition of pasture offered to Pampa Rocha pigs during the fattening period in the outdoor production system

Pasture	Month*	Trace elements				Botanical composition
		Fe	Zn	Cu	Mn	
		mg·kg^{-1} dry weight				% Dry matter
Trifolium pratense	Jul. 1	1101.8 ± 59.3	28.6 ± 2.8	6.6 ± 0.8	134.7 ± 2.6	15.4 ± 5.2
	Jul. 2	789.2 ± 31.1	24.8 ± 2.2	8.5 ± 1.5	129.5 ± 1.6	27.5 ± 3.4
	Sep. 1	608.7 ± 28.4	29.8 ± 4.9	14.9 ± 1.6	112.0 ± 3.7	50.6 ± 5.7
	Sep. 2	926.8 ± 55.3	15.7 ± 0.3	4.7 ± 0.5	128.7 ± 4.3	45.9 ± 8.6
Cichorium intybus	Jul. 1	738.1 ± 26.9	41.5 ± 5.3	8.6 ± 0.3	167.3 ± 4.7	65.7 ± 3.3
	Jul. 2	560.0 ± 36.8	35.0 ± 6.5	8.1 ± 0.8	145.0 ± 10.5	53.9 ± 6.8
	Sep. 1	577.7 ± 94.2	28.2 ± 2.5	12.4 ± 1.6	117.3 ± 8.7	36.3 ± 3.5
	Sep. 2	728.0 ± 238.0	28.5 ± 1.1	12.9 ± 0.4	151.9 ± 19.7	38.8 ± 7.7
Lolium multiflorum	Jul. 1	508.1 ± 48.7	10.1 ± 0.1	4.9 ± 0.4	111.8 ± 14.9	16.8 ± 3.3
	Jul. 2	351.4 ± 52.5	8.2 ± 1.2	4.7 ± 0.6	88.8 ± 6.0	13.7 ± 3.3
	Sep. 1	404.5 ± 67.7	10.9 ± 1.4	4.3 ± 0.8	72.3 ± 4.5	9.9 ± 1.8
	Sep. 2	656.1 ± 207.5	8.7 ± 0.9	3.6 ± 0.7	72.4 ± 6.7	8.8 ± 2.9
Concentrate		188.5 ± 10.7	250.3 ± 17.8	38.2 ± 4.5	74.1 ± 3.5	
Pasture	**Month***	**Macro minerals**				**Botanical composition**
		Ca	**Mg**	**Na**	**K**	
		g·100 g^{-1} dry weight				**% Dry matter**
Trifolium pratense	Jul. 1	0.61 ± 0.01	0.25 ± 0.01	0.17 ± 0.01	2.45 ± 0.02	15.4 ± 5.2
	Jul. 2	0.74 ± 0.04	0.27 ± 0.02	0.10 ± 0.01	2.44 ± 0.08	27.5 ± 3.4
	Sep. 1	0.85 ± 0.01	0.26 ± 0.01	0.45 ± 0.01	2.43 ± 0.06	50.6 ± 5.7
	Sep. 2	1.01 ± 0.01	0.30 ± 0.01	0.35 ± 0.01	1.58 ± 0.08	45.9 ± 8.6
Cichorium intybus	Jul. 1	0.72 ± 0.03	0.24 ± 0.01	0.30 ± 0.02	4.12 ± 0.23	65.7 ± 3.3
	Jul. 2	0.63 ± 0.07	0.21 ± 0.02	0.24 ± 0.02	4.18 ± 0.30	53.9 ± 6.8
	Sep. 1	0.90 ± 0.06	0.25 ± 0.02	0.56 ± 0.02	2.28 ± 0.09	36.3 ± 3.5
	Sep. 2	0.97 ± 0.02	0.29 ± 0.00	0.99 ± 0.11	2.43 ± 0.26	38.8 ± 7.7
Lolium multiflorum	Jul. 1	0.40 ± 0.01	0.19 ± 0.01	0.29 ± 0.01	2.92 ± 0.09	16.8 ± 3.3
	Jul. 2	0.41 ± 0.01	0.18 ± 0.01	0.27 ± 0.01	2.74 ± 0.10	13.7 ± 3.3
	Sep. 1	0.44 ± 0.01	0.19 ± 0.01	0.30 ± 0.01	2.85 ± 0.09	9.9 ± 1.8
	Sep. 2	0.44 ± 0.02	0.21 ± 0.02	0.48 ± 0.03	2.51 ± 0.15	8.8 ± 2.9
Concentrate		0.92 ± 0.08	0.62 ± 0.01	0.41 ± 0.02	1.37 ± 0.10	

Data represent mean ± standard error (SEM) of n=3 for each date of sampling or for concentrate. July and September 1 and 2 represents the initial and final dates for sampling during the fattening period of pigs in Outdoor production system report many different levels of grass consumption, depending on the type of grass, the level of concentrate supply, the breed of pig and the weight of the animals. The PRp breed generally presents a high consumption of pastures based on LW.

Iron forms

Rearing system impact the iron forms particularly the bioavailable iron content, heme iron, and the ratio heme iron/total iron, as shown in FIGS. 1 and 2, but no effect on the total iron and non-heme iron. Indeed, a higher content of heme iron in meat come from O with pasture rearing system related to I (P<0.04). The iron forms contents were no affected by the sex of pigs.

An interesting muscle effect show a differential content for total iron when all muscles were studied. The LD muscle showed lower total iron content (P<0.001) related the other muscles studied and also a lower hem iron (P<0.001; 2.50 and 2.07 $mg \cdot kg^{-1}$ raw meat in O and I FIG. 1).

In addition, LD iron content was higher in pigs reared I (4.71 vs. 3.97 $mg \cdot kg^{-1}$ raw meat). QF muscle showed the highest values of heme iron in both systems (8.08 and 6.50 $mg \cdot kg^{-1}$ raw meat in O and I, respectively). No differences were observed between systems, muscles or sex, for non-heme iron content (FIG. 2). Non-heme iron content differed only in BF muscle, and was higher in I pig meat than O pig meat (3.64 vs. 1.27 $mg \cdot kg^{-1}$ raw meat). The average values for non-heme iron content were 2.05, 2.47, and 2.53 $mg \cdot kg^{-1}$ of raw meat from LD, PM, and ham muscles, respectively. Finally, the Fe Heme/Fe Total ratio was higher in O pigs (P<0.02), and no differences were observed between muscles nor sex (FIG. 2).

Iron forms, as total iron and heme iron in meat depends on many factors as breed, muscle type, age at slaughter [4]. Previous works [21] have showed that quantity and chemical form of the myoglobin, the main heme pigment could influence the differences in the amount of heme iron in muscles. The more oxidative muscles, as PM, QF and the other ham muscles in the present work, has a high content of iron related to high content of myoglobin securing the anaerobic conditions and this is maximized with the animals physical activity [5, 34], as in the O with pasture system studied here (FIGS. 1 and 2). Comparing meats, pig meat is lower in total and heme iron related to beef meat, but this increased heme iron content observed in meat came from O is an added value for this local breed, particularly for the children nutrition. PRp meat contributes about 0.4–1.0 mg of total Fe with a portion of 100 g, contributing with a 5-15% of the dietary reference values for children [18]. By other side, a lower iron content in this pig meat compared to beef meat is also more indicate for adults to avoid the negative effects associated to high iron content [17]. Data about iron forms content reported by other authors vary greatly in local and commercial breeds [10, 31, 38, 40]. Genetic factors and experimental conditions (system, diet) and muscles studied could explain these differences [4, 34, 38].

Macro minerals: Ca, Mg, Na and K

For high value muscle as LD and PM, no differences were observed between systems or muscles in the contents of Ca, Mg, K (TABLE IV). The Na content being similar in both systems, and it was different between the LD and PM muscles, being higher in the latter (212.7 vs. 253.3 $mg \cdot kg^{-1}$ of raw meat). The Ca content was similar in both muscles studied, and stood at 42.36 $mg \cdot kg^{-1}$ of raw meat. On the other hand, Mg content was 257.8 $mg \cdot kg^{-1}$, on average, for raw meat from the LD and PM, but female has significantly more content of Mg (P<0.05). Additionally, average K content was 3527 $mg \cdot kg^{-1}$ of raw meat from these muscles. In previous work [10] have reported high Mg contents in the LD muscle but no details about sex was furnished.

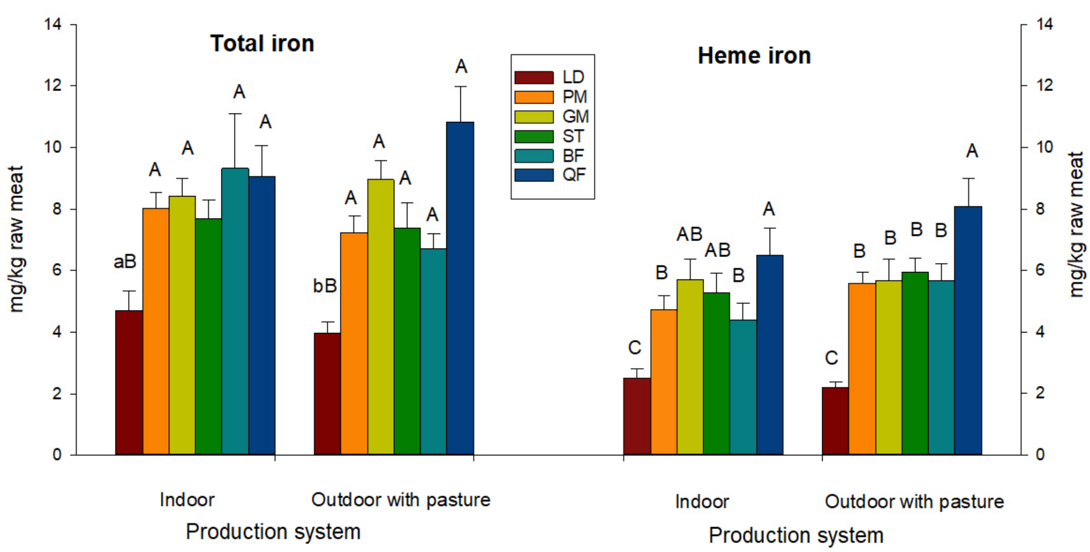

FIGURE 1. Iron forms as total iron and heme iron content in *Longissimus dorsi* (LD), *Psoas major* (PM), *Gluteus medius* (GM), *Semitendinosus* (ST), *Biceps femoral* (BF), and *Quadriceps femoris* (QF) muscles from Pampa Rocha pigs (f and males) reared on Indoor or Outdoor production system. Data are mean ± SEM of n=11–12. Values followed by different lowercase letters indicate significant differences between production systems for each muscle. Values followed by different uppercase letters indicate significant differences between muscles for each production system

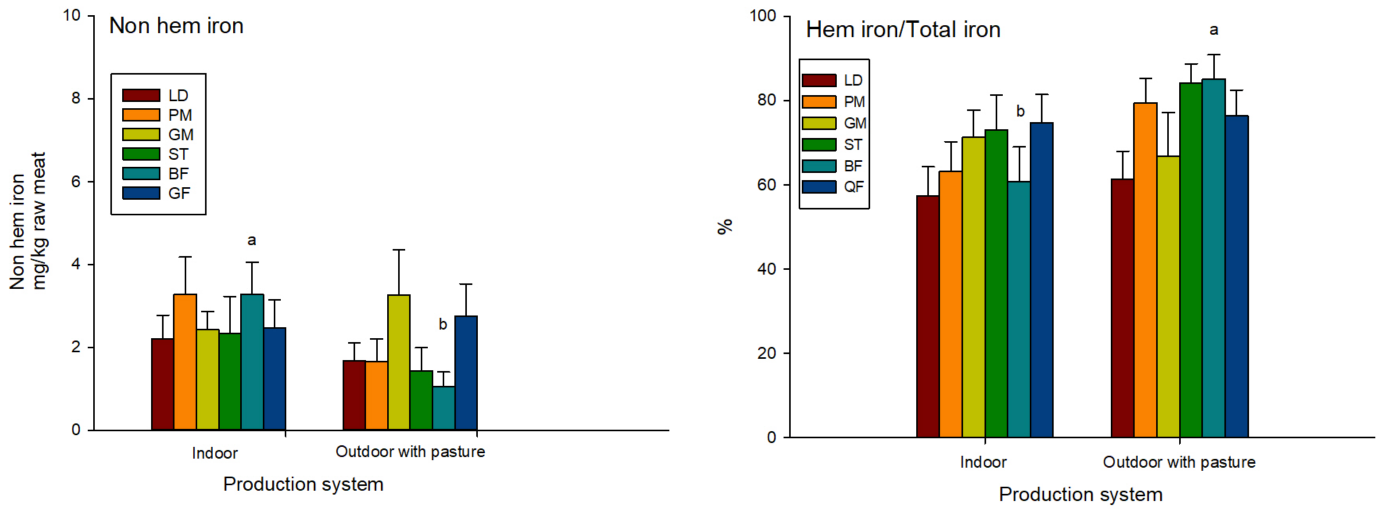

FIGURE 2. Non-heme iron and % of heme iron/total iron contents in *Longissimus dorsi* (LD), *Psoas major* (PM), *Gluteus medius* (GM), *Semitendinosus* (ST), *Biceps femoral* (BF), and *Quadriceps femoris* (QF) muscles from Pampa Rocha pigs reared on Indoor or Outdoor with pasture. Data are mean ± SEM of n=11–12. Values followed by different lowercase letters indicate significant differences between production systems for muscle

TABLE IV
Trace element and macro mineral contents in *Longissimus dorsi* (LD) and *Psoas major* (PM) muscles from Pampa Rocha pigs finished in indoor or outdoor with pasture

Items mg·kg^{-1} raw meat	Production system				System	Muscle	Sex
	Indoor		Outdoor with pasture				
	Muscle						
	LD	PM	LD	PM			
Zn	11.78 ± 0.82	20.38 ± 2.13	10.68 ± 0.33	20.49 ± 1.79	ns	*P*=0.001 PM>LD	ns
Cu	1.59 ± 0.13	1.79 ± 0.12	1.43 ± 0.18	1.58 ± 0.21	ns	ns	ns
Mn	1.57 ± 0.27	1.37 ± 0.15	0.94 ± 0.31	1.12 ± 0.11	ns	ns	ns
Ca	44.83 ± 4.60	43.13 ± 4.91	44.24 ± 2.20	44.02 ± 2.41	ns	ns	ns
Mg	267.56 ± 14.98	254.26 ± 5.92	258.09 ± 7.43	250.96 ± 4.02	ns	ns	*P*=0.026 (f>m)
Na	225.47 ± 13.08	255.79 ± 15.17	199.90 ± 8.51	250.86 ± 10.25	ns	*P*=0.002 PM>LD	ns
K	3642.00 ± 238.00	3432.00 ± 96.00	3573.00 ± 108.00	3466.00 ± 81.00	ns	ns	ns

Data are mean ± SEM of n=11–12. The main effects were analysed by ANOVA with GLM procedure and the Tukey–Kramer test for system, muscles and sex ($P<0.05$). f: female, m: male. ns: no significance

For ham muscles (TABLE V), differences between systems or muscles not were observed for macro minerals content. The average content was 41.38, 219.28, 283.74 and 3724 mg·kg^{-1} raw meat, for Ca, Mg, Na and K, respectively. It is necessaire to consider that these muscles are industrialized together for consume.

Trace minerals: Zn, Cu, Mn

For Zn, Cu and Mn no effect of system or sex were obtained (TABLE IV) but difference between muscles in PM and LD for Zn content was significantly ($P<0.05$), 20.43 and 11.23 mg·kg^{-1} raw meat, respectively for the I and O systems. For these muscles, the average content of Mn was 0.062 mg·kg^{-1} of fresh meat for LD and PM. Several authors have reported higher values for Mn content in pig meat in commercial pig breeds from intensive system [39] and pork available at markets [3].

For the muscles that made up the ham, no differences were observed between production systems for trace elements content. Only Mn content was different between male and female (0.036 vs. 0.030 mg·kg^{-1} raw meat for male and female respectively). Nicolik *et al*. [27] observed 15.8 and 15.2 mg·kg^{-1} Zn contents in ham and loin, respectively, from commercial pigs. Regarding the content of Cu, the average content was 1.51, 1.68, and 1.03 mg·kg^{-1} of meat from LD, PM, and ham muscles, respectively. This content is high compared to Figures reported in other works [3, 27, 39]. Nicolik *et al*. [27] reported a lower Cu content, and that represents about 30–40% of that observed in this experiment. By other side, Cu content was similar to that reported in Iberian pigs in LD and BF muscles [31]. Cheng *et al*. [10] evaluated mineral content in LD muscle in commercial breeds, and their study reports lower Zn and Cu contents and higher Mn contents than the GM muscle from PRp.

TABLE V
Trace element and macro mineral contents in *Gluteus medius* (GM), *Semitendinosus* (ST), *Biceps femoral* (BF), and *Quadriceps femoris* (QF) muscles from Pampa Rocha pigs finished in indoor or outdoor with pasture

Items mg·kg^{-1} raw meat	Indoor			
	Muscle			
	GM	ST	BF	QF
Zn	25.54 ± 2.86	25.71 ± 1.94	21.09 ± 3.15	24.16 ± 3.09
Cu	0.95 ± 0.10	0.96 ± 0.07	0.96 ± 0.08	0.99 ± 0.11
Mn*	0.035 ± 0.005	0.030 ± 0.003	0.031 ± 0.004	0.031 ± 0.004
Ca	41.16 ± 1.71	46.79 ± 4.62	43.52 ± 6.23	42.47 ± 3.89
Mg	198.44 ± 19.66	228.99 ± 14.94	202.19 ± 21.18	237.32 ± 12.49
Na	294.61 ± 30.08	331.60 ± 28.10	256.96 ± 13.58	294.58 ± 20.20
K	2939.00 ± 345.00	4137.00 ± 471.00	3083.00 ± 383.00	4031.00 ± 392.00
Items mg·kg^{-1} raw meat	**Outdoor with pasture**			
	Muscle			
	GM	**ST**	**BF**	**QF**
Zn	28.79 ± 1.84	20.97 ± 2.50	20.46 ± 2.73	32.62 ± 4.95
Cu	1.21 ± 0.10	1.00 ± 0.09	0.96 ± 0.11	1.21 ± 0.11
Mn*	0.039 ± 0.003	0.029 ± 0.002	0.034 ± 0.003	0.039 ± 0.004
Ca	42.23 ± 5.28	37.72 ± 4.02	39.03 ± 2.57	39.14 ± 3.90
Mg	222.12 ± 16.82	211.42 ± 12.24	216.69 ± 10.31	230.44 ± 9.90
Na	335.39 ± 22.93	249.93 ± 15.38	265.29 ± 19.87	268.05 ± 20.39
K	3718.00 ± 368.00	3945.00 ± 310.00	3545.00 ± 305.00	4071.00 ± 300.00

Data are mean ± SEM of n=11–12. The main effects were analysed by ANOVA with GLM procedure and the Tukey–Kramer test for production system, muscle type and sex (P<0.05). f: female, m: male. ns: no significance. Mn*: P=0.042; m>f; Interactions ns

The importance of PRp meat for people studied here is appreciable trough the contribution of this meat with the demands for human nutrition. Indeed, 100 g of PRp meat could contribute important amounts of minerals: 1.1–3.3 mg Zn, 0.1–0.2 mg Cu, 4.0–4.5 mg Ca, 19.8–26.8 mg Mg, 20.0–33.5 mg Na, 343–414 mg K, and 0.4–1.1 mg Fe. Considering the needs of children between 1 and 3 years old, 100 g of PRp meat represents about 100% of their required Zn and 20% of their required Cu, Mg, and K. A lack of micronutrients such as trace elements, iron, and zinc is prevalent in many countries [23] and this knowledge contributes to support the strategies food based to eliminate anaemia affecting preschool children. It is difficult to make a correct comparison and to generalize regarding the mineral content between the PRp and other breeds, because although there are many reports, the environment, feeding, breeds, age and handling are different.

Considering all the minerals elements determined in this study, the PRp produced I and O showed interesting levels of mineral contribution to human nutrition. For iron, a particular interest is offered by rearing in the O and this add a particular value to this animal protein in a friendly system for the consumers. In a study carried out by various institutions on the nutritional contribution of chicken (*Gallus gallus domesticus*) and pork meat produced in Uruguay, some mineral content in meat in different muscles from various industries was determined [7]. The contents (mg·100g^{-1}) of Fe, Zn, Na, Mg and K found were the following: <0.75, 1.45, 39, 25, and 398 in LD; 1.08, 1.88, 47, 26, and 410 in PM; and 0.89, 1.86, 45, 25, and 390 in ham. According to results obtained in this work, meat from PRp, produced in two alternative system, O with pastures and I on deep bed, presents a mineral content similar to meat offered in national market from commercial breeds. Regards to pasture consumption effect on mineral content, this not was observed, but the effect to physic activity could explain de major Fe Heme in meat produced in the O system.

Meat produced in O with pastures is healthier, since the FeHeme/FeTotal is higher, being a good way to promote and add nutritional value to this local breed, considering its importance for prevent the iron deficiency anaemia (DA). The consequences of DA, especially in children under 5 years of age, include poor immune function and response to vaccination, and moderate DA is associated with depressed neurodevelopment and impaired cognitive and academic performances [11]. In addition, the Myristic, Palmitic and Arachidonic acids, with atherogenic effects, are presents in significantly lower percentages in PRp meat [24]. These characteristics added to adequate sodium and potassium content in this meat, particularly in LD muscle, are very important from prevent cardiovascular diseases and arterial hypertension [26, 36].

CONCLUSIONS

According to the results obtained, it is possible to produce PRp meat with interesting mineral contents, in two alternative systems to the classic confinement. This pig, due to its native breed characteristics, is more adapted to the O system, in which it produces healthier meat, also improving the conversion efficiency of the concentrate. In the deep bed system made it possible to obtain animals for slaughter in less time without affecting the characteristics of the carcass, for example, the thickness of the back fat. It could be interesting to exploit some differences found between muscles, which are normally consumed as fresh meat. Particularly the PM that presented higher contents of Zn and Na. These results show that the characteristics of the mineral content in the muscles of PRp are adapted to the different demands of human nutrition and also rearing in O systems that include pastures is a good way to promote and add nutritional value to this local breed, in addition with others characteristics of PRp meat.

ACKNOWLEDGEMENTS

This research was a part of a doctoral thesis in the Doctoral Program in Agricultural Sciences of the Agronomy Faculty. Experiments were carried at the South Regional Center and Food and Product Quality Laboratory (Faculty of Agronomy) and the Physiology Laboratory (Faculty of Sciences). We are grateful to the National Agency for the Research and Innovation (ANII) and the Graduate Academic Commission (CAP) for the support to carry out this research with a grant to the first author for the development of the doctoral thesis project. We also want to thank to Sector Commission for Scientific Research (CSIC-Udelar) which financed the experiments and laboratory analysis.

CONFLICT OF INTEREST

We have no conflict of interest to declare.

BIBLIOGRAPHICS REFERENCES

[1] ARAÚJO, J.P.; CERQUEIRA, J.L.; PIRES, P.; AMORIN, I.; CARNEIRO, M.; SANTOS-SILVA, J.; DOMÍNGUEZ, R.; BERMÚDEZ, R.; LORENZO, J.M. Influencia del sistema de producción en la calidad de la canal de cerdos de raza Bísara. **Arch. Zoot.** 67(260): 554–559. 2018. https://doi.org/h52z.

[2] BABICZ, M.; KASPRZYK, A. Comparative analysis of the mineral composition in the meat of wild boar and domestic pig. **Ital. J. Anim. Sci.** 18(1): 1013–1020. 2019. https://doi.org/h522.

[3] BILANDŽIĆ, N.; SEDAK, M.; ČALOPEK, B.; ĐOKIĆ, M.; VARENINA, I.; SOLOMUN-KOLANOVIĆ, B.; BOŽIĆ-LUBURIĆ, Đ.; VARGA, I.; RONCARATI, A. Evaluation of element concentrations in beef and pork meat cuts available to the population in the Croatian capital. **Foods**. 9(12): 1861. 2020. https://doi.org/gpmr53.

[4] CABRERA, M. C.; RAMOS, A.; SAADOUN, A.; BRITO, G. Selenium, copper, zinc, iron and manganese content of seven meat cuts from Hereford and Braford steers fed pasture in Uruguay. **Meat Sci.** 84(3): 518–528. 2010. https://doi.org/crnm26.

[5] CABRERA, M. C.; TEREVINTO, A.; ZÁCCARI, F.; FELICE, A.; SAADOUN, A. Micronutrients of beef meat from pasture and concentrated based production systems. **Proceeding 63 International Congress of Meat Science and Technology**. Cork, 08/13-18-17, Ireland. Pp 301–302. 2017.

[6] CAPET, A.; MARIN, D.; PETROMAN, C. Patterns of consumer behaviour of swine meat and meat products. **Lucr. Ştiinţ. Manag. Agricol.** 23(3): 31–35. 2021.

[7] CAPRA, G.; SALLE, L.; MARTÍNEZ, R.; COZZANO, S.; MÁRQUEZ, R.; LUZARDO, S.; COSTAS, G.; BRITO, G.; DE SOUZA, G.; NARDO, D. Valor nutritivo de las carnes de cerdo y pollo producidas en Uruguay. 2017. Universidad Católica del Uruguay (UCU), Instituto Nacional de Investigación Agropecuaria (INIA), Instituto Nacional de Carnes (INAC), Laboratorio Tecnológico del Uruguay (LATU). En línea: https://bit.ly/3RW8lEa. 02/02/2022.

[8] CARBALLO, C. Evaluación de tres biotipos de cerdos en la etapa de posdestete-recría en un sistema pastoril. Universidad de la República (Uruguay). Facultad de Agronomía. Tesis de Grado. 49 pp. 2009. En línea: https://bit.ly/3cwSVpz. 02/02/2022

[9] CARBALLO, C.; TEREVINTO, A.; BARLOCCO, N.; SAADOUN, A.; CABRERA, M.C. pH, drip loss, colour, lipids and protein oxidation of meat from Pampa Rocha and crossbreed pigs produced outdoor in Uruguay. **J. Food Nutr. Res.** 5(5): 342–346. 2017. https://bit.ly/3cA7Clv.

[10] CHENG, Y.F.; CHEN, Y.P.; DU, M.F.; WEN, C.; ZHOU, Y.M. Evaluation of dietary symbiotic supplementation on growth performance, muscle antioxidant ability and mineral accumulations, and meat quality in late-finishing pigs. **Kafkas Üniv. Vet. Fak. Derg.** 24(5): 673–679. 2018. https://doi.org/h523.

[11] CHOURAQUI, J.P. Dietary approaches to iron deficiency prevention in childhood–A Critical public health issue. **Nutr.** 14: 1604. 2022. https://doi.org/h524.

[12] CRUZ, E.; ALMAGUEL, R.E.; MEDEROS, C.M.; GONZÁLEZ-ARAUJO, C. Sistema de cama profunda en la producción porcina a pequeña escala. **Rev. Cientif. FCV-LUZ.** XIX(5): 495–499. 2009. https://bit.ly/3PSjRym.

[13] DANG, H.D; THANH-TRAN, G. Explaining consumers´ intention for traceable pork regarding animal disease: The role of food safety concern, risk perception, trust and habit. **Int. J. Food Sci.** 2020: e8831356. 2020. https://doi.org/h525.

[14] FOOD AND AGRICULTURE ORGANIZATIO (FAO). Domestic Animal Diversity Information System (DAD-IS). 2022. On Line: https://bit.ly/3cG2jHm. 12/01/2020.

[15] GARIBALDI, L.; ANDERSON, G.; FERNÁNDEZ-FERRARI, C.; PÉREZ-MÉNDEZ, N. Seguridad alimentaria, medio ambiente y nuestros hábitos de consumo. **Ecol. Austral.** 28(3): 572–580. 2018.

[16] HORNSEY, H. The colour of cooked cured pork. I. –Estimation of the Nitric oxide– Haem Pigments. **J. Sci. Food Agric.** 7(8): 534–540. 1956. https://doi.org/d4xxvz.

[17] HSU, M.Y.; MINA, E.; ROETTO, A.; PORPORATO, P.E. Iron: an essential element of cancer metabolism. **Cells.** 9(12): 2591. 2020. https://doi.org/gnnm5h.

[18] HURRELL, R.; EGLI, I. Iron bioavailability and dietary reference values. **Am. J. Clin. Nutr.** 91(5): e1461S–1467S. 2010.

[19] JAKOBSEN, M.; KONGSTED, A; HERMANSEN, J. Foraging behaviour, nutrient intake from pasture and performance of free-range growing pigs in relation to feed CP level in two organic cropping systems. **Anim.** 9(12): 2006–2016. 2015. https://doi.org/f72mhd.

[20] JUSKA, R.; JUSKIENE, V.; LEIKUS, R. The influence of a free-range housing system on pig growth, carcass composition and meat quality. **J. Appl. Anim. Res.** 41(1): 39–47. 2013. https://doi.org/h526.

[21] LAWRIE, R.A.; LEDWARD, D.A. The conversion of muscle to meat. In: **Lawrie's Meat Sci.** 7th. Ed. Lawrie, R.A. (Ed.). Woodhead Publishing: Cambridge, UK. Pp 128–156. 2006.

[22] LEN, N.T.; LINDBERG, J.E; OGLE, B. Effect of dietary fiber level on the performance and carcass traits of Mon Cai; F1 Crossbred (Mon Cai x Yorkshire) and Landrace x Yorkshire pigs. **Asian-Australas J. Anim. Sci. V.** 21(2): 245–251. 2008. https://doi.org/h527.

[23] MARTÍNEZ-VILLEGAS, O.; BAPTISTA-GONZÁLEZ, H.A. Anemia por deficiencia de hierro en niños: un problema de salud nacional. **Rev. Hematol.** 20(2): 96–105. 2019. https://doi.org/h528.

[24] MERNIES, B.; CARBALLO, C.; CABRERA, C.; BARLOCCO, N.; SAADOUN, A. Ácidos grasos del músculo *Longissimus dorsi* de cerdos Pampa–Rocha y cruzas con Duroc y Large White. **Resúmenes IV Congreso de la Asociación Uruguaya de Producción Animal. Veterinaria.** Montevideo. 10/29-30. Uruguay: Pp 123. 2012.

[25] MOLITERNO, E. Estimación visual de la disponibilidad de forraje en pasturas. (I) Principios y usos de un método de doble muestreo. Nota técnica. **Rev. Cangüé.** 9: 32–36. 1997.

[26] NELSON, J.R.; RASKIN, S. The eicosapentaenoic acid:arachidonic acid ratio and its clinical utility in cardiovascular disease. **Postg. Med.** 131(4): 268-277. 2019. https://doi.org/h529.

[27] NICOLIK, D.; DJINOVIC-STOJANOVICA, J.; JANKOVICA, S.; STEFANOVICA, S.; RADICEVICA, T.; PETROVICA, Z.; LAUSEVICB, M. Comparison of essential metals in different pork meat cuts from the Serbian market. **Procedia Food Sci.** 5: 211–214. 2015. https://doi.org/h53b.

[28] NYACHOTI, C.M.; ZIJLSTRA, R.T.; DE LANGE, C.F.; PATIENCE, J.F. Voluntary feed intake in growing-finishing pigs: a review of the main determining factors and potential approaches for accurate predictions. **Can. J. Anim. Sci.** 84(4): 549–566. 2004. https://doi.org/dznhts.

[29] ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT–FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (OECD-FAO). 2020. On Line: https://doi.org/gmwsc7. Agricultural Outlook 2020–2029. OECD Publishing: Paris, France; Rome, Italy. 04/01/2022.

[30] OFICINA DE PROGRAMACIÓN Y POLÍTICA AGROPECUARIA–MINISTERIO DE GANADERÍA AGRICULTURA Y PESCA (OPYPA-MGAP). 2020. Anuario 2019. Publishing: Montevideo, Uruguay. On Line: https://bit.ly/3IZM5VU. 12/09/2021.

[31] PALMA-GRANADOS, P.; HARO, A.; NIETO, R.; LARA, L.; AGUILERA, J.F.; SEIQUER, I. Diferencias en el contenido muscular de hierro, cobre y cinc entre dos genotipos porcinos: Ibérico y Landrace x Large White. **AIDA XVI Jornadas sobre Producción Animal**; Zaragoza, 05/19-20, Spain. Pp 323–325. 2015.

[32] PUGLIESE, C.; MADONIA, G.; CHIOFALO, V.; MARGIOTTA, S.; ACCIAIOLI, A.; GANDINI, G. Comparison of the performances of Nero Siciliano pigs reared indoors and outdoors. 1. Growth and carcass composition. **Meat Sci.** 65(2): 825–831. 2003. https://doi.org/dxnvpf.

[33] RAMOS, A.; CABRERA, M.C.; ASTIGARRAGA, L.; SAADOUN, A. Variaciones estacionales del contenido de Ca, P, Mg, S, Fe, Zn y Cu de Alfalfa, Trébol rojo y Lotus y de su bioaccesibilidad por un método rápido in vitro. **XX Reunión Asociación Latinoamerica de Producción Animal.** Cusco, 10/22-25, Perú. Pp 1–6. 2007.

[34] RAMOS, A.; CABRERA, M.C.; SAADOUN, A. Bioaccessibility of Se, Cu, Zn, Mn and Fe, and hem iron content in unaged and aged meat of Hereford and Braford steers fed pasture. **Meat Sci.** 91(2): 116–124. 2012. https://doi.org/fzqndm.

[35] RIVERO, M.J.; RODRIGUEZ-ESTEVEZ, V.; PIETROSEMOLI, S.; CARBALLO, C.; COOKE, A.S; KONGSTED, A.G. Forage consumption and its effects on performance of growing swine–discussed in relation to European wild boar (*Sus scrofa* L.) in semi-extensive systems: A review. **Anim.** 9(7): 457. 2019. https://doi.org/h53c.

[36] SERGEEV, V.N.; NIKIFOROVA T.I.; MUSAEVA O.M.; DYDYKIN A.S.; ZOKHRABYAN P.R. Substantiation of the use of meat-based specialized products in nutrition of patients with arterial hypertension. **Adv. Heal. Scie. Res.** 28: 50–53. 2020.

[37] TEREVINTO, A.; SAADOUN, A.; CABRERA, M.C. From the fatty acid content perspective, is it healthier to eat a hindquarter or a forequarter cut? Angus steers in pasture or concentrate systems. **CyTA J. Food.** 18(1): 698–703. 2020. https://doi.org/h53d.

[38] TOMOVIC, V.; BRANISLAV, S.; JOKANOVIC, M.; SKALJAC, S.; IVIC, M.; TOMOVIC, M.; TOMASEVIC, I.; STAJIC, S.; MARTINOVIC, A. Mineral contents in pork and edible offal from indigenous pigs. **J. Eng. Process. Manag.** 11(1): 66–72. 2019. https://doi.org/h53f.

[39] UNTEA, A.E.; PANAITE, T.D.; SARACILA, M.; SOICA, C. Effects of dietary symbiotics and organic zinc on trace minerals composition of pork. **Sci. Papers Ser. D. Anim. Sci.** 60: 118–122. 2017. https://bit.ly/3ot1550.

[40] ZHAO, Y.; SHUMING-YANG, D. Effect of organic and conventional rearing system on the mineral content of pork. **Meat Sci.** 118: 103–107. 2016. https://doi.org/f8xqfb.