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Quality parameters in *L. thoracis*, and *P. major* from Pampa Rocha pig reared in indoor or outdoor

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SUMMARY

Local pig breeds have excellent characteristics of adaptation to the local environment. These qualities are exploited in outdoor production systems (O), with lower-cost facilities and the use of alternative foods to expensive concentrates. Fresh and aged *Longissimus thoracis* (LT) and *Psoas major* (PM) muscles from Pampa Rocha pig (local breed from Uruguay), reared indoors (I) with straw litter, or O with pastures, were studied. The *post mortem* pH kinetic was higher in meat from I than in the O system, and in LT than in PM. This difference remains in meat aged with an inverse effect on muscles. Drip loss was greater in the O system in fresh and aged meat. Lipid and protein oxidation and glycogen and lactate kinetics were not affected by the production system, but PM muscle showed more oxidation than LT. Fresh meat from O pigs was darker and the n6/n3 ratio was better than in the I system. The fatty acid profile is adequate for human nutrition in this local pork meat, independently of the production system, however, the type of muscle marked significant differences for fatty acids and health indices. This meat presents quality attributes for human health and technological purposes.

Palabras Clave
Carne de cerdo.
Calidad de la carne.
Raza local.
Oxidación de lípidos y proteínas.
Sistema alternativo.

Parámetros de calidad en *L. thoracis* y *P. major* de cerdos de Pampa Rocha criados en interior o exterior.

RESUMEN

Las razas locales de cerdos tienen excelentes características de adaptación al ambiente local, las que son aprovechadas en sistemas de producción al aire libre (O), que incluyen instalaciones de bajo costo y uso de alimentos alternativos a los costosos concentrados comerciales. Se estudiaron los músculos *Longissimus thoracis* (LT) y *Psoas major* (PM), frescos y madurados, de cerdos Pampa Rocha (raza local de Uruguay), criados en sistema de confinado de cama profunda (I) o al aire libre con pasturas (O). El pH *post mortem* medido como cinética, fue mayor en carne del sistema I que de O, y mayor en el LT que en PM. Estas diferencias se mantienen en carne madurada con un efecto inverso de los músculos. La pérdida por goteo fue mayor en O en carne fresca como en madurada. La oxidación lipídica y proteica, así como la cinética de glucógeno y lactato no fueron afectadas por el sistema de producción. El músculo PM mostró mayor oxidación que el LT. La carne fresca producida en O fue más oscura, y la relación n6/n3 fue mejor en carne producida en I. El perfil de ácidos grasos de la carne de este cerdo local es adecuado para la nutrición humana, independientemente del sistema. Sin embargo, el tipo de músculo marca diferencias tanto en el contenido de ácidos grasos como en los índices de salud. Esta carne presenta atributos deseables tanto para la salud humana como también condiciones para su procesamiento tecnológico.

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INTRODUCTION

Global pig meat consumption is projected to increase over the next ten years and account for 28% of the total increase in meat consumption (OECD-FAO 2020). Growth rates are sustained in most of Latin America, where *per capita* pig meat consumption has grown rapidly, backed by favourable relative prices that have positioned pork as one of the favourite meats (OECD-FAO 2020). Even in many developing countries, whose *per capita* consumption of pig meat is half of that of developed countries, an increase over the next years is expected (OECD-FAO 2020).

Pork contributes to the protein balance in children, gestating and lactating women, and elders (Dugan et

al. 2015) and it is one of the highest sources of functional compounds such as taurine (Wójcik *et al*. 2010). This meat is a valuable source of amino acids, lipids, minerals, and vitamins and fits the requirements of most people (Dugan *et al*. 2015). However, changes in the composition of the population influence the preference for healthy diets and pig meat is sometimes perceived as a less healthy food mainly due to a lack of knowledge on the fat composition and the possibility to improve it by feed manipulation (Wood *et al*. 2008). Although the new recommendations for fat animal intake and the impact on the cardio vascular diseases are available (Chowdhury *et al*. 2014), it is not always perceived by the common population. In addition to the health concerns, consumers in demanding markets pay for attributes of quality, differentiation, and brands, assuming that they are safe for consumption (Schleenbecker and Hamm 2013). It is increasing around the world, in young people, and in this scenario, animal well-being, environment, nutritional and functional characteristics of meat concerns (Bava *et al*. 2017, Clark *et al*. 2017, Verbeke *et al*. 2010, Honeyman 2005).

The high demand for pig meat is mainly supplied by the conventional intensive pig production systems (Robinson *et al*. 2014), however, alternative systems including pastures or hoop structures including bedded straw for small or middle-scale farms are increasing around the world. This is not only because of the reduced cost but also driven by the preference of consumers in eating animal protein coming from friendly systems, for animal well-being and with a less negative impact on the environment (Honeyman 2005). Small farmers around the world, who cannot afford the costs of intensive systems, find in these consumers a niche market to supply through alternative production systems (Dawkins 2017, Kapel 2005).

Some countries promote conservation policies of these traditional systems, associating them in addition to conservation of adapted local genetic resources (Kallas *et al*. 2019). These last challenges are positive for pig production and could contribute to the sustainability of the family in the small and middle-scale system and also with sustainable nutrition. Local pig breeds are generally characterized by having a pigmented coat, with greater fatness, lower weight gain, worse conversion efficiency, and lower prolificacy than the genetic types currently used in commercial pig production systems (Gan *et al* 2020). However, these have excellent characteristics of adaptation to the local environment due to the natural selection process they have gone through (González *et al*. 2013, Keambou *et al*. 2010). These qualities are exploited in outdoor production systems, with lower cost facilities and the use of alternative foods to expensive concentrates (Kambashi *et al*. 2014), associated with the possibility for these small-scale producers to sell the production mostly in the local market (Herold *et al*. 2010). There are examples in which this genotype-environment association has resulted in a high-value product that has managed to access a different commercial circuit, Iberian ham is mentioned as a well-known example worldwide (Amaya and Aguilar 2012).

A particular characteristic of local pig breeds is that they are more highly adapted to their local environment conditions, like shortages in food availability and repetitive seasonal cycles of fasting. After a period of food shortages, they can accumulate large amounts of body fat when food is more readily available (Switonski *et al*. 2010). Research conducted by Apple *et al*. (2009) and Tarricone *et al*. (2019) show a polyunsaturated fatty acid/saturated fatty acid (PUFA/SFA) ratio of 0.21 and 0.29, respectively, in the *Longissimus dorsi* of pigs finished with a diet based on corn, soybean meal, and barley. When foods rich in PUFA were included, such as soybean oil, this relationship improved in both studies, 0.36 and 0.70, respectively (Tarricone *et al.* 2019, Apple *et al*. 2009). The n3 content in meat is also modified when extruded flaxseed is included in the diet of finished pigs, and the n-6/n-3 ratio improves. These authors report an n-6/n-3 ratio of 9.35 and 3.55 in diets without and with extruded flaxseed in *Longissimus dorsi* of Nero Lucano pigs (Tarricone *et al*. 2019).

Outdoor systems including pastures are an opportunity for countries accounting for available surface (Lebret 2008) and small and middle-scale farmers, with poor development facilities (Durán *et al*. 2020), and could satisfy the new demands with a valued product. Concerning the local breed, previous studies have shown genetic aspects (Burgos-Serrano *et al*. 2019), and technological and nutritional characteristics in the meat of the Pampa Rocha pig breed (Montenegro *et al*. 2019, Carballo *et al*. 2017, Mernies et al. 2012) associated with an enriched environment with pasture in an outdoor system. This breed is conserved in the facilities of the University and in some schools of agricultural technicians of the country to avoid a decrease in the population. Generating useful knowledge about meat quality and nutritional composition concerning fatty acids, of these local pigs reared on pastures, might generate strategies for the sustainability of this genetic resource.

The aim of this study was to evaluate the Pampa Rocha pig meat through technological traits, glycogen and lactate kinetics, oxidative status, fatty acid profile, and lipid health indices, utilizing animals reared in two different production systems, indoor and outdoor.

MATERIAL AND METHODS

Animals and experimental conditions

The experiment was conducted with the approval of the animal ethical committee of the Faculty of Agronomy (CEUA, protocol N° 317, file N° 021130-001003-16) depending on the Honorary Commission of Animal Experimentation (CHEA-Udelar, Uruguay). The experimental research, including the birth, rearing, and finishing of pigs was carried out in the facilities of South Regional Center (CRS, Faculty of Agronomy, UDELAR), Canelones (Uruguay). Twenty-three castrated male (n=13) and female (n=10) pigs from the Pampa Rocha breed, born in an outdoor system with pastures, were used in the study. The piglets were weaned at 45 days of age (14.5 ± 3.5 kg LW). Post-weaning, all piglets were housed for rearing in a bedded indoor with wheat straw litter and received a commercial piglet diet of

up to 22.78 ± 1.58 kg of live weight. Then, gradually for one week fattening ration was incorporated at a rate of 100% of the maximum voluntary intake (MVI). At 39.60 ± 2.80 kg of live weight, pigs were assigned randomly to two experimental treatments for finishing: a) continue on the bedded indoors with wheat straw litter (Indoor, I; 6 males and 5 females), an alternative no conventional confined system, on a surface of 50 cm of wheat straw (1.5 m^2 per animal), or b) on an outdoor system with access to pasture (Outdoor, O; 8 males and 4 females). In this free-range type system, pigs were reared outdoors, in field facilities, with permanent access to pastures. Pasture consisted of a mixture of *Cichorium intybus* (48.6 %, dry matter basis), *Trifolium pratense* (34.9 %, dry matter basis), *Lolium multiflorum* (12.3 %, dry matter basis), and other herbs (4.2 %, dry matter basis). The available grazing area was 300 m^2 per animal, with feeders, and automatic drinkers. In each system, pigs were slaughtered in two sessions to facilitate the transport conditions of the abattoir taking into account the welfare of animals in transporting (CHEA, Udelar). Animals, in both treatments, received a concentrate based on rice bran, defatted and whole, sorghum grain, corn grain, wheat grain, soybean meal, minerals, vitamins, and additives (**Table I**). The amount of feed offered was calculated according to live weight, at a rate of 100% of the maximum voluntary intake (MVI) I (Lebret, 2008). In the O system, a restriction of 15 % of MVI was implemented up to 67.50 ± 12.79 kg of live weight and subsequently a restriction of 25 % up the slaughter weight, as a way to encourage pasture consumption. The day before the slaughter, the pigs were weighed (final live weight, kg) and loaded into conditioned transport using loading facilities, and transported to a commercially agreed slaughterhouse at 10 km of distance from the Experimental Station of Faculty. Once there, pigs were laired for 8 hours with water *ad libitum*, and no food. The muscles LT (between the 10th and 12th ribs) and PM, which were chosen because they are commonly consumed as fresh meat, were removed from the carcasses immediately after sacrifice and transported in refrigerated isothermal boxes to the laboratory. Each refrigerated muscle (1-2°C) was immediately sampled for the different determinations. A sample of each one muscle was immediately frozen at -20°C (fresh). Another sample was packaged in a vacuum and stored at 1-2°C for seven days (aged) and subsequently stored at -20 °C until analysis. In the remaining whole muscle, depending on the parameters studied, measurements were carried out at 60 min, 90 min, 6 h, and 24 h *post mortem*.

Productive and carcass parameters

Individual live weight (kg) was registered every 14 days to calculate body gain (g/day) and to adjust the ration offered. Concentrate intake was estimated daily considering the residual amount of the previous day measured. At the slaughtering process, carcasses were individually identified and weighed, and yield was calculated and expressed in %. The average of the dorsal fat thickness was calculated by measuring three points of each LT sample with a caliber and expressed as mm. Concentrate intake/ live weight gain ratio (kg/kg) was calculated.

pH, drip loss, and color measurement

The pH was determined in LT and PM at 60 min, 90 min, 6 h, and 24 h *post mortem*, and in LT and PM muscles aged for seven days. A Lutron pHmeter (Lutron Electronic Enterprise, Taiwan) was used equipped with a spear tip pH electrode (PE04HD). Before use, the pHmeter was calibrated with pH 4.0 and 7.0 standards (Lutron), and then its probe was inserted deeply into the muscle tissue. Three readings were carried out for each sample. The drip loss was measured in LT and PM at 60 min and 24 h *post mortem* and in aged meat, following the method of Honikel (1998), based on the difference of weight between initial and final weight registered during a period of 24 hours. The color was expressed according to the Commission International de l'Eclairage system and reported as CIE L* (lightness), CIE a* (redness), and CIE b* (yellowness). Measures were taken at 24 hours *post mortem* and in aged LT and PM using a Konica Minolta CR-10 (Japan) colorimeter with D65 standard illuminant and observer angle of 8º. The L*, a*, and b* values were determined

Table I. Composition and nutrient level of concentrate (air-dry basis) (Composición y nivel de nutrientes del concentrado (secado al aire).

Ingredient %		Nutrient Content [1] %	
Rice bran,defatted	20.00	Dry matter %	90.23
Rice bran, whole	10.00	DE (Mcal/kg)	2.79
Sorghum grain, ground	25.00	Crude Protein	14.49
Corn grain, ground	15.00	Crude ash	12.11
Wheat grain, ground	15.00	Ether extract	3.35
Soybean meal, 47% CP	10.00	Crude Fiber	8.30
Calcium carbonate	2.50	Calcium	0.63
Salt	0.35	Available phosphorus	0.27
Premix[2]	2.15		

[1]DE (digestible energy) is a calculated value and the others are measured values. [2]The premix include the following: ROVIMIX® Pig CT 2 %, providing 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 ROVABIO™ (multienzyme complex).

with successive three readings on the surface of each muscle.

Glycogen and lactate determination

Glycogen and lactate contents were determined in LT and PM, at 60 min, 90 min, 6 h, and 24 h *post mortem*. Briefly, a 3 g meat sample, obtained from three parts of the muscle to avoid the heterogeneity of glycogen distribution in the muscle (Nielsen and Ortenblad 2013) was homogenized and extracted with 6 ml of HCl 4M, for 2 hours at 100° C in sealed glass tubes. After cooling, it was filtered twice (cellulose filter, Macherey-Nagel, Germany), and neutralized by adding NaOH 4N. Glycogen was determined as glucose total equivalents following Bergmeyer and Bernt (1974) using colorimetric diagnostic kits (1001201, Spinreact, Spain) based on glucose-peroxidase enzymes measured in a Genesys-6 spectrophotometer (Thermo Scientific Inc. USA). Glycogen concentration was expressed as µmol/g of fresh meat. Lactate was assayed in the same hydrolyzed slurry using commercially available enzymatic colorimetric diagnostic kits (LO-PD; 1001330; Spinreact, Spain) and expressed as µmol lactate/g of fresh meat.

Lipid and protein oxidation determination

In fresh and aged LT and PM, the lipid oxidation was determined using the method of TBARs (Thiobarbituric acid reactive species) according to Gatellier et al. (2004) and Lynch and Frei (1993). Samples of 5 g frozen meat were homogenized in a Waring-Blender (Fisher Inc. USA) with 100 ml of an extraction buffer (0.15 M KCl, 0.02 M EDTA, and 0.30 M BHT) at 12,000 rpm for 1 minute. Part of this homogenate was frozen for protein oxidation assays and 5 ml of the homogenate were centrifuged at 2000 g at 4 °C for 10 minutes (Thermo Scientific Inc. USA) and 1 ml of the supernatant was incubated for 30 min with 1 ml of a 2-thiobarbituric acid (TBA) and trichloroacetic acid (TCA) solution (35 mM TBA and 10 % TCA in 125 mM HCl). After cooling in ice for 5 min and kept at room temperature for 45 min, 2 ml of n-butanol were added, and phase separation was done by centrifugation at 3000 g for 10 min (Sorvall ST16-R, USA). The absorbance was measured at 535 nm in a Genesys-6 spectrophotometer (Thermo Scientific Inc. USA) and the concentration of malondialdehyde (MDA) was calculated using the molar extinction coefficient of the MDA (156,000 M-1 cm-1). Results were expressed as mg MDA/kg of meat.

The protein oxidation level was determined by the carbonyl protein assay (Mercier et al. 2004). The homogenate samples frozen on the day before were thawed at room temperature and 4 ml were extracted and put in two tubes for sample (2 ml of homogenate sample/tube). Then were centrifuged at 2000 g for 10 min (Sorvall ST16-R, USA). 2 ml of HCl 2 M were added to one of the two tubes (blank) and 2 ml of a solution of DNPH (2,4-dinitrophenylhydrazine) 20 mM dissolved in HCl 2 M, on the other tube, both incubated for one hour at room temperature with regular stirring. Then 2 ml of TCA 20 % were added and left at room temperature for 15 min with regular stirring. The tubes were centrifuged at 2000 g for 10 min (Sorvall ST16-R, USA) and the supernatant was eliminated. Pellet was washed three times with 4 ml of ethanol:ethyl acetate (1:1), centrifuging each time, to eliminate traces of DNPH. The pellets were dissolved in 6 ml of 6 M guanidine HCl with 20 mM KH2PO4 (pH 6.5) and incubated at room temperature for 15 min with regular stirring. Finally, were centrifuged at 2400 g for 10 min, and the absorbance of the supernatant was measured at 370 nm in a Genesys-6 spectrophotometer (Thermo Scientific Inc. USA) and the concentration of DNPH was calculated using the DNPH molar extinction coefficient (22,000 M-1 cm-1). Results were expressed as nmoles of DNPH/mg of protein. Protein content was determined according to Stoscheck (1990) and adapted by Terevinto *et al.* (2010).

Lipid content and fatty acid profile

In fresh meat, intramuscular lipid extraction was performed following the Folch et al. method (1957). Briefly, meat samples were homogenized using a Virtis at 35000 rpm, with chloroform:methanol (2:1) for 1 min, then filtered to a separating funnel and evaporated. Evaporated to dryness lipids. These were weighed and total intramuscular fat content was expressed as grams per 100 g of muscle. Then, lipids were dissolved in hexane and submitted to methylation with methanolic KOH (Ichihara et al. 2010). The fatty acid analysis of fresh LT and PM was performed by gas chromatography following the Eder (1995) procedure. A Clarus 500 (Perkin Elmer Instruments, USA) split/splitless chromatograph with a fused-silica CPSIL-88 of 100 m capillary column, FID detector, and CPG grade hydrogen as carrier gas (rate: 1 ml/min) was used. A temperature of 250 °C was established for the injector and FID detector. Fatty acid methylated esters (FAMEs) were determined by comparing the retention time to fatty acid standards (Sigma Corp., USA) and individual FAME were quantified as a percentage of total detected FAMEs. Total lipids content and fatty acid composition of pastures and concentrate were measured following lipid extraction by Soxhlet procedure, methylation, and further quantification by Gas Chromatography, as detailed in 2.6 item. Fatty acids expressed as mg of fatty acids / 100 g of tissue were estimated based on the parameters developed by Weihrauch et al. (1977) and improved by Anderson (1976) specifically for pork tissues.

Lipid health indices

In each muscle, LT, and PM, index of Atherogenicity (AI), Thrombogenicity (TI), and Hypocholesterolemic/Hypercholesteraemic (h/H) ratio were calculated according to del Puerto *et al*. (2017) from fatty acids previously quantified.

Statistical analysis

Data are presented as mean ± standard error of the mean for 11 (I) and 12 (O) pigs. When the difference between males and females was relevant, the mean for each one was presented separately, for I (6 males, 5 females) and O (8 males, 4 females). Performance response variables were analyzed by ANOVA GLM procedure with system and sex as fixed effects. Considering that pigs of each system were slaughtered in two sessions,

it was included as a covariate in each analysis done to eliminate this effect. The main effects of the production system, muscle, sex, and time *post mortem*, on pH, drip loss, and glycogen, and lactate contents were analyzed using repeated measures ANOVA. The main effect of the production system, muscle, sex, on pH, drip loss, and color at 24 h *post mortem* or in aged meat were performed by ANOVA GLM. The main effect of the production system, muscle, sex, and ageing (24 hours vs aged) for pH, drip loss, color, and lipid and protein oxidation was analyzed by the GLM procedure. Data of fatty acids and health indices were analyzed by ANOVA GLM for production system, muscle, and sex effects. When significance in each ANOVA was obtained (at $p < 0.05$), *post hoc* Tukey-Kramer test multiple comparisons were used ($p < 0.05$). Interactions included in each analysis done were shown when significance was obtained. At last, for pastures composition, total lipids and fatty acids composition were summarized using descriptive statistics. Also, comparisons between systems for each muscle or between muscles for each system were carried out by T-Test ($p<0.05$). NCSS software (2019; 329 North 1000 East Kaysville, Utah 84037 USA) was used.

RESULTS AND DISCUSSION

Productive parameters and carcass characteristics

Data obtained for performance and carcass characteristics are presented in **Table II**. As expected, differences in age at slaughter and live weight daily gain were observed, being live weight gain significantly lower and age of slaughter significantly higher in pigs in the O system with pastures compared with pigs in the I system.

In the O system, pigs needed 12 days more to obtain the same slaughter weight that in the I system. The restriction for concentrate applied to pigs and the physical activity provoked lower growth in pigs reared in O, as shown by previous authors (Lebret *et al*. 2015, Pugliese *et al*. 2003). The intake of high fiber feeds, in the O, provoked in pigs a greater development and weight of the gastrointestinal tract, and a lower performance expressed as weight gain (Len *et al*. 2008). In spite of the fact that the I pigs consume more concentrate, in the present work, no significant differences in dorsal fat thickness between systems were observed (**Table II**). Local breeds have, frequently, a high dorsal fat thickness (29-63mm) although this feature can be modified through the feed, and the production system, and the rearing season (Araújo *et al.* 2018, Abeledo *et al*. 2004, Pugliese *et al*. 2003). Pasture intake with a restricted concentrated diet improved the ratio of concentrated intake: live weight gain. This is important for little and medium-scale farmers who search for lower production costs.

pH, drip loss, and color

A normal pH kinetic was observed in the pH in this trial in meat from both muscles and systems (**Table III**).

A correct decrease in pH is essential to achieve a good shelf life of meat (Cobanovic *et al*. 2016) and is a tool to detect technological problems in meat, such as the presence of Pale Soft Exudative (PSE), and Dark Firm Dry (DFD) meats, an important problem for the industry (Faucitano et al. 2010). Handling of pigs on farms, during transport and previous slaughter handling, influences the appearance of this type of unwanted meat (Cobanovic et al. 2016, Vermeulen *et al*. 2015). The pH decline in fresh meat was normal, but meat from the I system presented significantly higher pH values than from the O. This could be explained by differences in glycogen reserves (Rosenvold *et al*. 2002), obtained during the *post mortem* kinetic (Fig. 1), particularly for LT O which is higher than LT from pigs in the I system. The mentioned above also explains pH differences found between LT and PM. For LT, higher pH values were observed than for PM in fresh meat.

When only the pH at 24 h *post mortem* was analyzed, no differences were observed between I and O rearing, being this value the most important, agreeing with those observed by other authors, when comparing pigs reared in O and I systems (Dostálova *et al*. 2020, Blumetto et al. 2013). The average value for pH24 was 5.76. In pigs, like other animals, the composition of muscle fibers varies according to muscle and physical exercise, becoming less glycolytic when movement is

Table II. Productive parameters and carcass characteristics from Pampa Rocha pigs reared in an Indoor or an Outdoor with pasture production systems (Parámetros productivos y características de la canal de cerdos Pampa Rocha criados en Indoor o Outdoor con sistemas de producción de pasturas**).**

	Systems		
Parameters	Indoor	Outdoor	p-value
Age of slaughter (days)	171.00 ± 1.36	183.10 ± 1.30	0.001*
Live weight (kg)	94.55 ± 3.63	91.50 ± 3.38	ns
Live weight gain (g/day)†	801.20±33.00	686.30 ± 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	70.20 ± 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 Indoor and n= 12 (8 males, 4 females) for Outdoor systems. * Values of $p < 0.05$ indicate significant differences between production systems (S) by ANOVA GLM. As sex effect was not significant the means represent male and female together. ns: not significant. † Values for fattening period.

Table III. Post mortem pH kinetic in fresh meat and pH in aged meat from Longissimus thoracis (LT) and Psoas major (PM) muscles of Pampa Rocha pigs reared in Indoor (I) or Outdoor with Pastures (O) production systems (Cinética de pH post mortem en carne fresca y pH en carne envejecida de Longissimus thoracis (LT) y músculos Psoas major (PM) de cerdos de Pampa Rocha criados en sistemas de producción de interior (I) o exterior con pastos (O).

Time post mortem	Systems							
	Indoor		Outdoor					
	Muscle				Main effects			
	LT	PM	LT	PM	S	M	Tpm	Sex
60 min	6.54 ± 0.09	6.21 ± 0.09	6.40 ± 0.06	5.93 ± 0.04				
90 min	6.29 ± 0.10	6.04 ± 0.07	6.31 ± 0.02	5.89 ± 0.04	[1] $p < 0.01$	[1] $p < 0.01$	[1] $p < 0.01$	[1] ns
6 h	6.13 ± 0.07	5.97 ± 0.06	5.98 ± 0.04	5.82 ± 0.03	I > O	LT > PM	60 min > 24 h	
24 h	5.68 ± 0.05	5.84 ± 0.04	5.74 ± 0.02	5.74 ± 0.07				
Aged	5.73 ± 0.02	5.96 ± 0.05	5.72 ± 0.02	5.82 ± 0.03	[2] $p < 0.05$ I > O	[2] $p < 0.01$ PM > LT	[2] ns Aged vs 24 h	[2] ns

Values are mean ± SEM of n = 11 for indoor (6 m, 5 f) and n=-12 for outdoor (8 m, 4 f) pigs. Values of $p < 0.05$ indicate significant main effects for: [1] production system (S), muscles (M), time *post mortem* (Tpm) and sex for fresh meat by repeated measures ANOVA. [2] Ageing effect (Aged vs 24 h *post mortem*) was analyzed by ANOVA GLM with production system (S), muscle (M), ageing and sex as main effects. h: hours; ns: not significant.

not restricted (Graziotti *et al*. 2000). This agrees with Carballo et al. (2017) in a previous work, where a local breed was also studied, and the pH kinetic was adequate, whatever the production system used, which may preserve meat quality. The pH values obtained in the present work were similar to those reported in *Longissimus dorsi* of creole breed at 45 min and 24 h *post mortem* (Depres *et al*. 1994) and in a previous work comparing Pampa Rocha pigs with commercial genetic breeds (Carballo et al. 2017) and slightly higher in East Balkans local pork (6.11 initial and 5.58 at 24 h) with a similar live weight (Marchev *et al*. 2018). The pH of the aged meat during seven days was similar to pH at 24 hours *post mortem* in the fresh meat (**Table III**). However, when a comparison was made for each muscle and each production system, a significant lightly higher value is observed in PM aged from I versus 24 h *post mortem*. Recent works (Yu *et al*. 2021) found in *Longissimus lumborum*, a lightly increased pH value in Landrace x Large White meat during aging after 9 days of aging probably due to the changes in the charge caused by proteolytic enzymes during *post mortem* aging but this effect was not observed in the LL of this local breed.

In fresh meat, when the production system, muscle, time *post mortem*, and sex were analyzed as the main effects, meat from the O system showed higher drip loss than meat from the I system (**Table IV**), and the LT showed higher drip loss than the PM. Also, females lost significantly more water than males. In **Table IV**, significant differences were observed between 60 min and 24 hours *post mortem*.

Also, at 24 h, a significantly higher loss of water is observed in meat coming from the O system and for LT. Besides, it was observed a higher drip loss in meat from female pigs than from male pigs (1.78 % ± 0.28 males vs. 2.74 % ± 0.34 females, at 24 h). On the other hand, meat, whether LT or PM, aged for 7 days in a vacuum at 1-2 °C, lost significantly more water than at 24 h *post mortem* when coming from O systems (**Table IV**). However, drip loss in aged meat from the I system did not change significantly in comparison to 24 h. No differences due to sex were observed. Previous research from Warris *et al*. (1985,1983), Talbott *et al*. (2004), and Mkwanazi *et al*. (2019) with pigs in O rearing systems reported a higher drip loss in fresh meat. Contrarily, Lebret et al. (2015) observed a drip loss of 0.55 % in fresh meat from Basque pig reared in an extensive system, 0.85 % in a conventional system, and 1.11 % in an alternative system that included indoor bedding and free outdoor access. Dostálova *et al*. (2020) did not observe differences in fresh meat from Prestice Black-Pie pigs reared I or O housing, and reported values near 3.02 and 3.01 % of drip loss. These controversial findings related to the drip loss in local breeds, for O versus I rearing systems, could be due to factors such as the type of local breed, fiber type percentage (Taylor 2004), muscle type, or intramuscular fat (Mkwanazi *et al*. 2019) of muscles. Concerning sex, in the present work, females lost more water in the fresh meat than males, independently of the system, O or I. A high drip loss is related, among other factors, to a rapid *post mortem* glycolysis, that is observed mainly in pigs with stress susceptibility (Brewe 2014), or with increased lipid oxidation (Morrissey and Kerry 2004) or less intramuscular fat (Talbott *et al*. 2004) or with a lower pH24 (Koomkrong *et al*. 2017). Since no effect was found for sex in glycogen kinetic (**Fig. 1**), lipid oxidation (**Figure 2**), intramuscular fat (**Table VI**), or pH24 (**Table III**), a relation between these three factors and the drip loss observed in this work cannot be established. Considering that drip loss is one of the main attributes of meat affecting the texture during processing, the loss of weight, and acceptability by consumers (Ocampo *et al*. 2009), a comparison was done with other values obtained in the country or elsewhere. Echenique and Capra (2006) reported values of around 3.82 % for drip loss in fresh meat of commercial hybrids from the intensive system. Morlein et al. (2007), reported that values of drip loss higher than 7 % are related to an incidence of PSE meat of about 35.3 %. In the present work, at 24 hours *post mortem* values obtained are lower than values reported except for LT of females in the O system, not related to PSE. In previous work, Carballo et al. (2017)

Table IV. Drip loss (%) at 60 min and 24 hours post mortem (24 h) and in aged meat from Longissimus thoracis (LT) and Psoas major (PM) of Pampa Rocha pigs in an Indoor (I) or an Outdoor with pastures (O) production systems (Pérdida por goteo (%) a los 60 min y 24 horas post mortem (24 h) y en carne envejecida de Longissimus thoracis (LT) y Psoas major (PM) de cerdos Pampa Rocha en sistemas de producción de interior (I) o exterior con pasturas (O).

Time post mortem	Systems					Main effects					
	Indoor			Outdoor							
	Sex	Muscle									
		LT	PM	LT	PM	S	M	Tpm	A	Sex	I
60 min	m	0.90 ± 0.22	0.73 ± 0.14	1.69 ± 0.35	0.75 ± 0.16	[1]p< 0.01 O > I	[1]p < 0.01 LT > PM	[1]p < 0.01 24h > 60 min		[1]p< 0.05 f > m	
	f	1.43 ± 0.41	0.62 ± 0.12	1.40 ± 0.37	1.15 ± 0.37						
24 h	m	1.24 ± 0.43	2.39 ± 1.00	2.32 ± 0.40	1.13 ± 0.40	[2] p<0.01 O > I	[2]p<0.05 LT>PM			[2]p<0.05 f>m	[2]SxSex p < 0.05
	f	2.14 ± 0.64	1.31 ± 0.29	4.56 ± 1.06	2.97 ± 1.00						
Aged	m	1.08 ± 0.42	1.38 ± 0.60	6.96 ± 1.92	4.71 ± 1.98	[3]p< 0.01 O > I	[3]ns		[3]ns	[3]ns	[3]SxA p < 0.05
	f	1.82 ± 0.55	1.38 ± 0.72	4.08 ± 2.46	5.54 ± 1.87						

Values are mean ± SEM of n = 11 for indoor (6 m, 5 f) and n=-12 for outdoor (8 m, 4 f) pigs. Values of p < 0.05 indicate significant main effects for: 1 production system (S), muscles (M), time post mortem (Tpm), sex and interaction (I) for fresh meat by repeated measures ANOVA. 2 At 24 hours post mortem, data were analyzed by GLM ANOVA with system (S), muscle (M), sex and interaction (I) as main effects. 3Ageing effect (Aged vs 24 h post mortem) was analyzed by ANOVA GLM with production system (S), muscle (M), ageing (A), sex and interaction (I), as main effects. h: hours; ns: no significant, m: male, f: female.

found that drip loss in Psoas major from Pampa Rocha pig was lower than crossbreed Pampa X Large White or Pampa X Duroc. There are scarce reports about drip loss when local meat pig is conserved for 7 days in a vacuum bag under refrigerated conditions (aged) related to production systems. In this work, meat from the O system (male or female) has a higher drip loss and this continues during the aging process. Earlier works (Enfalt *et al*. 1997) reported that Longissimus lumborum from Duroc pigs from the O system has higher moisture, ash, and protein content, and low level of intramuscular fat, higher drip loss in fresh and stored meat, also high glycolytic potential and lower pH24 compared with pigs I. A combination of breed, muscle type, sex, and O conditions could be influencing drip loss observed in this research. Nevertheless, in I conditions drip loss follows a dynamic that matches that of Straadt et al. (2007) who reported that high drip loss occurs on the first days post mortem after which it diminishes until 14 days post mortem. In beef Kristensen and Purslow (2001) hypothesized that increased water holding capacity with aging can be due to the degra-

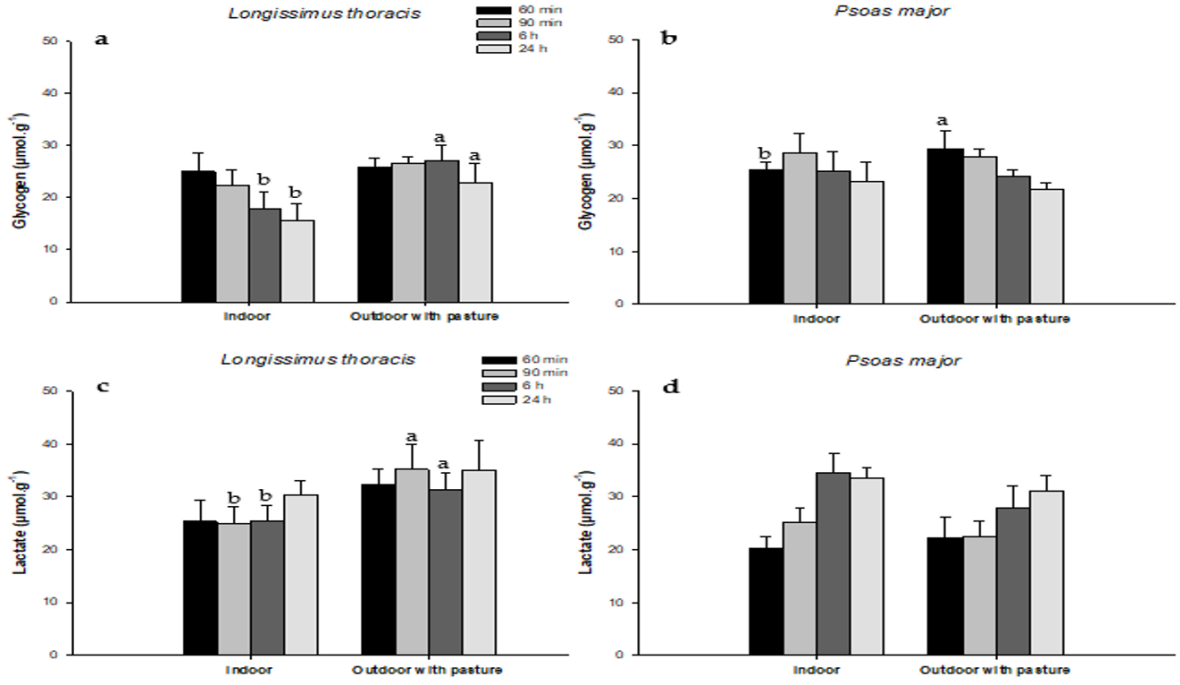

Figure 1. Glycogen (a,b; µmol.g-1) and lactate (c,d; µmol.g-1) kinetic at 60 min, 90 min, 6 hours and 24 hours post mortem in meat of Longissimus thoracis (LT) and Psoas major (PM) of Pampa pig reared Indoor or Outdoor with pasture. Data are mean ± SEM of n=11 for Indoor (6 m, 5 f) and n=2 for Outdoor (8 m, 4 f) pigs. For 1Glycogen and 2Lactate, main effects as production system (S), muscles (M), time post mortem (Tpm), sex and interaction (I), were analyzed by repeated measure ANOVA and post hoc Tukey-Kramer Test (p < 0.05). a,b: means represents significance between system for each muscle by T-Test (p<0.05). As sex was not significant means represent male and female.

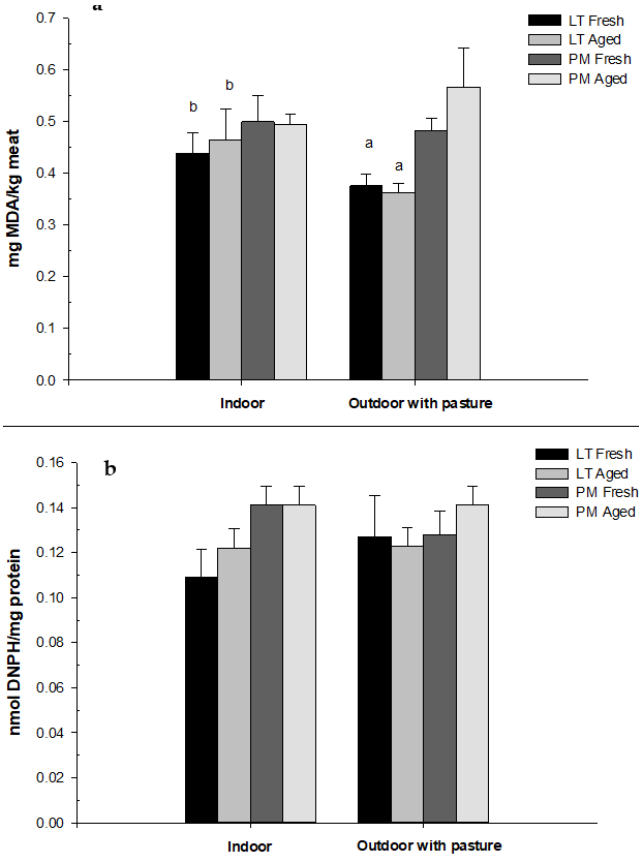

Figure 2. Lipid (a; mg MDA/kg meat) and protein oxidation (b; nmol DNPH/mg protein) in meat from Longissimus thoracis (LT) and Psoas major (PM), fresh, and aged from Pampa pigs reared in Indoor or Outdoor with pasture production system. Data are mean ± SEM of n=11 for Indoor (6 m, 5 f) and n=-12 for Outdoor (8 m, 4 f) pigs. Main effects of production system (S), muscle (M), sex, ageing (A) and interaction (I) on the 1lipid and 2protein oxidation were analyzed by ANOVA GLM and post hoc Tukey Kramer Test ($p < 0.05$). a,b means significant differences for lipid oxidation (a), by T-Test between systems in fresh or aged LT ($p<0.05$). As sex was not significant means represent male and female.

dation in the cytoskeleton during aging removing the linkage between the rigor-induced lateral shrinkage of myofibrils and the shrinkage of whole muscle giving to myofibrils the capacity to hold more water. Also, a possible purge loss could be increased during the aging in the vacuum bag (Yu *et al*. 2021) and this could explain a lesser volume as drip loss.

According to values shown in **Table V**, when the analysis includes results obtained at 24 h post mortem and in aged meat, no differences between systems were found for the L*, a*, and b* values. LT muscles showed an L* value higher than PM, and a* and b* values lower than PM. Aging did not affect the L* value, but a lower a* and b* is observed. At 24 h meat was redder, and more yellow than aged meat. A relevant difference between muscles showed that PM was darker, redder, and more yellow than LT at 24 h, and in aged meat. In general, no effect was observed for sex. Significant interactions between system and aging were found. Indeed, data were analyzed in meat at 24 post mortem and in aged meat separately.

At 24 hours post mortem, meat from the O system was darker than from the I one, with an L* value significantly lower. This is consistent with several authors who refer to physical activity in the O system to explain this result in other productive species (Terevinto *et al*. 2017, Guerrero et al. 2013). Gentry *et al*. (2004) reported that pigs reared outdoors have more IIA fibers and fewer IIB/X fibers than pigs reared indoors. For a* value, no system effect was observed at 24 h in meat. The PM was darker and redder than LT. Cabrera *et al*. (2007) observed similar results in muscles from Pampa Rocha pigs. A possible explanation is the higher oxygenation due to mobility, in consequence, more hemoglobin and higher content of heme iron in the more oxidative PM studied here (Carballo *et al*. 2022, Cabrera *et al*. 2007). This result is an indicator of high nutritional value for high demands of iron in the heme form. Comparing the present data and the results obtained by Echenique and Capra (2006), the meat of Pampa Rocha pigs is darker and redder than the national average with a predominance of hybrid lines. Several authors, evaluating local pigs, observed similar values for L* and a* in Longissimus dorsi (Auqui *et al*. 2019, Radovic *et al*. 2017) however, Tomazin *et al*. (2019) did not find differences in colour muscles when pigs were reared in outdoor conditions. In aged muscles, meat from the I system was darker with a lower L* value, but no significance was found for a* and b*. Also, PM was darker and redder than LT. In aged meat, biochemical degradation takes place, particularly in this work, in LT muscle from the O, and these modifications could affect the L* possibly due to a more tendency to oxidation of heme pigments. However, LT muscle showed significantly less oxidation for lipid and protein than PM (**Fig. 2**). Considering the significant interactions between system and muscle, and system and process (aging) and also a higher L* in females at 24 h, but not in aged meat, it is likely that the expression of colour as L* or a* to characterize a system O or I for a local breed, is not always the same, and it shall depend on how is affected by one or many of them. In this study, two muscles were included in fresh and aged meat, and sex, and the results are not conclusive.

Yellowness (b*) did not show differences among systems, but in PM was higher than in LT, and in fresh meat was higher than in aged meat. When the comparison was made at 24 h the PM muscle showed a more yellow colour than the LT (**Table V**) and no difference among muscles was observed in aged meat. Also, a* and b* values were lower in aged meat compared with meat at 24 h. These results show that aging in this local breed could reduce the stability of colour, particularly a* and b* in LT. Yu et al. (2021) report also, lower stability at the display of L*, a*, and b* with ageing the in *Longissimus lumborum* of Landrace x Large White for 16 days in a vacuum. Finally, interesting results were obtained in meat from the O with pastures, showing that colour parameters, L*, a*, and b*, were more stable in PM muscles than in LT. This result could indicate that the O system is a more adequate system to preserve a high-valued cut as PM of this local breed follows an aging process.

Glycogen and lactate content

Glycogen and lactate contents were not affected by the production system, the type of muscle, and the sex

Table V. Lightness (L*) and redness (a*) and yellowness (b*) values at 24 hours post mortem (24 h) and in aged meat in vacuum during seven days, from Longissimus thoracis (LT) and Psoas major (PM) of Pampa Rocha pigs reared in an Indoor (I) or Outdoor with pastures (O) production system (Valores de ligereza (L*) y enrojecimiento (a*) y amarillez (b*) a las 24 horas post mortem (24 h) y en carne envejecida al vacío durante siete días, a partir de Longissimus thoracis (LT) y Psoas major (PM) de cerdos Pampa Rocha criados en un sistema de producción Indoor (I) o Outdoor con pasturas (O).

Item		Systems				Main effects				
		Indoor		Outdoor						
	Process	Muscle				S	M	[1]A	Sex	I
		LT	PM	LT	PM					
L*	24 h	44.84 ± 0.96	40.14 ± 0.95	39.33 ± 0.78	39.72 ± 0.67	[1]ns [2]p < 0.01 (I > O) [3]p < 0.01 (O > I)	[1,2,3]p < 0.01 (LT > PM)	ns	[1]ns [2]p < 0.05 (f > m) [3]ns	[1]SxA p < 0.01 [2]SxM p < 0.01
	Aged	43.02 ± 0.72	36.24 ± 1.03	45.27 ± 0.80	38.93 ± 0.62					
a*	24 h	8.40 ± 0.97	13.80 ± 0.95	8.83 ± 0.75	13.40 ± 0.50	[1,2,3]ns	[1,2,3]*p* < 0.01 (PM > LT)	*p* < 0.01 (24 h > A)	[1,2,3]ns	[3]SxM *p*< 0.05
	Aged	4.85 ± 0.43	11.41 ± 0.66	4.04 ± 0.29	13.50 ± 0.54					
b*	24 h	11.36 ± 0.72	12.38 ± 0.72	10.78 ± 0.51	11.20 ± 0.49	[1,2,3]ns	[1]*p* < 0.05 (PM > LT) [2]ns [3]*p* < 0.02 (PM > LT)	*p* < 0.001 (24 h > A)	[1,2,3]ns	[3]SxM *p* < 0.01
	Aged	8.32 ± 0.38	8.29 ± 0.34	7.97 ± 0.34	9.95 ± 0.38					

Values are mean ± SEM of n = 11 for Indoor (6 m, 5 f) and n=12 for Outdoor (8 m, 4 f) pigs. Values of p < 0.05 indicate significant main effects of production systems (S), muscles (M), ageing (A) , sex and interaction (I), for L* lightness or a* redness or b* yellowness. [1]. By GLM ANOVA for 24 h and aged meat. [2]. By GLM ANOVA for 24 h meat. [3]. By GLM ANOVA for aged meat. h= hours; ns = not significant.

of the pigs, as observed through mean effects analysis (**Fig.1**).

Main effects analysis showed no effect of production system and muscle on glycogen and lactate content, and the time post mortem was significant in both, p < 0.024; 60 min > 24 h for glycogen, and p < 0.019; 24 h > 60 min for lactate. During time post mortem glycogen content significantly decreased as expected, obtaining higher values at 60 min than at 24 h (**Fig. 1 a, b**). The values found for glycogen content were 22.59 ± 1.01 and 25.7 ± 1.02 µmol/g of meat in pigs from the I and O systems, respectively. When muscles were compared in each system, differences in glycogen content were observed in I only and PM showed higher glycogen levels than LT (28.3 vs. 26.5 µmol/g). On the other hand, when the analysis was made into each muscle, glycogen in LT from pigs O was higher than from I (25.5 vs. 20.2 µmol/g) and this difference was significant at 6 and 24 h post mortem (**Fig. 1**). In PM, glycogen from the I system was similar to that from the O (25.6 vs. 25.8 µmol/g), but a significant difference was observed between systems at 60 min post mortem, where the O system had more glycogen (29.3 µmol/g) than the I (25.3 µmol/g) (**Fig. 1**). This initial difference was missing at 6 and 24 h post mortem.

No differences were observed in lactate content within systems, muscles, or sex and when time post mortem was considered, lactate content was significantly higher at 24 h (32.5 µmol/g) than at 60 min (25.0 µmol/g; Fig. 1c,d). Values observed for lactate content were 27.4 ± 1.8 and 29.7 ± 1.8 µmol/g of meat from the I and the O system, respectively. In LT from O at 90 min and 6 h post mortem a significantly higher lactate content than in the I system was observed. Zybert *et al*. (2020) associated the higher glycogen and lactate values (higher than obtained in the present work), with low glycolytic potential, and mentioned that this explained the 42 % of the variation in ultimate pH. Concerning this, no differences in pH24 were observed in this experiment. Production system effects were observed only during post mortem and that could affect other parameters such as drip loss or colour. The different responses of each muscle, LT and PM, less or more oxidative, could be explained by the glycogen reserves ante mortem, affecting the resulting high pHu (England *et al*. 2016). Besides, glycogen and lactate contents are affected by other several factors such as breed, muscle fiber, diet, environmental factors, and others (Moreno *et al*. 2020, de Oliveira *et al*. 2018, Lebret *et al*. 2015, Gentry *et al*. 2004). In this work, differences between systems were found during the degradation of the glycogen or the accumulation of lactate at some time points during the pH drop (**Fig. 1**), and this impacts the pH differences observed during post mortem decline of pH for both systems (pH I > pH O), however, it did not impact the final pH at 24 hours. Perhaps other parameters not measured here could be affected and this could be the subject of another study considering these aspects.

Lipid and protein oxidation

Lipid oxidation and protein oxidation were not affected by the production system, sex, or ageing of meat. The main effect due to muscle was observed, in both I and O rearing, resulting in higher oxidation of lipids and protein in PM than in LT (**Fig. 2**).

Average values in LT were 0.45 and 0.37 mg MDA/kg meat and 0.12 and 0.13 nmoles DNPH/mg protein, for I and O respectively. In PM 0.50 and 0.52 mg MDA/kg meat and 0.14 and 0.13 nmoles DNPH/mg protein, for I and O respectively. In fresh and aged meat, differences between systems were observed in LT, where lipid oxidation was lower (0.38 and 0.36) in O than in

I (0.44 and 0.46) respectively (**Fig. 2**). No differences were observed for lipid oxidation and carbonyl content between fresh and aged meat, in each muscle studied. But lipid and protein oxidation in PM are higher than in LT muscle. Important concentrations of antioxidant molecules in green herbage (Choe *et al*. 2011, Jayawardana *et al*. 2011, Lara *et al*. 2011) and adaptation of Pampa Rocha pigs to pasture consumption could explain lower oxidation in the O system in LT muscle than in the same muscle from I. Similar results were found in a previous report (Carballo *et al*. 2017). Other studies have reported positive effects of forage-feeding on oxidation levels in meat from different species (Siphambili *et al*. 2020, Hajji *et al*. 2016, Popova and Marinova 2013). Considering that oxidation is responsible for meat deterioration and loss of nutritional and commercial value (Zhang *et al*. 2013), is relevant to obtain acceptable levels of protein oxidation in this local pig meat in both rearing systems. Considering a particular muscle, such as LT, O is an opportunity to improve the stability of both, fresh and aged meat. Differences between muscles, LT more stable than PM, also may select the adequate muscle to minimize the oxidation process.

Fatty acid content and Lipids health indices

According to the results shown in **Table VI**, total lipid content as intramuscular fat (IMF) is higher in PM than in LT (3.23 and 2.10 % respectively) and no significant differences were observed between systems or sex.

When the total lipids content is expressed as mg/100g tissue, the values are 1985 and 1895 mg/100 g tissue for LT in O and I, and in the PM are 2712 and 3052 mg/100 g tissue O and I, respectively. This higher content of lipids in PM could explain the higher lipid and protein oxidation observed in **Figure 2** and a possi-

Table VI: Lipid content (g/100 g of meat) and fatty acids composition (g/100g of total fatty acids) of Longissimus thoracis (LT) and Psoas major (PM) of Pampa pigs from the Indoor (I) or Outdoor with pastures (O) production system (Contenido lipídico (g/100 g de carne) y composición de ácidos grasos (g/100g de ácidos grasos totales) de Longissimus thoracis (LT) y Psoas major (PM) de cerdos de Pampa del sistema de producción Indoor (I) o Outdoor con pasturas (O).

	Longissimus thoracis		Psoas major		Main effects		
	O	I	O	I	Systems	Muscle	Sex
Lipids, (%)	2.09 ± 0.23	2.12 ± 0.19	3.08 ± 0.24	3.39 ± 0.52	ns	p < 0.001 PM > LT	ns
Fatty acids, (%)							
C12:0	0.06 ± 0.01	0.06 ± 0.01	0.05 ± 0.01	0.06 ± 0.01	ns	ns	p < 0.01 m > f
C14:0	1.22 ± 0.06	1.23 ± 0.05	1.22 ± 0.04	1.20 ± 0.11	ns	ns	ns
C14:1	0.05 ± 0.00	0.04 ± 0.00	0.08 ± 0.01	0.06 ± 0.00	p < 0.04 O > I	p < 0.0001 PM > LT	ns
C16:0	25.04 ± 0.52	25.35 ± 0.59	26.47 ± 0.31	25.95 ± 0.84	ns	ns	ns
C16:1	2.91 ± 0.10	2.97 ± 0.12	2.49 ± 0.11	2.41 ± 0.10	ns	p< 0.0001 LT > PM	ns
C17:0	0.32 ± 0.02	0.30 ± 0.02	0.40 ± 0.02	0.38 ± 0.01	ns	p < 0.0001 PM > LT	p < 0.03 m > f
C17:1	0.19 ± 0.01	0.16 ± 0.01	0.21 ± 0.01	0.19 ± 0.01	p=0.07 O>I*	p < 0.02 PM > LT	ns
C18:0	13.84 ± 0.98	13.26 ± 0.28	15.12 ± 0.34	14.52 ± 0.43	ns	p < 0.001 PM >LT	p < 0.04 m > f
C18:1	42.46 ± 0.71	43.28 ± 0.87	41.20 ± 0.47	40.62 ± 0.97	ns	p < 0.005 LT > PM	ns
C18:2n-6	10.38 ± 0.68	10.12 ± 0.50	10.07 ± 0.60	11.45 ± 0.89	ns	ns	ns
C18:3n-3	1.16 ± 0.05 a	0.99 ± 0.05 b	1.13 ± 0.06	1.09 ± 0.07	ns	ns	ns
C18:4n-3	0.35 ± 0.03	0.34 ± 0.02	0.36 ± 0.02	0.41 ± 0.04	ns	ns	ns
C20:0	0.19 ± 0.02	0.17 ± 0.01	0.22 ± 0.01	0.21 ± 0.02	ns	ns	ns
C20:1	0.03 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.02 ± 0.00	ns	ns	ns
C20:3n-3	0.04 ± 0.01	0.04 ± 0.01	0.16 ± 0.02	0.21 ± 0.04	ns	*p*< 0.004 PM > LT	ns
C20:4n-6	1.07 ± 0.24	1.09 ± 0.17	0.29 ± 0.05	0.61 ± 0.20	ns	*p* < 0.0001 LT > PM	ns
C22:4n-6	0.16 ± 0.03	0.18 ± 0.02	0.06 ± 0.09	0.11 ± 0.03	ns	*p* < 0.002 LT > PM	ns
Unidentified	0.54 ± 0.06	0.38 ± 0.05	0.43 ± 0.04	0.52 ± 0.07	ns	ns	ns
∑ SFA	40.67 ± 0.66	40.38 ± 0.83	43.49 ± 0.54	42.31 ± 1.09	ns	*p* < 0.003 PM > LT	ns
∑ MUFA	45.64 ± 0.75	46.49 ± 0.92	44.00 ± 0.55	43.31 ± 0.96	ns	*p* < 0.001 LT > PM	ns
∑ PUFA	13.16 ± 3.38	12.76 ± 0.68	12.08 ± 0.72	13.87 ± 1.19	ns	ns	ns

Data presented are mean ± SEM of n=11 for Indoor (6 m, 5 f) and n=-12 for Outdoor (8 m, 4 f) pigs. Main effects were analyzed by ANOVA GLM for production system, muscles, sex and interactions (not shown) and *post hoc* Tukey-Kramer Test ($p < 0.05$). a, b: means significant differences between systems for each muscle by ANOVA one way and Tukey-Kramer Test ($p < 0.05$).*males outdoor>males indoor ($p < 0.05$). ^{a,b}: means significant difference between system for LT muscle by T-Test ($p<0.05$). m: male; f: female. ns= non significant. note: in this table values of the columns represent the mean for male and female together.

ble more lipogenic capacity for this muscle in this local breed (Poklukar *et al*. 2020). Oleic (C18:1, 42 %), palmitic (C16:0, 26 %), stearic (C18:0, 14 %), and linoleic (C18:2n-6, 10 %) fatty acids are present in a higher percentage in both muscles. Oleic is a monounsaturated fatty acid important to reduce cardiovascular diseases and linoleic is an essential fatty acid (López-Huertas 2010). Miristoleic acid (C14:1), margaric acid (C17:0), heptadecanoic acid (C17:1), stearic acid (C18:0), and eicosatrienoic acid (C20:3n-3) content were higher in PM, and palmitoleic acid (C16:1), oleic acid (C18:1), arachidonic acid (C20:4n-6) and docosatetraenoic acid (C22:4n-6) content were higher in LT. Only the content of miristoleic fatty acid was different between systems ($p < 0.05$), and was higher in animals raised in the O production system. Alfa-linolenic acid (C18:3n-3) content was not significantly different between systems, muscles, or sex (**Table V**). In LT, the content of alfa-linolenic acid is significantly higher in the O system than in the I ($p < 0.03$). In PM, C14:1 and C17:1 content were higher in O, and C18:2n-6, C20:4n-6, and C22:4n-6 content were higher in I. Docosahexanaenoic acid (DHA) and docosapentaenoic acid (DPA) were not detected in the IMF of these pigs, and this could be explained likely by a specific genetic characteristic and biotype of our local breed, Pampa Rocha. Similar observations have been reported by Poklukar *et al*. (2020).

Differences between muscles in SFA and MUFA content were observed (**Table VI**). SFA content was higher in PM and explained by O system differences between muscles. MUFA content was higher in LT than in PM, and no differences between muscles were observed for PUFA content. Regarding the production system, differences were observed for PUFA content only in PM (I higher than O). Local breeds have higher lipogenic capacity resulting in a higher capacity to deposit fat than modern breeds and the content of monounsaturated and saturated fatty acids is also higher than in modern breeds (Poklukar *et al*. 2020). This is a crucial point because shows that in the lipid metabolism of local pigs predominates the monounsaturated fatty acids, showing a more lipogenic than lipolytic activity, and a higher capacity for desaturation (Poklukar *et al*. 2020). Results obtained in the present study concerning fatty acids profile are not clear with respect to differences between systems and partially agree with those reported by several authors (Dostálova et al. 2020, Parunovic *et al*. 2012). It is necessary to consider that I or O pigs studied here intake concentrate that contains more total fatty acid than pastures (**Table VII**).

Although pastures have a percentage of C18:3n-3 higher than concentrate, the total intake and the lower digestibility (González *et al*. 2020) are probably limiting to increase this fatty acid in the meat. A much earlier inclusion of feeds rich in fatty acids n-3 would be likely necessary to increase long-chain polyunsaturated fatty acids in this local breed because it exhibits an early maturation of adipose tissue than modern breeds (Vincent *et al*. 2012; Mourot *et al*. 1996).

Using the calculation factor of 0.91 developed by Weihrauch *et al*. (1977) and specifically adapted for pork by Anderson (1976), it is possible to estimate the total fatty acids in 100 g of fresh tissue from the data in g/ 100 g of fatty acid, determined in the present investigation by gas chromatography (**Table V**). Greenfield and Southgate (2003) and some Food Databases, such as the Danish Food Database (2022) used this approach to estimate actual fatty acid values in g of tissue. Thus, it is possible to express the total content of fatty acids (g/ 100 g fresh tissue) starting from the percentage of total lipids (g/100 g fresh tissue) as reported in **Table V**. Indeed, in the present work, it was possible to appreciate the contribution of the total content of PUFA and 18:3n-3 from data obtained from their composition expressed in % (g/ 100 g fatty acids). Those values ranged between 12.1 - 13.9 g/100 g fatty acids and 1.0 – 1.2 g/100 g fatty acids for PUFA and 18:3n3, respectively, for the two systems and muscles studied here. A quantity of 287 mg/100 g fresh tissue and 324 mg/100 g fresh tissue of PUFA for O and I system, respectively was found with a significant difference ($p < 0.001$) due to muscle type, LT (241 mg/100 g fresh tissue) and PM (369 mg/100 g fresh tissue). This contribution is of the same order as those found by Dugan

Table VII. Total lipids (% of dry matter) and fatty acid composition (g/100 g of fatty acids) of Red clover (Trifolium pratense), Chicory (Cichorium intybus), Raygrass (Lolium multiflorum) from pasture and concentrate available for pigs during the experimental period (Lípidos totales (% de materia seca) y composición de ácidos grasos (g/100 g de ácidos grasos) de trébol rojo (Trifolium pratense), achicoria (Cichorium intybus), raigrás (Lolium multiflorum) procedentes de pastos y concentrado disponible para cerdos durante el período experimental)**.**

Items	Red clover	Chicory	Raygrass	Concentrate
Total lipids (% dry matter)	0.56	0.88	0.95	3.35
Fatty acids (g/100g total fatty acids)				
C16:0	11.7 ± 0.62	11.6 ± 0.20	16.6 ± 0.33	15.9 ± 0.20
C16:1	1.40 ± 0.33	0.99 ± 0.01	1.59 ± 0.20	1.4 ± 0.38
C18:0	4.10 ± 0.29	4.52 ± 0.95	3.70 ± 0.65	4.11 ± 1.15
C18:1	1.84 ± 0.73	2.62 ± 0.46	5.09 ± 0.59	39.4 ± 2.95
C18:2n-6	21.9 ± 0.71	22.2 ± 0.96	14.7 ± 0.45	29.3 ± 0.40
C18:3n-3	46.7 ± 0.70	49.8 ± 1.97	45.6 ± 2.23	2.12 ± 0.22
Unidentified	12.3 ± 1.36	8.24 ± 0.57	12.6 ± 1.60	7.73 ± 1.38

Values are mean ± SEM of $n = 3$ samples of each one of pastures and concentrate.

et al. (2015). Concerning the linolenic acid (18:3n-3), we found 26.9 and 26.7 mg/100 g of fresh tissue for the O and I systems with a significant difference ($p < 0.006$) between muscles (21.2 and 32.4 mg/100 g fresh tissue for LT and PM, respectively). This contribution is similar for LT and higher for PM in comparison to those reported for modern pigs in *Longissimus* (22.7 mg/100 g fresh tissue) by Dugan *et al*. (2015), and from earlier studies (Turner *et al*. 2014, Juárez *et al*. 2011). Those data are from animals used as control fed barley/wheat/soybean meal.

From another point of view, in this work, both systems produced meat with an interesting and healthy fatty acids profile. Regarding health indices, results are shown in **Table VIII**.

A higher n-6/n-3 ratio was observed in the I system compared to the O. Differences between production systems were observed only in the PM muscle. In this muscle, the n-6 content, the PUFA/SFA and n-6/n-3 ratios were higher in the I system than in the O. The higher n-6 content found in this muscle from pigs fed I can explain the higher n-6/n-3 ratio, as n-3 content was not different between systems. The sex of the animals did not significantly affect the variables studied.

CONCLUSIONS

Fresh and aged Pampa Rocha pig meat, a local breed of Uruguay, reared in O or I systems, was studied through technological parameters, oxidative state and fatty acid composition. Although less weight gain and final weight were obtained from pigs raised O compared to the I system, the meat presented similarity in technological parameters, oxidative state and fatty acid composition. However, muscle type, and gender affect pH, drip loss, color, glycogen, lipid oxidation, and fatty acid composition. A particular aspect in O meat, related to higher drip loss than I, at 24 h *post mortem*, and in aged meat, requires further investigation. Furthermore, an interesting attribute in LT is the lipid antioxidant capacity when stored under vacuum for seven days, showing the potential of this muscle for processing purposes. Pampa Rocha meat presents interesting levels of fatty acids and health indices that contribute to the requirements of the human diet, slightly improved by the use of pastures, particularly alpha-linolenic acid (C18:3n-3), which could probably increase with feeding time. Considering the high quality of this meat, further research is needed on the O system to improve meat through increased n-3 PUFA and decreased drip loss.

Table VIII. Calculated lipid health indices in meat from Longissimus thoracis (LT) and Psoas major (PM) of Pampa pig from an Indoor (I) or Outdoor with Pasture (O) production system (Calculó los índices de salud lipídica en carne de Longissimus thoracis (LT) y Psoas major (PM) de cerdo de Pampa de un sistema de producción de interior (I) o exterior con pasto (O).

	Longissimus thoracis		Psoas major			
	O	I	O	I	Systems	Muscle
P/S	0.33 ± 0.03	0.32 ± 0.03	0.28 ± 0.03b	0.34 ± 0.03a	ns	Ns
n-6	11.61 ± 0.93	11.39 ± 0.67	10.42 ± 0.64b	12.16 ± 0.08a	ns	Ns
n-3	1.54 ± 0.07	1.37 ± 0.06	1.65 ± 0.09	1.71 ± 0.13	ns	p < 0.05; PM > LT
n-6/n-3	7.51 ± 0.42	8.41 ± 0.44	6.30 ± 0.42b	7.18 ± 0.44a	p < 0.05; I > O	p < 0.05; LT > PM
AI	0.51 ± 0.02	0.51 ± 0.02	0.56 ± 0.02	0.54 ± 0.02	ns	Ns
IT	1.38 ± 0.05	1.37 ± 0.05	1.55 ± 0.05	1.49 ± 0.05	ns	p < 0.003; PM > LT
h/H	2.26 ± 0.08	2.25 ± 0.08	2.03 ± 0.08	2.14 ± 0.08	ns	Ns

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