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Organic practices and gender are effective strategies to provide healthy pork loin

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Abstract

This study evaluated the influence of husbandry (organic feed and management but not free-ranging *vs*. conventional) and sex (barrows *vs*. gilts) on pork meat quality. A total of 60 *Longissimus thoracis* pork muscle samples from different 3-way crossbred genotypes were chosen from 3 conventional and 2 organic pig farms. Technological meat quality was measured at 24 h post-mortem and muscle fatty acid content and composition was analysed by gas chromatography. The loin from organic pigs at 24 h of retail display had lower pH, but it had no detrimental effects on drip loss. All the International Commission on Illumination colour attributes except meat lightness differed between husbandry systems. Moisture and crude protein content were lower whereas intramuscular fat content was greater in organic than in conventional pork. Total saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), polyunsaturated fatty acid (PUFA) and PUFA *n*-6 contents did not differ between husbandry systems, but total PUFA *n*-3 (mainly C18:3 *n*-3) were greater in organic than in conventional pork. Sex did not affect ultimate pH or meat colour attributes but barrows showed lower moisture and greater intramuscular fat than gilts. Total SFA and MUFA content were similar but all the PUFA (both *n*-6 and *n*-3) were lower in barrows than in gilts. These results suggest that some bioactive compounds from dietary origin, i.e., linolenic acid (C18:3 *n*-3) content from dietary vegetable oils (soybean or olive olein), might be used to highlight the nutritive value of (not free-ranging) organic pork meat. In addition, gilts were leaner than barrows and showed a more favourable PUFA/SFA ratio.

Keywords: *Longissimus* muscle, chemical composition, intramuscular fat, fatty acids, pigs

1. Introduction

In Spain, pork production has increased from 3 to 3.4 millions tonnes over the last decade (2002–2013). At present, this country is the second-largest swine producer within the European Union (28 member states) (15.3% of the total pork yield). However, its organic pig production according to European Community standards is negligible (less than 0.1% of the total pork yield) (MAGRAMA 2015), in part because another alternative husbandry system based on free-range fattening of Iberian pigs is practised in some areas of the South Western Iberian Peninsula.

Organic pigs must be reared in accordance with the European Union (EU) standards for organic livestock and livestock products (Council Regulation EC 834/2007 and EC 889/2008 amending Directive EEC 2092/91). Pigs in an organic system must have access to an outdoor area (1 m^2/pig<110 kg of live-weight according to EU Directive) and should have twice the space allowance provided

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usually to conventional pigs (1.3 *vs*. 0.65 m^2/pig<110 kg of body-weight according to EU Directive). They must be provided an organic diet (which consists of a minimum of 95% of organic feed ingredients) and roughage, either from pasture in extensive organic farms or from supplementary feed (silage, root crops, straw) in other systems. The main differences in organic feed concern the ban of synthetic aminoacids and feedstuffs from genetically modified crops, as well as the inclusion of concentrate protein sources composed by full oilseeds or mechanically oil extracted (not solvent extracted oils).

Product quality attributes associated with outdoor pig production are probably the sum of combined effects of genotype, diet, climatic environment, exercise and environmental enrichment (Edwards 2005). It has been suggested that meat quality characteristics will be influenced by housing and management parameters, although unambiguous conclusions on the effects of one housing type on these parameters cannot be drawn, and other factors such as nutrition and genotype have to be considered (Millet *et al.* 2005).

A variety of strategies have been put into practice with the aim of reducing stress and enriching the living environment as well as improving pork quality. These management factors include modifications in floor type, space allowance and outdoor access. A gradient of increasingly improved (or perceived as such) housing conditions can be found, from enriched environment indoors (with higher space allowance and bedding), to indoor housing with outdoor access, to free-range rearing (Lebret 2008). Perhaps the uneven response of husbandry system on meat quality may be explained by these broad lodging conditions, while free-range fattening is the most referenced system to compare with conventional pork characteristics (for example, Tejerina *et al*. 2012). A number of the afore-mentioned studies have been conducted with heavy pigs from local breeds, which are primarily aimed at the production of high value-added processed products, mostly dry-cured, especially in the Mediterranean area (Bonneau and Lebret 2010; Bermúdez *et al.* 2012, 2014). Latorre and Rodríguez-Sánchez (2010) evaluated some factors (husbandry system, sex and slaughter weight) affecting meat quality of commercial crossbred heavy pigs reared outdoors in Northern Spain, but few data are available concerning commercial lighter pigs reared according to organic standards and used for fresh pork production. In addition, consumer concerns about food security, animal welfare and environmental impact suggest that niche pork production will move forward during the next years, although there is a lack of knowledge on pork quality attributes derived from the (not free-range) organic pigs raised in Spain.

Therefore, the objective of this study was to assess the effect of husbandry system on the technological and fatty acid composition of *Longissimus* muscle from crossbred barrows and gilts.

2. Results

The interaction between husbandry system and sex was not significant for any variable related to pork meat. Therefore, both effects were independent and are shown separately.

2.1. Husbandry system effect

Carcass weight did not differ between husbandry systems

Table 1 Technological quality of *Longissimus thoracis* pork muscle as affected by husbandry system and sex

	Husbandry system		SE[3)]	Sex		SE	Significance	
	CONV[1)]	ORG[2)]		Barrow	Gilt		Husbandry	Sex
Carcass weight (kg)	74.10	77.50	1.20	74.80	76.8	0.90	NS	NS
pH 24 h post-mortem	6.19 a	5.76 b	0.07	5.95	6.00	0.05	**	NS
Drip loss (%)	3.69	4.17	0.61	4.03	3.83	0.44	NS	NS
Colour traits								
Lightness (L*)	47.50	47.30	1.40	47.80	47.00	1.00	NS	NS
Redness (a*)	5.99 b	3.51 a	0.61	4.53	4.96	0.44	*	NS
Yellowness (b*)	8.94 a	16.18 b	0.52	12.20	12.93	0.37	***	NS
Hue angle (H*)	59.90 a	78.40 b	2.10	69.00	69.30	1.50	***	NS
Chroma (C*)	10.56 a	16.64 b	0.64	13.18	14.02	0.46	***	NS
Chemical composition (%)								
Moisture	74.40 a	71.20 b	0.40	72.30 b	73.30 a	0.30	***	*
Intramuscular fat	1.34 b	5.07 a	0.41	3.76 a	2.65 b	0.30	***	**
Crude protein	22.75 a	20.65 b	0.46	21.23	22.17	0.33	**	NS

[1)] CONV, conventional.
[2)] ORG, organic (not free-ranging).
[3)] SE, standard error.
Within each row and effect, different letters denote statistical differences (P<0.05). *, P<0.05; **, P<0.01; ***, P<0.001; NS, not significant (P>0.05).
The same as below.

(Table 1; *P*>0.05). Ultimate pH was lower in organic than in conventional pork meat (*P*<0.01) but drip loss was unaffected by husbandry system (*P*>0.05). All meat colour attributes except lightness (L*) differed between husbandry systems at 24 h post-mortem (Table 1; *P*<0.05). Redness index (a*) was lower while yellowness (b*), hue angle (H*) and chroma (C*) were greater in organic than in conventional pork loin (*P*<0.05). Concerning meat chemical composition, moisture and crude protein content were lower (*P*<0.01) whereas intramuscular fat (IMF) content was greater in organic than in conventional pork meat (*P*<0.001). There was a high correlation between IMF content calculated as the sum of each individual fatty acid (FA) expressed as triglyceride equivalents and crude fat analysis by Sohxlet method (*r*=0.99).

There were no differences between husbandry systems in any saturated fatty acid (SFA) from *L. thoracis* muscle (*P*>0.05), except C17:0, which was lower in organic than in conventional pork (*P*<0.01; Table 2). Concerning the monounsaturated fatty acid (MUFA), there were differences in C17:1, which was lower in organic than in conventional pork (*P*<0.001), as well as in C20:1, which was greater in organic than in conventional pork (*P*<0.001).

Among the PUFA *n*-6, eicosatrienoic (C20:3 *n*-6) and C20:4 *n*-6 FA were lower in organic than in conventional pork, while the opposite occurred with C20:2 *n*-6 FA (*P*<0.001). Finally, among the *n*-3 PUFA, linolenic FA (C18:3 *n*-3) was greater (*P*<0.001) and C22:6 *n*-3 FA was lower in organic than in conventional pork (*P*<0.05).

Overall, total SFA, MUFA and PUFA and PUFA *n*-6 contents did not differ between husbandry systems (*P*>0.05), but total PUFA *n*-3 were greater in organic than in conventional pork (*P*<0.01). Accordingly, there were no differences between husbandry systems in the PUFA/SFA ratio (*P*>0.05) but organic pork showed lower PUFA *n*-6/PUFA *n*-3 ratio than conventional pork (*P*<0.001; Fig. 1-A).

2.2. Sex effect

There were no differences in carcass weight, ultimate pH or meat colour attributes between sexes (Table 1; *P*>0.05). However, meat from barrows showed lower moisture (*P*<0.05) and greater IMF (*P*<0.01) than meat from gilts, while no differences were observed between sexes in the crude protein content of meat (*P*>0.05).

There were no differences between sexes in any SFA (*P*>0.05) except C16:0, which was greater in barrows than in gilts (*P*<0.05; Table 2). No differences were observed in any MUFA content either (*P*>0.05). However, all the detected PUFA (both *n*-6 and *n*-3) were lower in barrows than in gilts (*P*<0.05). Accordingly, the PUFA/SFA ratio was lower in barrows than in gilts (*P*<0.001; Fig. 1-B), but no differences

Table 2 Fatty acid (FA) composition in *Longissimus thoracis* muscle as affected by husbandry system and sex (g 100^{-1} g FA)

	Husbandry system			Sex			Significance	
	CONV	ORG	SE	Barrow	Gilt	SE	Husbandry	Sex
Saturated fatty acid (SFA) (%)								
C10:0, decanoic	0.12	0.13	0.007	0.12	0.12	0.005	NS	NS
C12:0, dodecanoic	0.10	0.10	0.004	0.10	0.10	0.003	NS	NS
C14:0, tetradecanoic	1.39	1.48	0.04	1.46	1.41	0.030	NS	NS
C16:0, hexadecanoic	23.50	25.38	0.59	25.19 b	23.70 a	0.430	NS	*
C17:0, heptadecanoic	0.30 b	0.21 a	0.02	0.25	0.26	0.010	**	NS
C18:0, octadecanoic	13.29	13.49	0.46	13.66	13.12	0.340	NS	NS
C20:0, eicosanoic	0.16	0.17	0.008	0.17	0.16	0.005	NS	NS
Total SFA	38.85	40.97	1.04	40.94	38.88	0.760	NS	NS
Monounsaturated fatty acid (MUFA) (%)								
C16:1, palmitoleic	3.25	3.55	0.15	3.55	3.25	0.11	NS	NS
C17:1, heptadecenoic	0.27 b	0.17 a	0.01	0.22	0.22	0.01	***	NS
C18:1, oleic	40.54	39.33	1.13	40.80	39.07	0.83	NS	NS
C20:1, eicosenoic	0.69 a	0.92 b	0.03	0.84	0.78	0.02	***	NS
Total MUFA	44.75	43.97	1.23	45.41	43.31	0.90	NS	NS
Polyunsaturated fatty acid (PUFA) (%)								
C18:2 *n*-6, linoleic	11.49	11.72	0.74	10.10 a	13.11 b	0.53	NS	***
C18:3 *n*-3, linolenic	0.50 a	0.91 b	0.06	0.63 a	0.78 b	0.04	***	*
C20:2 *n*-6, eicosadienoic	0.38 a	0.54 b	0.02	0.41 a	0.50 b	0.02	***	**
C20:3 *n*-6, eicosatrienoic	0.40 b	0.22 a	0.03	0.27 a	0.35 b	0.02	***	**
C20:4 *n*-6, arachidonic	3.51 b	1.65 a	0.24	2.21 a	2.96 b	0.17	***	**
C22:6 *n*-3, docosahexaenoic	0.13 b	0.01 a	0.04	0.03 a	0.11 b	0.03	*	*
Total PUFA *n*-6	15.78	14.13	0.95	12.99 a	16.92 b	0.69	NS	***
Total PUFA *n*-3	0.63 a	0.92 b	0.07	0.66 a	0.88 b	0.05	**	**
Total PUFA	16.40	15.05	1.00	13.65 a	17.80 b	0.72	NS	***

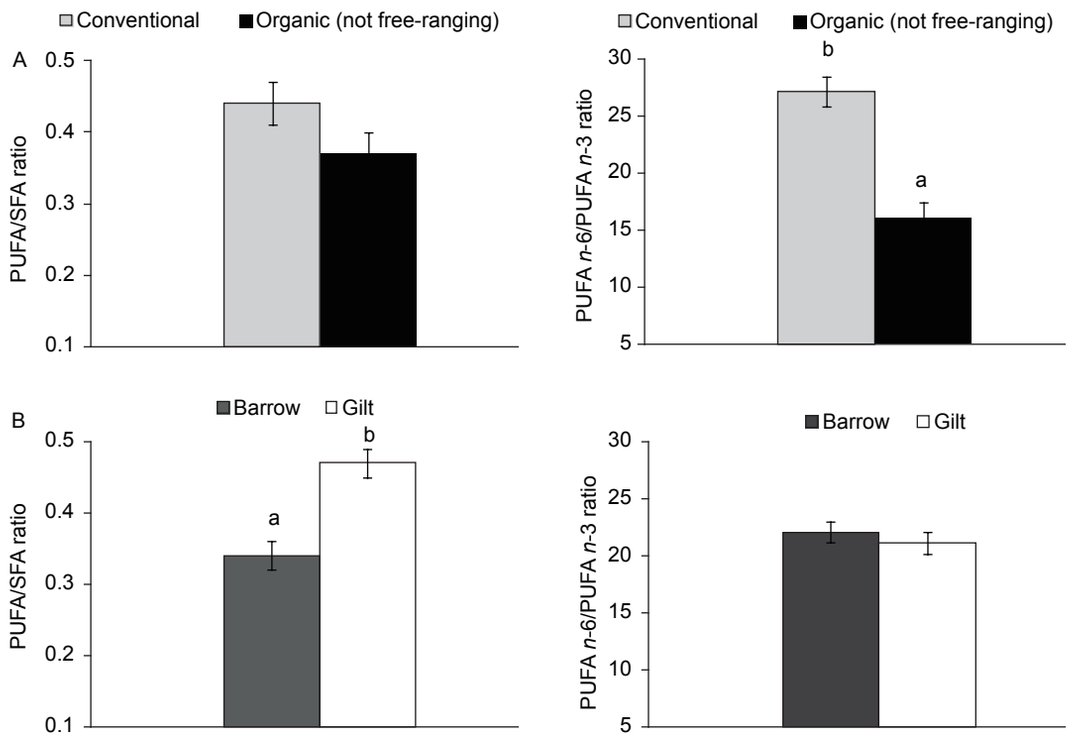

Fig. 1 Fatty acid ratios (PUFA/SFA and PUFA *n*-6/PUFA *n*-3) in *Longissimus thoracis* muscle from conventional and organic pork loin (A) and barrow and gilt pork loin (B). Within each bar chart, different letters denote statistical differences (P<0.001) between husbandry system and sex. PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid.

between sexes were observed in the PUFA *n*-6/PUFA *n*-3 ratio of *L*. *thoracis* muscle (P>0.05).

3. Discussion

3.1. Husbandry system effect

This study was primary designed to compare pork muscle characteristics from (not free-ranging) organic and conventional husbandry systems using commercial crossbreds in Spain. Latorre and Rodriguez-Sanchez (2010) evaluated the effect of husbandry system (indoor *vs*. free-range outdoor) on meat and fat quality from crossbreed pigs intended for dry-cured products in a close Spanish area. In that study, the outdoor pigs were slaughtered at 170 kg of live-weight (LW) (137 kg carcass weight) trying to resemble them to Iberian pigs. In contrast, indoor pigs were slaughtered at 130 kg of LW (99 kg carcass weight) because it is a regular slaughter weight in Spain for pigs intended for dry-cured products (i.e., for Teruel ham). In the present trial, all the pigs were slaughtered at light LW (95–105 kg) used for fresh pork production (approximately 76 kg carcass weight) to allow comparison of pork quality traits among similar sized pigs from organic and conventional husbandry. Accordingly, slaughter weight may not interfere with meat quality traits and differences, if any, might be then induced by dietary and housing factors.

The ultimate pH was lower in organic than in conventional pork samples whereas no differences were found in drip losses. In a meta-analysis of 33 published studies comparing meat characteristics from organic and conventional pig production (Apple 2013), no differences in initial and ultimate pH values were observed while the water-holding capacity of fresh pork was reduced significantly in outdoor pig production. In a recent experiment comparing (not-free ranging) outdoor and indoor Polish Landrace pigs (Maiorano *et al.* 2013), also lower ultimate pH was measured in the outdoor husbandry system (2 m^2/animal) while drip losses were similar between groups. Differences in pH could be due to the variation in muscle glycogen content: Outdoor-reared pigs could have greater glycolytic store, indicating more glycogen in the muscle at slaughter, which then results in more lactate in the post-mortem process (Bonneau and Lebret 2010).

Concerning meat colour attributes at 24 h after retail display, both pork muscle groups showed similar lightness (L*) but organic meat was less red (lower a*) and more yellow (greater b*) than conventional meat. This led to greater hue angle and chroma index (colour intensity) in organic than in conventional pork. In the above cited meta-analysis (Apple

2013), pork from pigs reared outdoors was darker (lower L*) and tended to be more yellow (greater b* values) than pork from pigs reared indoors. Interestingly, several studies reported increases of 20% or more in the redness (a*) values of pork from pigs reared outdoors but meta-analysis indicated that a* values did not differ significantly between groups. The red colour of muscle is caused by the presence of haem pigments, so that International Commission on Illumination (CIE) a* values of meat are positively correlated with the haem pigment and iron content (Estévez *et al.* 2006). In turn, these are increased by physical exercise because of increased ratio of fast-twitch oxidative to fast-twitch glycolytic muscle fibres (Petersen *et al.* 1998). However, spontaneous activity in the current organic pigs did not have carry over effect on pork redness. In a previous study, neither dietary feedstuffs nor housing enrichment for organic pigs (not free-ranging) altered pork meat colour evolution during retail storage (7 days), which should be conducted for 3 days to optimise the objective colour attributes and contents of metmyoglobin and oxymyoglobin (Alvarez-Rodriguez *et al.* 2015). The CIE b* value has been related to the intramuscular fat characteristics and the oxidative status of the myoglobin (González *et al.* 2012). Indeed, the greater intramuscular fat content of organic pork muscles may explain their greater yellowness colour.

The chemical composition of meat differed between husbandry systems, the organic pork muscles containing less moisture and crude protein and greater fat than their conventional counterparts. The literature results concerning chemical composition of meat are not conclusive, in part because the diets compared usually differ greatly in their roughage and essential aminoacid contents. These two factors have been reported to have the most important consequences on muscle traits, but their influence largely depends on husbandry methods (Lebret 2008). For instance, Hansen *et al.* (2006) showed that pigs reared in organic housing conditions (outdoor access) and fed restricted concentrate (70%) plus *ad libitum* intake of roughage (either barley/pea silage or clover/grass silage) had increased carcass lean meat content compared with pigs fed 100% concentrate and reared under either organic or conventional housing. In addition, restricted concentrate feeding did not influence meat pH or drip loss, but led to lower meat lipid content. This could explain the tendency for lower intramuscular fat content in organic meat which has been reported by meta-analysis (Apple 2013). In most lowland from North Eastern Spain, a common practice in organic pig farms is providing cereal straw as roughage source, which also serves as bedding material. Therefore, concentrate feed is not restricted and the differences observed are probably due to reduced supply in the key essential aminoacids (lysine, methionine, threonine and/or tryptophan) at the end of the fattening period. Indeed, exclusion of synthetic amino acids in *ad libitum* feeding regimes increases intramuscular fat content (Lebret *et al.* 2006; Sundrum *et al.* 2011) and could thereby improve eating quality (Bonneau and Lebret 2010). Interestingly, Sundrum *et al.* (2000) observed that combining faba beans and potato protein as protein sources were as effective as synthetic amino acid supplementation to match nutritional requirements (and also preventing excessive increases in intramuscular fat content) compared to a mixture of peas and lupines or faba beans and lupines.

The current gas chromatography procedure detected 28 FA in feed and 17 FA in *L. thoracis* muscle. The main FA in feed were (in decreasing order of importance) C18:2 *n*-6, C18:1 *cis*-9 and C16:0. The 4th FA was C18:0 in conventional feed while it was C18:3 *n*-3 in organic feed. The main FA in pork muscle were (in decreasing order of importance) C18:1 *cis*-9, C16:0, C18:0 and C18:2 *n*-6, regardless the pig husbandry system. *De novo* synthesis of C18:1 *cis*-9 from dietary carbohydrate (Enser *et al.* 1996) may explain its greatest content in pork muscles even though the greatest fatty acid in feed was C18:2 *n*-6.

Contrary to expected, the muscle content of odd-chain fatty acids (C17:0 and C17:1) was lower in organic than in conventional pork. These fatty acids have been suggested to increase due to endogenous synthesis coming from the propionic acid derived from dietary fibre fermentation in the hindgut (Díaz *et al.* 2009), although volatile fatty acids production in the caecum and proximal colon could not be related to changes in the composition of odd-chain fatty acids of the subcutaneous tissue in pigs fed sugar beet pulp and cereal straw as fibre sources in a dose response experiment (Hernández-Matamoros *et al.* 2012). Then, we hypothesized that the lowest proportion of odd-chain fatty acids in the *L. thoracis* muscle of organic pigs could be associated to decreased undigested starch rather than lower proportion of structural carbohydrates reaching the hindgut.

In the current study, the main differences in intramuscular fatty acid composition were observed in PUFA *n*-3 content, which was greater in organic than in conventional pork meat. There is no general agreement concerning the effect of husbandry system on fatty acid profile, but the most consistent result is an increase in PUFA *n*-3 and a decrease in SFA content of pork due to free-range feeding (Latorre and Rodriguez-Sanchez 2010; Tejerina *et al.* 2012) or dietary PUFA *n*-3 enrichment (Burgos *et al.* 2010). However, organic pig husbandry according to EC Regulations does not necessarily increase PUFA *n*-3 level in intramuscular fat (Karwowska and Dolatowski 2013). According to Rodríguez-Sanchez *et al.* (2011), dietary lysine restriction during the finishing period did not influence fatty acid composition of pigs. Hence, differences in the fat composition of meat might be related to other dietary nutrient differences, i.e.,

feed fatty acids.

In the present study, dietary SFA were numerically lower (nearly 5%) in organic feed but this was not translated into significant lower SFA in pork muscle. In pigs, saturated and monounsaturated fatty acids are synthesised *in vivo* and, as a result, are less readily influenced by diet than the polyunsaturated fatty acids linoleic (C18:2 *n*-6) and linolenic (C18:3 *n*-3), which cannot be synthesised and, therefore, reflect dietary intake. The longer chain (C20–22) fatty acids of the *n*-6 and *n*-3 series can be synthesised from their dietary precursors, C18:2 *n*-6 and C18:3 *n*-3, respectively (Enser *et al.* 2000). Herein, dietary PUFA *n*-6 was numerically lower in organic feed (4%) but their presence in meat did not differ statistically between groups. However, dietary PUFA *n*-3 content of organic feed was three-fold the level of conventional feed and this turned into significantly greater content of this fatty acid group in pork meat. This trait may have implications for human health, because some dietary recommendations suggest limiting the *n*-6/*n*-3 ratio at no more than 9:1 (reviewed by EFSA 2010), which would be more close to the organic PUFA profile. The greater PUFA *n*-3 content in organic feed could be due to differences in oilseeds used (without oil extraction or mechanically yielded) and the exclusive use of vegetable fat (soya oil or oleins), which is known to provide more PUFA *n*-3 content than animal or blended fat sources (FEDNA 2010). The lower long chain PUFA *n*-6 and *n*-3 in organic compared to conventional pork muscles could be explained because the 18-carbon precursor fatty acids (C18:2 *n*-6 and C18:3 *n*-3) compete within the elongation/desaturation pathway, and this imbalance may limit the production of C20:4 *n*-6 and C20:5 *n*-3 (EPA) (Wall *et al.* 2010).

3.2. Sex effect

The effect of sex on technological meat quality was more limited than that of husbandry system. Indeed, the ultimate pH, drip loss and colour attributes at 24 h post-mortem were independent of sex, as previously referenced (Rodríguez-Sanchez *et al.* 2009; Franco and Lorenzo 2013). In contrast, the chemical composition of loin meat differed between sexes, the barrows being more marbled and having lower moisture than gilts. These results are in line with Latorre *et al.* (2009) which also verified that this effect was independent of slaughter weight (120–140 kg). However, Franco and Lorenzo (2013) found minimal differences in marbling between sexes in an unselected breed (Celta pig) reared outdoors and slaughtered at 140 kg of body-weight.

Concerning intramuscular fatty acid composition, the proportion of total SFA in meat was similar in both sexes, although the content of C16:0 was greater in barrows than in gilts. Earlier studies have not reported consistent results in the difference of SFA content between sexes, with some detecting differences (Latorre *et al.* 2009; Lorenzo *et al.* 2012) but some others not (Rodríguez-Sanchez *et al.* 2009, 2011). Likewise, the MUFA content of pork muscles did not differ between sexes, a result repeatedly observed by the afore-mentioned works. In this study, all the PUFA (*n*-6 and *n*-3) were lower in barrows than in gilts. As previously discussed, the main PUFA are essential fatty acids (C18:2 *n*-6 and C18:3 *n*-3) from dietary origin. According to Latorre *et al.* (2009) and Rodríguez-Sanchez *et al.* (2011) the greater C18:2 *n*-6 in the adipose tissue of gilts would be related to their greater feed intake, and overall it would explain the greater total PUFA/SFA ratio in gilts compared to barrows. However, such response was not observed by Lorenzo *et al.* (2012), who reported lower SFA and greater PUFA *n*-6 in barrows than in gilts, perhaps because they belonged to Celta pig breed which was slaughtered at an older age (12 months of age and 115 kg of body-weight).

4. Conclusion

In summary, the loin from organic pigs at 24 h of retail display had lower pH, but it had no detrimental effects on drip loss. Concerning meat colour, it was more yellow and had more colour intensity (chroma index) than that of conventional pigs. Likewise, organic pork showed more intramuscular fat and polyunsaturated fatty acids *n*-3 content than conventional pork muscles. These results suggest that some bioactive compounds from dietary origin, i.e., linolenic acid (C18:3 *n*-3) content from dietary vegetable oils (soybean or olive olein), might be used to highlight the nutritive value of (not free-ranging) organic pork meat. Concerning the animal sex effect, gilts showed a healthier loin than barrows because it was leaner and showed a more favourable PUFA/SFA ratio.

5. Material and methods

5.1. Animals, diets and slaughter procedures

A total of 60 pigs (barrows *n*=22 *vs*. gilts *n*=38) from different 3-way crossbred genotypes were chosen from 3 conventional (*n*=31) and 2 organic farms (*n*=29) and slaughtered at the same commercial abattoir (Avinyó slaughterhouse S.A., Barcelona, Spain) at 100–105 kg of body-weight on 2 sample days between February and March 2012. Animal husbandry and slaughter procedure followed strictly EU regulations (European Union Directive No. 86/609/CEE 1986). The crossbred pigs were the progeny of purebred Pietrain or Duroc sires with Landrace×Duroc or Landrace×Large-White dams. On average, the experimental pigs had 25% of Duroc genes. All the Duroc genetic types derived from the Duroc line of Selección Batallé (Riudarenes, Girona,

Spain). Conventional and organic pigs, barrows and gilts, and the different genetic types were in the same proportion in both slaughter days. In these sampled animals, the main differences between conventional and (not-free ranging) organic pig husbandry (European Union Regulation (EC) No. 889/2008) were related to space allowance (0.70 *vs*. 2.2 m^2/pig), floor type (concrete slatted floor without outdoor area *vs*. straw deep litter indoors and concreted outdoor area) and feed ingredients (conventional feed includes oilseeds after solvent extracted oil *vs*. organic feed is composed by full oilseeds or mechanically oil extracted). In addition, organic pigs must be provided dietary roughage, which was met through cereal straw supply also serving as bedding material. In both husbandry systems, feed was composed mainly from cereals (barley, maize, wheat, and/or sorghum), oil extracted meals (soybean, sunflower, and/or canola), cereal by-products (middlings, bakery) and animal, blended or vegetable fat (soybean oil or olive olein). Organic feed did not contain synthetic aminoacids or genetically modified crop yields. Feed samples were analysed for dry matter, total nitrogen, ether extract and crude fibre content according to the AOAC methods (2000). The relative contribution of feedstuffs' groups used and proximate chemical composition of compound feeds is shown in Table 3, while average feed fatty acid composition is detailed in Table 4.

At the abattoir, animals were allowed a 3-h rest period with full access to water but not to feed. Then, pigs were stunned by CO_2 (concentration 87%) using a dip lift system, exsanguinated, scalded, skinned, eviscerated according to standard commercial procedures and split down the midline. Hot carcass weight was individually recorded before the carcass sides were refrigerated in line processing at 2°C. At approximately 1 h post-mortem, the loins were excised from the carcass and they were trimmed by expert staff of the abattoir. This consisted in eliminating part of the external fat for commercial requirements. Afterwards, individual 3 cm-cranial *L. thoracis* samples (200 g approximately) were sliced from the half left loin, packaged in polyethylene bags and stored at 4°C in darkness overnight.

Table 3 Feedstuffs and chemical composition of compound feed provided to finishing pigs in the different farms (g 100 g^{-1} fresh matter, as-fed basis unless otherwise stated)

	CONV	ORG
Feedstuffs		
Cereals	67.7±7.6	62.1±9.7
Oil-extracted meals	18.7±2.2	12.2±12.2
Pea or protein concentrate feed	5.0±0.0	28.4±3.8
Cereal by-products	8.2±5.0	8.0±2.8
Animal or blended fat	1.1±0.2	
Vegetable oils		2.9±1.5
Dicalcium biphosphate	0.5±0.2	1.0±0.1
Calcium carbonate	1.0±0.1	0.9±0.1
Sodium chloride	0.4±0.0	0.4±0.0
Vitamin and mineral premix	0.3±0.03	0.4±0.1
L-Lysine (HCl 78% CP/Liquid 50% CP)	0.31±0.16	
DL-Methionine hydroxyanalogue	0.04±0.01	
L-Threonine	0.06±0.05	
Analyzed nutrient composition		
Dry matter	90.0±0.8	90.1±0.3
Crude protein (N×6.25)	18.5±2.4	15.3±1.6
Crude fibre	4.3±1.2	5.5±0.5
Ether extract	4.7±1.2	3.9±0.6
Ash	5.7±0.4	7.3±2.2

Data are means±standard deviation. The same as below.

Table 4 Feed fatty acid composition (g 100 g^{-1} fatty acids)

	CONV	ORG
C10:0 (decanoic)	0.09±0.06	0.03±0.00
C12:0 (dodecanoic)	0.33±0.42	0.03±0.00
C13:0 (tridecanoic)	0.04±0.00	0.04±0.01
C14:0 (tetradecanoic)	0.92±0.35	0.22±0.06
C16:0 (hexadecanoic)	15.38±0.75	12.14±0.67
C17:0 (heptadecanoic)	0.18±0.03	0.10±0.01
C18:0 (octadecanoic)	4.50±0.84	2.61±0.26
C20:0 (eicosanoic)	0.24±0.02	0.32±0.05
C21:0 (heneicosanoic)	0.01±0.00	0.13±0.12
C22:0 (docosanoic)	0.14±0.00	0.27±0.03
C24:0 (tetracosanoic)	0.15±0.06	0.24±0.08
Total SFA	21.98±2.30	16.14±0.91
C14:1 *cis*-9 (myristoleic)	0.08±0.05	0.02±0.01
C16:1 *cis*-9 (palmitoleic)	1.20±0.18	0.39±0.15
C17:1 *cis*-10 (heptadecenoic)	0.20±0.04	0.10±0.03
C18:1 *trans*-9 (elaidic)	0.13±0.11	0.01±0.01
C18:1 *cis*-9 (oleic)	22.94±2.44	25.93±8.22
C20:1 *cis*-11 (gondoic)	0.70±0.10	0.66±0.13
C22:1 *cis*-13 (erucic)	0.04±0.01	0.18±0.20
C24:1 *cis*-15 (nervonic)	0.02±0.02	0.05±0.02
Total MUFA	25.30±2.56	27.33±8.38
C18:2 *cis*-9, 12 *n*-6 (linoleic)	48.45±3.69	44.24±11.58
C18:2 *trans*-9, 12 *n*-6 (linolenelaidic)	0.02±0.02	0.01±0.01
C18:3 *cis*-6, 9, 12 *n*-6 (gamma-linolenic)	0.02±0.01	0.03±0.00
C18:3 *cis*-9, 12, 15 *n*-3 (linolenic)	3.80±0.94	9.46±3.57
C20:2 *cis*-11, 14 *n*-6 (eicosadienoic)	0.27±0.03	0.20±0.05
C20:3 *cis*-11, 14, 17 *n*-3 (eicosatrienoic)	0.07±0.18	2.54±3.46
C20:4 *cis*-5, 8, 11, 14 *n*-6 (arachidonic)	0.09±0.02	0.00±0.00
C20:5 *cis*-5, 8, 11, 14, 17 *n*-3 (eicosapentaenoic, EPA)	0.01±0.01	0.04±0.04
C22:6 *cis*-4, 7, 10, 13, 16, 19 *n*-3 (docosahexaenoic, DHA)	0.01±0.00	0.01±0.01
Total PUFA *n*-6	48.84±3.69	44.48±11.55
Total PUFA *n*-3	3.88±0.84	12.05±5.58
Total PUFA	52.72±4.51	56.53±8.81
Total PUFA/SFA ratio	2.44±0.43	3.52±0.65
PUFA *n*-6/PUFA *n*-3 ratio	13.00±2.32	4.49±2.41

5.2. Technological meat quality analyses

At 24 h post-mortem, ultimate pH of these samples was measured in the laboratory with a pH-meter equipped with

a spear-tipped probe (Testo 205, Testo AG, Lenzkirch, Germany). Pork loin pieces were then cut by half and placed at random on polystyrene white trays. The technological *L. thoracis* muscle colour was measured after 1 h of blooming the inner surface with a Konica Minolta CM-700d spectrophotometer (Konica Minolta Sensing Inc., Osaka, Japan) in the CIELAB space (CIE 1986) with a measured area diameter of 8 mm, including specular component and a 0% ultraviolet, standard illuminant D65, which simulates daylight (colour temperature 6504 K), observer angle 10° and zero and white calibration. The CIE lightness (L*), redness (a*), and yellowness (b*) colour-space values were reported as the average of three randomly selected readings taken on each slice without any covering film, and mean values were used for statistical analysis. Hue angle (H*) was calculated as: $H^*=\tan^{-1}(b^*/a^*)\times 57.29$, expressed in degrees, whereas chroma (C*) (colour intensity, also known as saturation index) was calculated as: $C^*=\sqrt{a^{*2}+b^{*2}}$.

After colour measurement, drip loss was determined by centrifugation in a muscle sample, according to a modification of the method used by Kristensen and Purslow (2001). Briefly, raw meat samples were weighed, cut carefully with a scalpel to avoid slight water losses, and transferred to centrifugation tubes which allow separating meat from exudate during centrifugation. The tubes were centrifuged at 500×g for 10 min at 4°C. Centrifugation losses were calculated as the percentage of initial sample weight (approximately 0.1 g).

Another small *L. thoracis* sample (2 g) was used to analyse subsequently moisture according to the AOAC (2000) and the remaining sample was freeze-dried and pulverized using an electric grinder. A representative aliquot from the pulverized freeze-dried muscle was used for protein (N×6.25) analysis by automated Kjeldahl method.

5.3. Fat and fatty acid analyses of feed and meat

Feed lipids were extracted using a chloroform/methanol/water mixture (2/2/1.8, v/v/v) (Hanson and Olley 1963). Feed and meat fatty acid (FA) methyl esters were directly obtained by transesterification using a solution of boron trifluoride 20% in methanol (Rule 1997), followed by 2 h heating at 80°C, centrifugation at 2 500 r min^{-1} during 5 min and collection of the final supernatant. Analysis of FA methyl esters were performed in duplicate by GC with a 30 m×0.25 mm capillary column SP2330 (Supelco, Tres Cantos, Madrid) and a flame ionization detector with helium as the carrier gas at 1 mL min^{-1}. The oven temperature program increased from 150–225°C at 7°C min^{-1}, and the injector and detector temperatures were both 250°C (Tor *et al.* 2005).

The quantification was carried out through area normalization after adding into each sample 1,2,3-tripentadecanoylglycerol as internal standard. IMF was calculated as the sum of each individual FA expressed as triglyceride equivalents (AOAC 2000, Chap. 39), following the methodology described in Bosch *et al.* (2009). In addition, crude fat of meat was analysed by Sohxlet method (AOAC 2000) to verify the correlation between both analytical methods. Fatty acid composition was calculated as the percentage of each individual acid relative to total FA and expressed as g 100 g^{-1} FA. The proportion of polyunsaturated (PUFA) (C18:2 *n*-6; C18:3 *n*-3; C20:2 *n*-6; C20:3 *n*-6; C20:4 *n*-6; C20:4 *n*-6 and C22:6 *n*-3), monounsaturated (MUFA) (C16:1 *n*-7; C17:1 *n*-7; C18:1 *n*-9; and C20:1 *n*-9) and saturated (SFA) (C10:0; C12:0; C14:0; C16:0; C17:0; C18:0; and C20:0) fatty acid contents were calculated. The PUFA/SFA and PUFA *n*-6/*n*-3 ratios were calculated accordingly.

5.4. Statistical analyses

Data were analysed through analysis of variance with a general linear model (GLM procedure), using the SAS statistical software (SAS Institute Inc., Cary, NC, USA), including the husbandry system and sex as fixed effects and the percentage of Duroc genes as a covariate:

$$y_{ijk}=\mu+\alpha_i+\beta_j+b\delta+(\alpha\beta)_{ij}+\varepsilon_{ijk}$$

Where, y_{ijk} is dependent variable, μ overall mean, α_i husbandry system effect, β_j sex effect, δ percentage of Duroc genes, b regression coefficient and ε_{ijk} residual error.

Data are reported as least square means and their associated standard errors. The level of significance was set at 0.05.

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