Effect of age and feeding area on meat quality of wild boars

Martina Pedrazzoli , Alessandro Dal Bosco , Cesare Castellini, David Ranucci , Simona Mattioli, Mariano Pauselli & Valentina Roscini

Published online: 22 Feb 2017.

Submit your article to this journal

Article views: 113

View related articles

View Crossmark data

Taylor & Francis
Taylor & Francis Group

PAPER

Effect of age and feeding area on meat quality of wild boars

Martina Pedrazzoli[a] , Alessandro Dal Bosco[a] , Cesare Castellini[a], David Ranucci[b] , Simona Mattioli[a], Mariano Pauselli[a] and Valentina Roscini[a]

[a]Dipartimento di Scienze Agrarie, Alimentari ed Ambientali, University of Perugia, Perugia, Italy; [b]Dipartimento di Medicina Veterinaria, University of Perugia, Perugia, Italy

ABSTRACT

The stomach content and samples of *Longissimus dorsi* muscle of 32 feral wild boars were collected in two different feeding areas (forest and farmland) of Umbria region (Italy). The animals from each feeding area were divided into two age classes: class 1 (12–24 months of age; 48 kg average weight) and class 2 (animals older than 2 years of age; 84 kg average weight). The major food categories consumed were hard mast and crops (89.02–75.98%). The L*(lightness) and a*(red to green colour) values of the meat were affected by the feeding area as well as the b*(yellow colour) value; the age significantly affected only the a* and the b* value of the meat. The α-tocopherol was the most abundant vitamin E homologue, ranged between 520.63 and 1881.33 ng/g and was higher in farmland areas. The index of lipid oxidation (TBARS) ranged from 0.093 and 0.140 mg MDA/kg and was higher in wild boars from farmland. The monounsaturated fatty acids (MUFA) ranged between 38.36 and 46.75% and were higher in wild boar of class 2. The total polyunsaturated fatty acids (PUFA) as well as PUFAn-6 were affected by age, while PUFAn-3 was only affected by feeding area and ranged from 0.91 and 1.99 in farmland and forest, respectively. The feeding area affects the intramuscular fat contents in terms of nutritional characteristics of the meat: the n-6/n-3 ratio that was lower in meat from animals hunted in the forest area ($p \leq .001$), as well as the ARA/(EPA + DHA) ratio ($p \leq .01$).

Introduction

Wild boar has been increasing in numbers for the last three decades in Europe (Saez-Royuela & Telleria 1986; Feichtner 1998; Maillard et al. 2010; Wotschikowsky 2010) and in Italy (Monaco et al. 2003). Several factors, such as the absence of natural predators, rural depopulation, expansion of forest areas and spread of game-managed areas, promoted a widespread intensifying of wild boar densities (Sales & Kotrba 2013). Consequently, during the last 10 years, the total wild boar harvest increased by almost 70% (Ramanzin et al. 2010), with a consistent increase in their meat availability. The meat consumption of wild boar in Italy has increased in recent years to approximately 0.2 kg per capita/year; this value is low if compared with pork and poultry consumption but in some regions rises to higher levels, especially in hunters' families (1.0–4.0 kg per capita/year; Ramanzin et al. 2010).

Consumers are increasingly becoming concerned about healthy products and the demand for food low in energy and cholesterol and balanced in n-6/n-3 ratio is continuously growing (MacRae et al. 2005). Game meat are considered healthy food (Hoffman & Wiklund 2006), characterised by high-nutritional value and special sensory properties (Soriano et al. 2006). Furthermore, consumers are also increasingly concerned about the environment and therefore they are interested in products made with a low input, such as organic and natural production methods (Steenkamp 1997; Dransfield 2003).

Because of these positive factors meat from wild animals could be more widely consumed: wild animals can perform their natural behavioural patterns without limitations, have unlimited access to natural feed and they are naturally selected. In spite of consumer's interest for game and wild boar meat, studies and information on its nutritional quality, particularly of feral wild boars are scarce. Several studies have been carried out on characteristics of meat of farmed wild boars compared with pigs and of feral wild boars in

Europe (Marchiori & Felicio 2003; Szmańko et al. 2007; Quaresma et al. 2011; Razmaite et al. 2012; Dannenberger et al. 2013) but data on the macro- and micronutrient compositions and fatty acid profiles of feral wild boars in Italy are scarce.

In nature, wild boar has an opportunist and omnivorous feeding behaviour, eat a great variety of vegetable material including herbs, grains and seeds, roots, soft and hard mast, but also insects, earthworms, slugs and small mammals, eggs and nestlings of ground-nesting birds, furthermore cultivated crops can represent an important dietary intake (Laurent & Timothy 2003).

The objective of this study was to investigate the effect of age and feeding area on physical and chemical characteristics, oxidative status and fatty acid composition of *Longissimus dorsi* (LD) muscles of wild boar.

Materials and methods

Animals and samples

The LD samples were collected from a total of 32 wild boards in the Umbria region (Italy) in two different feeding areas (mainly characterised by forest and farmland), with a high percentage of land cover characterised by forest (41%) and cultivated fields, orchard and vineyard (43%), respectively. The forest area was located in the north-east of Umbria Region (district of Gubbio, PG) and it was mainly featured by *Quercus pubescens, Quercus cerris, Ostrya carpinifolia, Quercus robur*. The farmland area was chosen in the west of Umbria Region, in the district of Trasimeno lake characterised by cultivated fields (*Zea mais, Helianthus annuus, Triticum, Hordeum vulgare, Vicia faba minor, Vitis vinifera, Olea europaea, fruit trees*) interspersed with woods of limited size (*Quercus pubescens, Quercus ilex, Ostrya carpinifolia* mainly).

Wild boards were shot in October, during the hunting season, in accordance with the Italian and regional hunting rules (Law n. 157/92 Official Journal of Italian Republic n. 46, 25-2-1992 - Ordinary supplement n. 4).

The samples from each feeding area were divided into two age classes through the analysis of tooth eruption according to Mattioli and De Marinis (2009): class 1 (animals of 12–24 months of age) and class 2 (animals older than 2 years of age). The average weight of wild boars was 48 and 84 kg (age class 1 and 2, respectively).

The LD muscle used for the analysis was taken from the last thoracic vertebra to the 4th lumbar vertebra. Samples of all the animals were collected after each hunting session, placed in polyethylene plastic bags and transported to the laboratory of the Department of Agricultural, Food and Environmental Science of Perugia in refrigerated bags, then cooled at 4 °C for 24 h.

Diet composition identification

Half-litre samples were taken from the stomach content and analysed as described by Merta et al. (2014). The diet of the wild boar was calculated as percentage of dry matter of each food categories or fraction to the total weight of all food items. The food items were grouped in eight categories: hard mast (acorns and seeds), crops (grains and legumes), browse (feed fractions as wood, bark and leaves), soft mast (grapes, berries, olives, drupes), herbage (all the ground flora), mammals and birds, invertebrates (insects, earthworms, mollusks), others (no identified plants, stones and minerals).

Chemical and physical characteristics of LD muscle

Proximal composition (moisture, protein, lipid and ash) was performed in duplicate, according to the Association of Analytical Chemists methods (AOAC 2000). The moisture content was determined by oven drying meat samples (125 °C for 2 h) (method 950.46). The fat content was determined gravimetrically using ether solvent extraction (method 960.30). The protein content was obtained multiplying the total Kjeldahl nitrogen (method 992.15) with a coefficient factor of 6.25. The ash content was determined using a muffle furnace at 600 °C (method 923.03).

The pH was measured using a penetrating electrode connected to a portable pHmeter (Thermo scientific Orion star A111).

The colour traits were assessed on meat samples following the CIE Lab system (Commission International de l'Eclairage 1976), using a Minolta chromometer CR-200 (Azuchi-Machi Higashi-ku, Osaka 541, Japan; light source of D65, standard observer of 10°, 45°/0° geometry, in light surface, calibrated against a standard white tile) on muscle subjected to a 30 min blooming period at 7 °C. To avoid variation in the colour differences within the same samples, three measures from different points of the samples were performed and the mean of the results were considered. The results were expressed as lightness (L*), redness (a*), and yellowness (b*). The hue value ($\tan^{-1}$ b*/a*) and saturation index, or chroma (($a^{*2} + b^{*2})^{1/2}$), were also calculated.

The water holding capacity (WHC), the cooking loss and the shear force were performed in duplicate. The WHC was estimated by placing 1 g of muscle on tissue paper inside a tube and centrifuging for 4 min at 1500 g. The water remaining after centrifugation was quantified by drying the samples at 70 °C overnight. WHC was calculated as follows: [(weight after centrifugation–weight after drying)/initial weight × 100] (Castellini et al. 1998).

The cooking loss was estimated as described by Honikel (1998). Briefly, meat samples (average weight: 100 ± 2 g) were held in vacuum plastic bags, cooked in a water-bath at 80 °C for 1 h and then cooled under running tap water for 30 min. Samples were weighed before and after the test, and losses were calculated as [(initial weight − final weight)/initial weight) × 100].

The shear force determination, expressed in kg/cm^2, was performed according to Ranucci et al. (2015). Three cylindrical cores (Ø 1.25 cm), cut parallel to the LD muscle fibres, were obtained from cooking loss samples and tested using a INSTRON universal testing machine equipped with a Warner–Bratzler (WB) shear device (INSTRON model 1011, INSTRON Instrument, Norwood, MA; 50 kg loading range, shearing velocity 100 mm/min).

Oxidative status of LD muscle

Tocopherols and retinol were quantified by HPLC (Schuep & Rettenmeier 1994). Briefly 2 g of tissues was accurately weighed and homogenised in 2 mL of distilled water and 5 mL of ethanol solution of 0.06% BHT was added. The mixture was saponified with water KOH (60%) at 70 °C for 30 min and extracted with hexane/ethyl acetate (9:1, v/v). It was centrifuged at 5000 g × 10 min and then the supernatant was transferred into a glass tube. Five millilitres of the mixture was dried under N_2 and resuspended in 200 μL of acetonitrile. A 50 μL volume of filtrate was then injected into the HPLC/FD-UV (Jasco, pump model PU-1580, equipped with an autosampler system, model AS 950-10, Tokyo, Japan) on an Ultrasphere ODS column (250 × 4.6 mm internal diameter, 5 μm particle size; CPS Analitica, Milan, Italy). Tocopherols and α-tocotrienol was identified using a FD detector (model Jasco, FP-1520) set at excitation and emission wavelength of 295 and 328 nm, respectively, whereas the retinol was identified with an UV detector set at 350 nm. All peaks were quantified using external calibration curves (Sigma-Aldrich, Bornem, Belgium) and expressed as ng/g of meat.

The extent of lipid oxidation was evaluated with a spectrophotometer set at 532 nm (Shimadzu

Corporation UV- 2550, Kyoto, Japan) that measured the absorbance of thio-barbituric acid-reactive substances (TBARS) and a 1,1,3,3-tetraethoxypropane calibration curve (Ke et al. 1977). Oxidation products were quantified as malondialdehyde equivalents (mg MDA/kg muscle). All the samples were performed in duplicate.

Fatty acids composition of LD muscle

The meat lipid extraction was performed according to Folch et al. (1957) method and esterification was according to Christie (1982). The trans-metilation procedure was obtained with nonadecanoic acid methyl esters (Sigma Chemical Co.) as the internal standard. The fatty acid composition was determined using gas-chromatograph Varian (CP-3800) equipped with a FID and a capillary column of 100 m length ×0.25 mm ×0.2 μm film (Supelco, Bellefonte, PA). Helium was used as carrier gas with a flow of 1.5 mL/min. The split ratio was 1:80. The oven temperature was programmed at 40 °C and held for 1 min, then increased up to 163 °C at a rate 2 °C/min, held for 10 min, increased up to 180 °C at a rate 1.5 °C/min held for 7 min, increased up to 187 °C at a rate 2 °C/min held for 2 min, and then increased up to 230 °C at a rate 3 °C/min held for 25 min. The injector and detector temperatures were set at 270 °C and 300 °C, respectively. Individual FAME were quantified using C19:0 methyl ester (Sigma Chemical Co.) as internal standard; their identifications was done by comparison the relative retention time of peaks in the sample and those of standard (FAME Mix Supelco, Bellefonte, PA; 4:0–24:0) plus cis-9, cis-12 C18:2; cis-9 cis-12 cis-15 C18:3; cis-9 cis-12 cis-15 C18:3 (all from Sigma-Aldrich, St. Louis, MO). Fatty Acids were expressed as g/100g of fatty acids. In order to evaluate some health parameters, the n-6/n-3 ratio as cardiovascular diseases risk index (Simopoulos 2000) and ARA/(EPA + DHA) ratio as substrate availability and desaturase ability were calculated. All the samples were performed in duplicate.

Statistical analysis

Data were analysed using GLM procedure of Stata software system (Stata, 2015); the effects of age and feeding area were estimated using a two-way ANOVA model, including interaction. Since the interaction was never significant it was eliminated from the model.

The means of values and the pooled standard error (SE) are reported in the tables. Post-hoc tests were performed using the Tukey–Kramer correction for multiple tests at a significance level of $p \leq .05$.

Results and discussion

Diet composition

The dry weight percentages of each categories of food identified in samples of stomach contents obtained from wild boards of age class 1 and 2, are showed in Figures 1 and 2.

Hard mast (acorns mainly) and crops (grain and legumes) were the major feed categories consumed by wild boar; the highest proportion of hard mast was found in wild boars from forest (age class 1: 89.02%,

age class 2: 84.64%; $p \leq .05$) whereas crops was consumed in highest proportion by wild boars from farmland (age class 1: 75.98, age class 2: 62.91; $p \leq .05$). The grains found in the stomach of wild boars from farmland were mainly represented by corn; it is supposed that in autumn wild boars can consume the remnants of food plants left on unplugged fields where crops had earlier been harvested (Merta et al. 2014), furthermore, it is necessary to consider the widespread practice of artificial provisioning by hunters, with the aim of attracting wild boar to particular

Figure 1. Dry weight percentages of each categories of food identified in samples of stomach contents obtained from wild boards of age class 1. Means with * differ: $p < .05$.
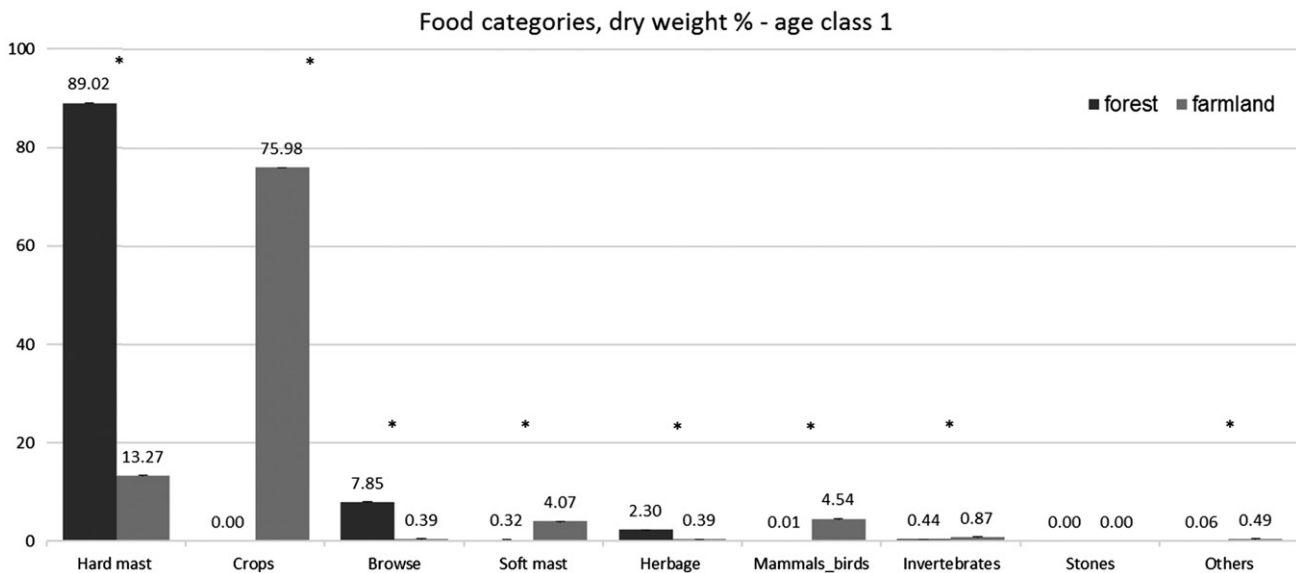

Figure 2. Dry weight percentages of each categories of food identified in samples of stomach contents obtained from wild boards of age class 2. Means with * differ: $p < .05$.
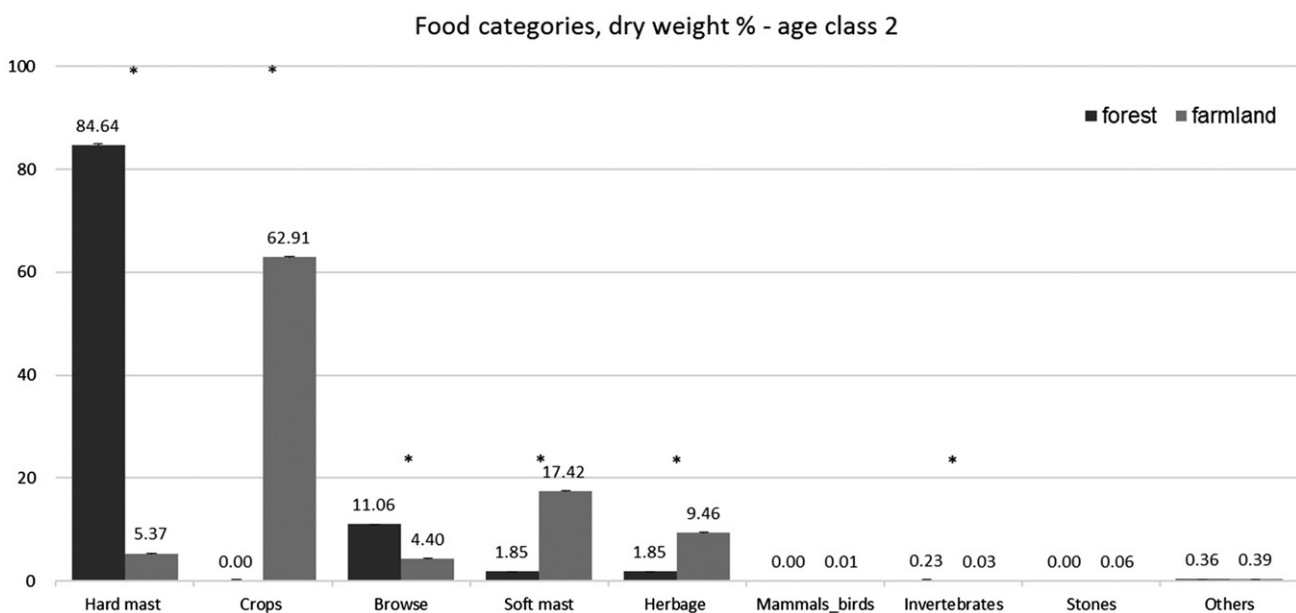
areas, or sometimes, reducing the damage that they inflict on agricultural crops (Vassant & Breton 1986). Since the food provided by hunters is usually cereals (in most cases, corn) it is often impossible to know whether cereals found in the stomachs of wild boar result from raiding of crops or from deliberate provisioning.

As described by Genov (1981), wild boar performs different feeding strategies in relation to food availability: the use of one or another plant depends on its abundance and also on its accessibility.

Wild boars of age class 1 tended to have a less varied diet compared to adult, maybe due to the less explorative behaviour of young animals indeed adult subjects seem to have a greater exploratory attitude than the young one: the diet of adult showed higher percentage of other categories like browse, soft mast, mammals and birds. Furthermore, in farmland, wild boars can approach to cultivated fields, vineyards and orchards (as showed by the highest percentage of soft mast as grapes, olives, herbage, mammals and birds) while a higher proportion of browse ($p \leq .05$ – mainly leaves) was found in wild boar from forest (age class 1: 7.85%, age class 2: 11.06%), comparing to wild boar from farmland (age class 1: 0.39%, age class 2: 4.40%) either in young and adult.

Chemical and physical characteristics of LD muscle

The effect of age and feeding area on chemical and physical characteristics of LD muscle of wild boars is summarised in Table 1. The water content ($p \leq .001$), protein ($p \leq .01$) and intramuscular fat ($p \leq .001$) were significantly affected by the age. Lipids level varied from 0.69% up to 1.52% and was higher in adult (age class 2). These results were lower respect what reported by Dannenberger et al. (2013) in LD muscle and Quaresma et al. (2011) in *Psoas major* muscles even if they reported a large variation in intramuscular fat (from 1.1% to 7.6%). LD muscle of young boars had higher amount of moisture and, in forest, a lower content of protein.

The ultimate pH ranged between 5.46 and 5.72 according to Szmańko et al. (2007) and Marchiori and Felicio (2003).

The L*(lightness) and a*(red to green colour) values were affected by the feeding area ($p \leq .01$) as well as the b*(yellow to blue colour) value ($p \leq .05$); the age affected only the a* value ($p \leq .001$) and the b* value ($p \leq .05$). Meat of wild boars older than 2 years in farmland was slightly brighter than meat of wild boars in forest (age class 1 and 2) and with higher a* and b* values. The higher b* value could be explained by carotenoids present in corn grain and relationship between b* value and yellow plant pigments (Humphries et al. 2004).

The WHC tended to be lower at older age and in farmland ($p > .05$) and values from wild boar of age class 1 are in agreement with Szmańko et al. (2007) in wild boar of 9 months of age.

The age and the feeding area did not affect the cooking loss (from 26.35 to 29.57%) and the shear force.

Oxidative status and antioxidant compounds of LD muscle

The concentrations of some fat-soluble vitamins (retinol, α-tocotrienol, δ-tocopherol, γ-tocopherol and

Table 1. Chemical and physical characteristics of *Longissimus dorsi* muscle in wild boar of different age and feeding area.

Age class	1		2		p		
Feeding area	Forest	Farmland	Forest	Farmland	Age	Feed	SE
Moisture, %	74.60[b]	74.26[b]	73.60[a]	73.10[a]	***	ns	0.21
Protein, %	23.41[a]	23.98[b]	24.09[b]	24.30[b]	**	**	0.15
Lipid, %	0.85[ab]	0.69[a]	1.19[ab]	1.52[b]	***	ns	0.13
Ash, %	1.14[b]	1.07[a]	1.13[b]	1.07[a]	ns	**	0.01
pH	5.72	5.63	5.46	5.67	ns	ns	0.08
L*	42.42[a]	46.70[ab]	43.39[a]	50.05[b]	ns	**	1.76
a*	15.72[a]	16.53[a]	17.68[a]	22.33[b]	***	**	0.98
b*	4.55[a]	4.23[a]	4.99[a]	8.12[b]	*	*	0.90
WHC, %	56.26	55.09	53.93	51.49	ns	ns	1.79
Cooking loss, %	26.35	28.79	29.57	27.94	ns	ns	1.17
Shear force, kg/cm^{2}	3.56	3.48	3.66	3.33	ns	ns	0.33

$n = 8$ animals per each group performed in duplicate; SE = Pooled standard error.
Age class 1: 12–24 months of age; age class 2: older than 2 years.
Means with different superscript within the same row differ: $p < .05$, $p \leq .01$, $p \leq .001$.
*$p \leq .05$.
**$p \leq .01$.
***$p \leq .001$.
ns: Not significant.

Table 2. Antioxidant compounds of *Longissimus dorsi* muscle in wild boar of different age and feeding area.

Age class	1		2		p		
Feeding area	Forest	Farmland	Forest	Farmland	Age	Feed	SE
Retinol, ng/g	1119.84[b]	1351.58[c]	1087.09[b]	692.90[a]	*	**	188.86
alpha-T_3, ng/g	1.49[a]	7.30[c]	1.45[a]	2.11[b]	**	***	0.75
delta-T, ng/g	0.89	1.46	0.48	2.29	ns	ns	0.63
gamma-T, ng/g	33.76[d]	12.96[b]	27.57[c]	7.25[a]	**	***	2.22
alpha-T, ng/g	656.07[b]	1881.33[d]	520.63[b]	1669.31[c]	**	***	123.19
TBARS, mg MDA/kg	0.093[a]	0.135[c]	0.117[b]	0.140[c]	ns	ns	0.023

$n = 8$ animals per each group performed in duplicate; SE = Pooled standard error.
Age class 1: 12–24 months of age; age class 2: older than 2 years.
Means with different superscript within the same row differ: $p < .05$, $p \leq .01$, $p \leq .001$.
*$p \leq .05$.
**$p \leq .01$.
***$p \leq .001$.
ns: Not significant.

α-tocopherol) in LD muscle of wild boars are shown in Table 2.

The α- and γ-tocopherol were the most abundant vitamin E homologues in meat and were affected by age ($p \leq .01$) and the feeding area ($p \leq .01$). At this regard Dannenberger et al. (2013) showed that age did not affect the α- and γ-tocopherol concentrations in *Psoas major* muscle whereas, Quaresma et al. (2011) found a higher vitamin E contents of both α- and γ-tocopherols in adult animals. Such differences may be consequence of several factors like different feeding habits and different metabolic rates between adults and youngsters.

The α-tocopherol concentration in wild boars of age class 1 and 2 from forest was 3-fold lower than in farmland at the same age; α-tocotrienol concentrations in young wild boar (age class 1) from forest was 5-fold lower than in farmland, whereas the γ-tocopherol, both in young and adult, was higher in forest.

This difference could be due to the feeding strategies of wild boars, that is related to abundance in a given area and also on its accessibility (Genov 1981).

At this regard, the γ-tocopherol is produced by many plants and it is the primary tocopherol found in the lipid fraction of many seeds and nuts, such as soybeans, walnuts and acorn (Machlin 1980). Rey et al. (2006) reported that pigs raised *free-range* had higher γ-tocopherol concentration in muscle and subcutaneous fat than conventional pigs confirming that the feeding intake affects the α- and γ-tocopherol concentrations due to the high content of γ-isomer in acorns.

As previously reported, the wild boar from forest ate higher amount of hard mast, particularly acorn, rich in such vitamin E isoform. On the contrary, the higher content of α-isoform in wild boar from farmland should be connected on one side with the higher intake in herbage and soft mast, and on the other side to the presence of other antioxidants, as phenolic compounds, which are able to protect vitamin E

throughout the gastrointestinal and circulatory transit until it is stored in cellular membranes.

Moreover, the higher intake of cereal seeds in wild boar from farmland could explain the major deposition of α-tocotrienol in the meat, being tocotrienols more abundant than tocopherols in cereal seeds, respect to grass and fruits (Machlin 1980).

It should be underlined that not all the vitamin E isomers have the same antioxidant activity; Serbinova et al. (1991) reported that α-tocotrienol is 1.5-fold more active than α-tocopherol in scavenging peroxyl radicals.

Moreover, it has been already shown that isoforms of the vitamin E are not redundant with respect to their biological functions (Qureshi et al. 1991; Parker et al. 1993). Indeed, a part the antioxidant role, all the other non α-isoforms have other relevant functions (Guallar et al. 2005); for example, the γ-tocopherol and other isoforms are stronger inhibitor of cyclooxygenase and lipoxygenase than α-tocopherol and have unique bioactivities that may be important for improving human health (Jiang et al. 2001; Dietrich et al. 2006).

The retinol (vitamin A) concentrations were affected by the feeding area ($p \leq .01$) and by the age ($p \leq .05$). Retinol is an important antioxidant compound which is a normal constituent of the blood and tissues of humans, cows, birds, fish and some crustaceans (Olson 1989). It is converted by α- and β-carotene, primarily in the intestinal mucosa but also, to some extent, in the liver and other organs (Olson 1989).

The highest retinol concentration was detected in young wild boar from farmland and the lowest in adult wild boars from the same feeding area. With respect to the feeding area, in forest the concentration of retinol was lower than farmland in young animals but higher in adult. Despite the lower antioxidant amount in the meat of wild boars from forest, their TBARS level was lower ($p \leq .01$). Discrepancy between

the amount of total tocopherols and the extent of lipid peroxidation could be due to different facts. One reason could be due to the higher PUFA concentration of animal from farmland feeding area. The higher lipid oxidation in wild boar from farmland could be also affected by the higher motility inducted before shooting. Indeed, even if the hunting method is the same, there are other factors that could involve the *pre-mortem* stress such as duration of chase with dogs before shooting or the animal recovery after a not fatal shooting.

Fatty acids profile of LD muscle

The fatty acid composition (Table 3) of wild boar LD muscle found in this study was within the range of values reported by other Authors (Quaresma et al. 2011; Razmaite et al. 2012; Dannenberger et al. 2013).

The total saturated fatty acids (SFA) ranged between 33.90 and 37.62% of the total fatty acids. Among them, C16:0 and C18:0 were the most abundant according to Dannenberger et al. (2013) and Razmaite et al. (2012). All the other SFA showed were very low percentage. Among them, C17:0 and C21:0 were influenced by age and they are higher in younger animal.

The total monounsaturated fatty acids (MUFA) were influenced by age ($p \leq .05$) and were higher in wild boar aged more than 24 months. The main MUFA was the oleic acid ($18:1^{9c}$), the highest amount was detected in wild boar of age class 2. These results are in accordance with Razmaite et al. (2012) who found an increase of the MUFA and oleic acid when the body weight increases. Even in domestic pigs, as the live weight increases, the intramuscular fatty acid composition changes with an increase in oleic acid (Kouba et al. 2003; Wood et al. 2008). The high amount of oleic acid might be related to the abundance of acorns, especially in forest, as well as the abundance of crop residues, included sunflowers seeds, corn and olives, especially in farmland, indeed hard mast, included acorns, represents the major feed categories in the diet of wild boars from forest (86.83%), while crops represents the major food categories in the diet of wild boars from farmland (69.4%).

Cava et al. (1997) reported that acorn fatty acid profile is dominated by oleic acid (63.8%) followed by linoleic acid (16.1%) and palmitic acid (14.6%).

The total polyunsaturated fatty acids (PUFA) and PUFAn-6, were affected by age ($p \leq .01$), while PUFAn-3 was only affected by feeding area ($p \leq .05$).

In particular, the linoleic acid (LA, C18:2n-6) was more abundant in young animal respect to adults

Table 3. Fatty acids profile (g/100g) of *Longissimus dorsi* muscle in wild boar of different age and feeding area.

Age class	1		2		p		
Feeding area	Forest	Farmland	Forest	Farmland	Age	Feed	SE
C14:0	0.45	0.43	0.61	0.55	ns	ns	0.16
C16:0	20.91	20.20	22.53	20.17	ns	ns	1.69
C18:0	13.98	13.96	13.50	12.35	ns	ns	1.40
Others	1.25[b]	1.28[b]	0.98[a]	0.84[a]	*	ns	0.34
$\sum$ SFA	36.59	35.85	33.90	37.62	ns	ns	4.17
C14:1	0.03	0.01	0.05	0.02	ns	ns	0.02
C16:1Δ^9	2.13[ab]	1.70[a]	2.96[b]	2.80[b]	**	ns	0.75
C18:1Δ^{9c}	37.34[a]	35.77[a]	41.41[b]	43.23[b]	*	ns	5.92
Others MUFA	0.90[b]	0.88[b]	0.66[a]	0.69[a]	**	ns	0.16
$\sum$ MUFA	40.40[a]	38.36[a]	45.08[b]	46.75[b]	*	ns	6.31
C18:2$\Delta^{9c.12c}$ [n-6]	18.05[b]	19.32[b]	13.02[a]	14.68[a]	*	ns	4.34
C18:3$\Delta^{6c\ 9c.12c}$ [n-6]	0.54	0.52	0.62	0.70	ns	ns	0.29
C20:2$\Delta^{11.14}$ [n-6]	0.10	0.14	0.10	0.08	ns	ns	0.07
C20:3$\Delta^{8c.11c.14c}$ [n-6]	0.10[b]	0.01[a]	0.04[ab]	0.01[a]	ns	*	0.03
C20:4$\Delta^{5c.8c.11c.14c}$ [n-6]	2.09[ab]	3.94[b]	1.71[a]	2.65[ab]	*	ns	1.25
C18:3$\Delta^{9c.12c.15c}$ [n-3]	1.47[b]	0.67[a]	0.99[ab]	0.50[a]	ns	**	0.51
C20:5$\Delta^{8c.11c.14c.17c}$ [n-3]	0.26	0.36	0.28	0.29	ns	ns	0.08
C22:6$\Delta^{4c.7c.10c.13c.16c.19c}$ [n-3]	0.26[b]	0.18[a]	0.33[b]	0.12[a]	ns	**	0.09
Others n-6	0.12[a]	0.60[b]	0.21[a]	0.30[ab]	*	ns	0.19
$\sum$ PUFA	23.00[b]	25.77[b]	17.30[a]	19.34[a]	**	ns	5.45
$\sum$ PUFAn-6	21.00[ab]	24.55[b]	15.71[a]	18.43[a]	**	ns	5.21
$\sum$ PUFAn-3	1.99[b]	1.22[ab]	1.59[ab]	0.91[a]	ns	*	0.59
n-6/n-3	11.01[a]	22.34[b]	12.11[a]	21.69[b]	ns	***	5.10
ARA/(EPA + DHA)	3.87[a]	7.29[b]	2.80[a]	6.46[b]	ns	**	21.57

$n = 8$ animals per each group performed in duplicate; SE = Pooled standard error.
Age class 1: 12–24 months of age; age class 2: older than 2 years.
Means with different superscript within the same row differ: $p < .05$, $p \leq .01$, $p \leq .001$.
*$p \leq .05$.
**$p \leq .01$.
***$p \leq .001$.
ns: Not significant.

($p \leq .05$). The arachidonic acid (ARA, 20:4n-6) was affected by feeding area ($p \leq .05$) and resulted higher in meat of wild boars from farmland. This results should be justified by the higher availability of LA sources as corn or sunflower seeds residuals in farmland and consequently by a probable higher LA availability for elongation to ARA.

Razmaite et al. (2012) evaluating the effect of live weight on fatty acid profile did not show any effect on LA content of LD, while found an effect on ARA.

Among PUFA n-3, feeding area influenced the level of alpha linolenic acid (ALA) and docosahexaenoic acid (DHA) ($p \leq .01$), which resulted higher in animals from forest. These results could be linked to the different availability of feed sources respect to farmland area: indeed, wild boar from forest had a diet richer in acorns and browsed vegetable parts (tree leaves) higher in ALA respect to farmland; at this regard Karolyi et al. (2007), found that pigs fed with acorn *ad libitum* for a period of three weeks prior slaughter, significantly increased the content of ALA in the LD muscle in comparison to concentrate fed pigs.

The n-6/n-3 ratio was lower in meat from animals hunted in the forest area ($p \leq .001$).

These results put in evidence that different feeding areas influence the intramuscular fatty acids in terms of nutritional characteristics of the meat. In particular, the increase in PUFAn-3 of wild boar from forest determines a strong decrease in n-6/n-3 ratio and ARA/(EPA + DHA) ratio mainly due to the increase in ALA and DHA levels.

Conclusions

This study is a comprehensive assessment of the nutritional values, including chemical and physical characteristic, fatty acid profiles and antioxidant compounds of wild boar meat, as consequence of different age and feeding area (also by diet composition identification). The main difference between the diets of wild boars from forest and farmland was the source of carbohydrates ($p \leq .05$), represented by acorns and corn, respectively. Such differences affected the antioxidant content of meat: higher intake of acorns in forest area resulted in a higher levels of γ-tocopherol while α-tocopherol and α-tocotrienol were higher in farmland where crops and herbages were favourites. As consequence the meat of wild boars that lived in forest had a higher oxidative stability (lower TBARS value) and showed better characteristics in terms of nutritional factors as level of PUFAn-3 ($p \leq .05$), n-6/n-3 ($p \leq .001$) and ARA/(EPA + DHA) ($p \leq .01$) ratio. Furthermore, the

meat quality was also affected by the age, resulting better in the young than in the older subjects.

In order to understand the role of other factors that could affect the quality of hunted wild boars' meat (as the *pre-mortem* stress), further investigations are highly desirable.

ORCID

Martina Pedrazzoli ⓘ http://orcid.org/0000-0003-1134-6296
Alessandro Dal Bosco ⓘ http://orcid.org/0000-0002-4021-2281
David Ranucci ⓘ http://orcid.org/0000-0002-5919-7122

References

AOAC. 2000. Official method of analysis. Association of Official Analytical Chemists Inc., 17th ed. Arlington (VA), USA.

Castellini C, Dal Bosco A, Bernardini M, Cyril HW. 1998. Effect of dietary vitamin E on the oxidative stability of raw and cooked rabbit meat. Meat Sci. 50:153–161.

Cava R, Ruiz J, López-Bote C, Martín L, García C, Ventanas J, Antequera T. 1997. Influence of finishing diet on fatty acid profiles of intramuscular lipids, triglycerides and phospholipids in muscles of the Iberian pig. Meat Sci. 45:263–270.

Christie W. 1982. A simple procedure for rapid transmethylation of glycerolipids and cholesteryl esters. J Lipid Res. 23:1072–1075.

Dannenberger D, Nuernberg G, Nuernberg K, Hagemann E. 2013. The effects of gender, age and region on macro- and micronutrient contents and fatty acid profiles in the muscles of roe deer and wild boar in Mecklenburg-Western Pomerania (Germany). Meat Sci. 94:39–46.

Dietrich M, Traber MG, Jacques PF, Cross CE, Hu Y, Block G. 2006. Does gamma-tocopherol play a role in the primary prevention of heart disease and cancer? A review. J Am Coll Nutr. 25:292–299.

Dransfield E. 2003. Consumer acceptance – meat quality aspects. In: Consistency of quality 11th International Meat Symposium. Pretoria, South Africa; p. 146–159.

Feichtner B. 1998. Ursachen der Streckenschwankungen beim Schwarz – wild im Saarland. Z Jagdwiss. 44:140–150.

Folch J, Lees M, Stanley GHS. 1957. A simple method for the isolation and purification of total lipids from animal tissue. J Biol Chem. 226:497–509.

Genov P. 1981. Food composition of wild boar in North-eastern and western Poland. Acta Theriol. 26:185–205.

Guallar E, Hanley DF, Miller ER. 2005. 3rd An editorial update: *Annus horribilis* for vitamin E. Ann Intern Med. 143:143–145.

Hoffman LC, Wiklund E. 2006. Game and venison – meat for the modern consumer. Meat Sci. 74:197–208.

Honikel KO. 1998. Reference methods for the assessment of physical characteristics of meat. Meat Sci. 49:447–457.

Humphries JM, Graham RD, Mares DJ. 2004. Application of reflectance color measurement to the estimation of carotene and lutein content in wheat and triticale. J Cereal Sci. 40:151–159.

Jiang Q, Christen S, Shigenaga MK, Ames BN. 2001. Gamma-tocopherol, the major form of vitamin E in the US diet, deserves more attention. Am J Clin Nutr. 74:714–722.

Karolyi D, Salajpal K, Kis G, Dikic M, Juric I. 2007. Influence of finishing diet on fatty acid profile of longissimus muscle of Black Slavonian Pigs. Agriculture. 13:176–179.

Ke PJ, Ackman RG, Linke BH, Nash DM. 1977. Differential lipid oxidation products in various parts of frozen mackerel. J Food Technol. 12:37–47.

Kouba M, Enser M, Whittington FM, Nute GR, Wood JD. 2003. Effect of a high-linolenic acid diet on lipogenic enzyme activities, fatty acid composition, and meat quality in the growing pig. J Anim Sci. 81:1967–1979.

Laurent S, Timothy JR. 2003. Diet of wild boar *Sus scrofa* in Western Europe, with particular reference to consumption of agricultural crops. Mammal Rev. 33:43–56.

Machlin LJ. 1980. Vitamin E. A comprehensive treatise (Basic and clinical nutrition, Volume 1). New York (NY): Marcel Dekker, Inc.

MacRae J, O'Reilly L, Morgan P. 2005. Desirable characteristics of animal products from a human health perspective. Livest Prod Sci. 94:95–103.

Maillard D, Gaillard JM, Hewison M, Ballon P, Duncan P, Loison A, Toïgo C, Baubet E, Bonenfant C, Garel M, Saint-Andrieux C. 2010. Ungulates and their management in France. In: Apollonio M, Andersen R, Putman R, editors. European ungulates and their management in the 21st century. Cambridge, UK: University Press, Cambridge; p. 441–474.

Marchiori AF, Felicio PE. 2003. Quality of wild boar meat and commercial pork. Sci Agri. 60:1–9.

Mattioli S, De Marinis AM. 2009. Guida al rilevamento biometrico degli Ungulati. Istituto Superiore per la Protezione e la Ricerca Ambientale, Documenti Tecnici. 28:1–216.

Merta D, Mocała P, Pomykacz M, Frackowiak W. 2014. Autumn-winter diet and fat reserves of wild boars (*Sus scrofa*) inhabiting forest and forest-farmland environment in south-western Poland. Folia Zool. 63:95–102.

Monaco A, Franzetti B, Pedrotti L, Toso S. 2003. Linee guida per la gestione del cinghiale. Ministry of Agriculture and Forestry (MiPAF), ed. National Institute for Wildlife (INFS). Ozzano nell'Emilia (BO), Italy.

Olson JA. 1989. Provitamin A function of carotenoids: the conversion of beta-carotene into vitamin A. J Nutr. 119:105–108.

Parker BA, Pearce BC, Clark RW, Gordon DA, Wright JJK. 1993. Tocotrienols regulate cholesterol production in mammalian cells by post-transcriptional suppression of 3-hydroxy-3-methylglutaryl-coenzyme a reductase. J Biol Chem. 268:11230–11238.

Quaresma MAG, Alves SP, Trigo-Rodrigues I, Pereira-Silva R, Santos N, Lemos JPC, Barreto AS, Bessa RJB. 2011. Nutritional evaluation of the lipid fraction of feral wild boar (*Sus scrofa scrofa*) meat. Meat Sci. 89:457–461.

Qureshi AA, Qureshi N, Wright JJ, Shen Z, Kramer G, Gapor A, Peterson DM. 1991. Lowering of serum cholesterol in hypercholesterolemic humans by tocotrienols (palmvitee). Am J Clin Nutr. 53:1021S–1026S.

Ramanzin M, Amici A, Casoli C, Esposito L, Lupi P, Marsico G, Mattiello S, Olivieri O, Ponzetta MP, Russo C, Trabalza Marinucci M. 2010. Meat from wild ungulates: ensuring quality and hygiene of an increasing resource. Ital J Anim Sci. 9:318–331.

Ranucci D, Beghelli D, Trabalza Marinucci M, Branciari R, Forte C, Olivieri O, Badillo Pazmay GV, Cavallucci C, Acuti G. 2015. Dietary effects of a mix derived from oregano (*Origanum vulgare L.*) essential oil and sweet chestnut (*Castanea sativa* Mill.) wood extract on pig performance, oxidative status and pork quality traits. Meat Sci. 100:319–326.

Razmaite V, Švirmickas GJ, Šiukščius AU. 2012. Effect of weight, sex and hunting period on fatty acid composition of intramuscular and subcutaneous fat from wild boar. Ital J Anim Sci. 11:174–179.

Rey AI, Daza A, López-Carrasco C, López-Bote CJ. 2006. Feeding Iberian pigs with acorns and grass in either free-range or confinement affects the carcass characteristics and fatty acids and tocopherols accumulation in *Longissimus dorsi* muscle and backfat. Meat Sci. 73:66–74.

Saez-Royuela C, Telleria JL. 1986. The increased population of wild boar (*Sus scrofa* L.) in Europe. Mammal Rev. 16:97–101.

Sales J, Kotrba R. 2013. Meat from wild boar (*Sus scrofa L.*): a review. Meat Sci. 94:187–201.

Schuep W, Rettenmeier R. 1994. Analysis of vitamin E homologous in plasma and tissue: high-performance liquid chromatography. Method Enzymol. 234:294–302.

Serbinova E, Kagan V, Han D, Packer L. 1991. Free radical recycling and intramembrane mobility in the antioxidant properties of alpha-tocopherol and alpha-tocotrienol. Free Radic Biol Med. 10:263–275.

Simopoulos AP. 2000. Human requirement for N-3 polyunsaturated fatty acids. Poult Sci. 79:961–970.

Soriano A, Cruz B, Gomez L, Mariscal C, Ruiz AG. 2006. Proteolysis, physicochemical characteristics and free fatty acid composition of dry sausages made with deer (*Cervus elaphus*) or wild boar (*Sus scrofa*) meat: a preliminary study. Food Chem. 96:173–184.

Steenkamp JEM. 1997. Dynamics in consumer behaviour with respect to agricultural and food products. In: Wierenga B, Van Tilburg A, Grunert K, Steenkamp, JEM, Wedel M, editors. Agricultural marketing and consumer behaviour in a changing world. Boston: Kluwer Academic Publishers; p. 143–188.

Szmańko T, Górecka J, Korzeniowska M, Malicki A, Eeremenko E. 2007. Comparison of chosen quality parameters of meat from wild boar and domestic pigs. Pol J Food Nutr Sci. 57:523–528.

Vassant J, Breton D. 1986. Essai de réduction de dégâts de sangliers (*Sus scrofa scrofa*) sur le blé (*Triticum sativum*) au stade laiteux par distribution de maïs (*Zea mais*) en forêt. Gibier Faune Sauvage. 3:83–95.

Wotschikowsky U. 2010. Ungulates and their management in Germany. In: Apollonio M, Andersen R, Putman R, editors. European ungulates and their management in the 21st century. Cambridge, UK: Cambridge University Press; p. 201–222.

Wood JD, Enser M, Fisher AV, Nute GR, Sheard PR, Richardson RI, Whittington FM. 2008. Fat deposition, fatty acid composition and meat quality: a review. Meat Sci. 7:343–358.