

IMAGING, SENSORY PROPERTIES AND FATTY ACID COMPOSITION OF PARMA HAM AND “NERO DI PARMA HAM”

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ABSTRACT

This paper provides preliminary results on “Nero di Parma” ham analysing fatty acid composition from fat and muscle tissues in three locations. Computerized Tomography (CT) and sensory characteristics were also performed. The same measurements were investigated in Parma ham too. Significant differences in terms of saturated and monounsaturated fatty acids composition were observed between hams resulting lower and higher in “Nero di Parma” ham than Parma ham respectively. Results detected by CT showed an inverse ratio of fat and muscle between the hams. “Nero di Parma” ham highlighted some descriptors such as oiliness, brightness, redness significantly different from Parma useful to define the sensory profile of a typical product, which had never been tested.

Keywords: fatty acids, “Nero di Parma ham”, Parma ham, sensory profile

1. INTRODUCTION

Dry curing is a common way to preserve pork in some Mediterranean countries. In Italy, Parma ham is the main Consortium for the production of dry cured ham labeled with Protected Designation of Origin (PDO), processing over 8 million thighs (data referred to 2017).

Parma ham represents a product of great economic value covering about half of the trading value of carcasses from Italian heavy pigs. In addition, new interest is now addressed to the health promoting characteristics of Parma ham and therefore, the fatty acid composition of its lipids is important to relate the profile to medical guidelines.

Alongside the intensive pig farming conducted according to criteria of industrialization, an attractive production related to tradition is emerging. It concerns native breeds that are characterised by peculiar traits low input rearing conditions and suitable high quality food products. In the present work "Nero di Parma" breed has been considered. It is a modern recreation of the ancient Nera Parmigiana breed, which significantly declined almost to the point of extinction. However, selection programs are being designed to reintroduce the "Nero di Parma" pig breeding tradition; with the DM 11781 of 20 May 2016 the "Nero di Parma" pig obtained the recognition of the breed. Animals are fed fresh grass, corn, barley and wheat, as well as broad beans, berries, roots and acorns. The characteristics of the meat of "Nero di Parma" are linked to the presence of intramuscular fat due to the ability to accumulate subcutaneous fat between the muscle fibers compared to the white breeds such as the Large White and Landrace and their crossings. Fat plays an important role in the development of the chemical and sensorial characteristics of cured meat products (VENTANAS *et al.*, 2007; JIMENEZ-COLMENERO *et al.*, 2010). Moreover, much attention is being paid to fatty acid profile in animal products because of its effects on consumers' health (WOOD and ENSER, 1997). Scientific evidence (WHO, 2003) and nutritional guidelines recommend a reduction in total fat intake, particularly of saturated fatty acids (SFA), which are associated with an increased risk of obesity, hypercholesterolaemia and some cancers (WOOD *et al.*, 2004), while a high intake of monounsaturated and n-3 polyunsaturated fatty acids has been shown to have an inverse effect (GANJI *et al.*, 2003). However, there are few data on "Nero di Parma" pigs in terms of meat quality and those related to seasoned ham to the best of our knowledge are missing. The aim of paper is to provide preliminary results on some qualitative parameters of the "Nero di Parma" ham by evaluating fatty acid composition in fat and muscle in three locations (initial part, central and the final part of the ham), the structure of the ham through the computerized tomography (CT), sensory characteristics and measuring the same parameters in Parma ham.

2. MATERIAL AND METHODS

2.1. Sampling

A total of 6 raw cured hams, 3 "Nero di Parma" hams and 3 Parma (PDO) were provided by a local producer, within the same factory in order to ensure the same production technology. The two types of hams had different ripening maturation times: 30 and 24 months respectively. The choice depended on the high fat (either fat coverage either as intermuscular fat) of "Nero di Parma" that requires longer times of ripening. Therefore "Nero di Parma" ham is marketed at 30 months, and Parma ham at 24 months. Before starting chemical analysis, on the whole ham the spiral multi slice CT was carried out; subsequently the hams were sliced and used for sensory analysis. During the sensory

analysis whole slices (including muscle and external fat) at three different locations (initial, central and final part) were sampled according to Fig. 1. Samples were vacuum-packaged and stored at -20°C for 2 weeks until subsequent chemical analysis.

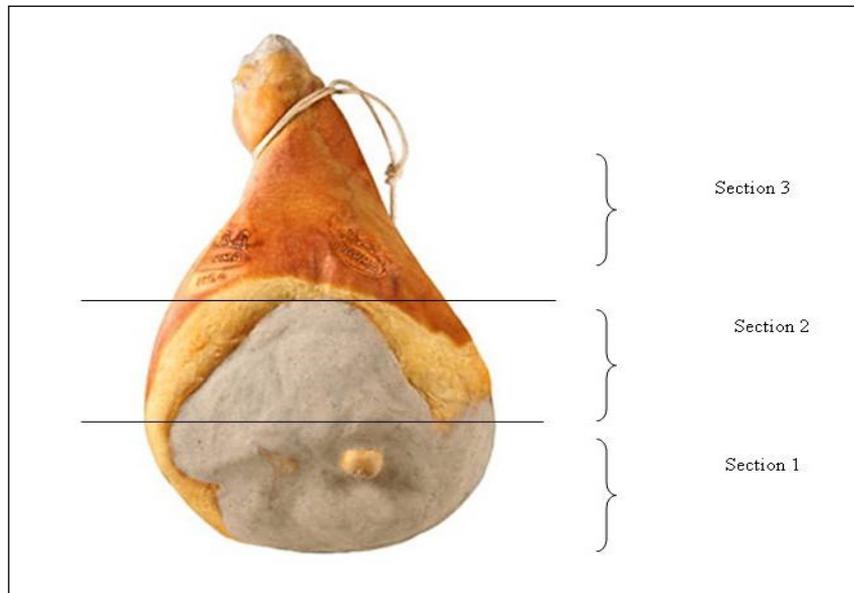


Figure 1. Sampling location. Section 1 corresponds to initial part; Section 2 corresponds to central part; Section 3: corresponds to final part

2.2. Fatty acid analysis

Lipid extraction was conducted using chloroform: methanol (2:1) according to the method of FOLCH *et al.* (1957). Lipids were extracted from each sample of the muscle, and from each sample of trimmed adipose tissue. The extracts were dried under vacuum on a rotary evaporator (Laborota 4000, Heidolph Instruments, Milan, Italy). Fatty acid composition was measured after methylation of the samples. Fatty acid methyl esters were prepared with boron trifluoride methanol according to procedures developed by MORRISON and SMITH (1964). The methyl esters were separated on a Carlo Erba Instruments chromatograph (GC 6000 Vega series 2) equipped with fused silica gel capillary column (0.25 mm i.d. 25 m) having a 0.2-mm internal coating of cyanopropyl siloxane (CP-Sil 88, Chrompack). The furnace temperature was 180°C, and injector and detector temperatures were 240°C. For all samples, retention times and peak areas were determined by chromatography (Nelson Analytical, Manchester, NH). The identities of the peaks were verified by comparison with the retention times of standard fatty acid methyl esters. The results were expressed as the percentage of the total fatty acid composition. All the analyses were carried out in duplicate.

Atherogenicity (AI) and thrombogenicity (TI) indices (ULBRICHT and SOUTHGATE 1991), which characterize the potential proneness to atherosclerosis and thrombosis in humans were used to assess dietetic values of ham.

In detail IA indicates the relationship between the sum of the main saturated fatty acids and that of the main classes of unsaturated; the former being considered pro-atherogenic (favoring the adhesion of lipids to cells of the immunological and circulatory system), and the latter anti atherogenic (inhibiting the aggregation of plaque and diminishing the levels

of esterified fatty acid, cholesterol, and phospholipids, by preventing the appearance of micro and macro coronary diseases).

Index of thrombogenicity is defined as the relationship between the pro-thrombogenic (saturated) and the anti-thrombogenic fatty acids (MUFAs, PUFAs – n6 and PUFAs – n3).

2.3. Sensory analysis

Eleven trained assessors belonging to ONAS (National Organization Salumi Taster) undertook the sensory analysis on 2-mm slices of ham. The choice of descriptors was decided by open discussion in two preliminary sessions. Twenty sensory descriptors covering appearance (redness, whiteness, marbling, oiliness, brightness), odor (aged, fresh pork meat, rancid, mold), taste (sweetness, saltiness, bitter), flavor (aged, fresh pork meat, rancid, butter, fresh fat), texture (fibrousness, dryness, firmness) were chosen. A 9-point scale was used, where 0 meant absence and 9 meant maximum intensity of the descriptor. The sensory evaluation was repeated in three sessions carried out on three different days (EN ISO 13299, 2010). Each member of the panel assessed two types of hams in each session. Slices of ham samples were coded with three random numbers and were presented to the members according to MACFIE *et al.* (1989).

2.4. Computed axial tomography

Hams were submitted to 16-slices CT scanner (Brightspeed® - GE Medical Systems Italia S.p.A., Milan, Italy) applying the following protocol: Tube Voltage 110 kVp, X-Ray Tube Current 200 mA, Revolution Time 1, Slice Thickness 1.25 mm, Spiral Pitch Factors 0.9375, Convolution Kernel Standard, Rows and Columns 512x512.

All images were transferred to the picture archiving and communication system (MyPACS – MD Saronno - Italy), processed with a certified medical software (OsirixPRO® 64 Bit, Aycan Medical Systems) and reconstructed using smoothing and edge enhancement algorithms in all the three spatial transverse planes.

The program can differentiate the fat from the lean as a consequence of the significant difference in Hounsfield Units (HU) existing between the two tissues (negative values for fat and positive for lean). Hounsfield Units (also named CT numbers) express the X-ray attenuation of the tissues, which is a measure of its density in a given Region of Interest (ROI).

In each slice, a ROI based on the density of the tissues examined (fat or lean) was selected in order to obtain the HU surface area values. Therefore, the “Compute Volume” function of the software was used to calculate the volume.

2.5. Statistical analysis

The ham was the experimental unit for statistical analysis. Data were analyzed by means of variance analysis including typology (Parma and “Nero di Parma”), tissue (muscle and fat) and location (initial, central and distal part), as main effect. Newman-Keuls test was used to assess differences between means.

The sensory data for each attribute were submitted to three-way ANOVA with typology, judges, replicates and their interaction as effects. The significance of these effects was tested with the F-test and the comparison between mean values was tested with T Student. Differences with probability levels of $P < 0.05$ were considered significant. Effects were deemed significant at $P < 0.05$, and a trend was noted when $P < 0.10$. Statistical analyses of the data were performed using SPSS software (SPSS Inc., Chicago, IL)

3. RESULTS AND DISCUSSION

Pig farming plays a key role within animal production, particularly in North Italy where about 70% of the Italian pig production is located. The main strength factor of the Italian pig industry is represented by the top quality of its production labeled with the PDO (Protected Designation of Origin) or PGI (Protected Geographical Indication) marks. They represent an important market value and must continuously be monitored from a qualitative point of view.

Fat and fatty acids, whether in adipose tissue or muscle, contribute importantly to various aspects of meat quality and are central to meat nutritional value (WOOD *et al.*, 2008). It is generally assumed that intramuscular fat (IMF) content positively influences sensory quality traits, including flavor, juiciness and tenderness of meat, whereas a low amount of fat results in a less tasty meat (TOUS *et al.*, 2013).

It is well known that traditional breeds are fatter than industrial ones. Generally, they have more adipose tissue thickness and more intramuscular fat (GANDEMER, 2009). Dry-cured ham from conventionally reared modern breeds of pigs compared to dry-cured ham from Iberian pigs had lower levels of saturated fatty acids (SFA) and polyunsaturated fatty acids (PUFA) (JIMÉNEZ-COLMENERO *et al.*, 2010).

The FA composition of dry-cured hams is due to many factors, such as genetic features and differences in the rearing and feeding systems.

Results of FERNÁNDEZ *et al.* (2015) for fatty acid composition of analyzed samples of Spanish dry cured ham showed approximate mean percentages of SFA and monounsaturated fatty acid (MUFA) of about 43% of the total FA, and 13.87% of PUFA. In a study conducted by BERMÚDEZ *et al.* (2012) on the effect of the inclusion of chestnut in the finishing diet (from three different diets: concentrate, mixed and chestnut) on fatty acid profile of dry-cured Celta the percentage of SFA (35 %) PUFA (13%) and MUFA (51%) in mixed diet were similar to those found herein. In the present study the most abundant fatty acids in both types were monounsaturated fatty acids (MUFA) (mainly C18:1 n-9) followed by SFA and finally polyunsaturated fatty acids. The different typology caused some changes in the fatty acid composition of dry-cured ham (Table 1).

In particular, "Nero di Parma" ham showed a significant lower SFA content and higher MUFA than Parma ham as a direct consequence of the high oleic acid content of acorns as reported in Iberian pigs (RUIZ *et al.*, 1998; RUIZ-CARRASCAL *et al.*, 2000). Numerically, the values of oleic acid in "Nero di Parma" agree with those found in Spanish ham (PEREZ-PALACIOS, 2010). Moreover, CAMPO and SIERRA (2011) monitored different varieties of Spanish dry cured ham produced from the same company in two years (1995-2007). The oleic acid (C18:1 n-9) levels found overlap those found in "Nero di Parma" ham in the present work. The levels found in this study are lower but not too far from those of FERNÁNDEZ *et al.* (2007) who found approximately 49% of C18:1 n-9, considered a healthy product in a diet. Moreover, the oleic acid content of "Nero di Parma" ham agrees with values coming from pigs of Parma DOP circuit fed with 6% sunflower oil in which a significant increase of oleic acid in the treated group was found (BOSI *et al.*, 2000). "Nero di Parma" ham compared to Parma showed a significantly lower content of both stearic acid (C18:0) and myristic acid (C14:0).

Moreover, the content of total n-3 PUFA and particularly α -linolenic acid (ALA, C18:3n-3) was greater ($P < 0.05$) in "Nero di Parma" than Parma dry cured ham. This is likely due to the different rearing system, which characterize the two typologies. According to MURIEL *et al.* (2002), free-range rearing and feeding pigs on pasture increase the levels of long chain n 3 fatty acids in porcine muscles which is in agreement with the present results.

Table 1. Effects of typology (Parma ham and “Nero di Parma ham”) on fatty acid composition of muscle and adipose tissue of dry-cured ham.

| | Muscle tissue | | Fat tissue | | T ² | P value ¹ | |
|----------|---------------|----------------|------------|-----------------|----------------|----------------------|-----------|
| | Parma | “Nero di Parma | Parma | “Nero di Parma” | | Typ ³ | Tex x Typ |
| C14:0 | 1.07±0.17 | 0.87±0.2 | 1.17±0.36 | 0.92±0.3 | ns | * | ns |
| C16:0 | 24.00±0.87 | 23.40±0.86 | 24.01±0.85 | 24.03±2.4 | ns | ns | ns |
| C16:1n7 | 2.42±0.81 | 2.37±0.77 | 2.00±0.81 | 2.24±0.59 | ns | ns | ns |
| C17:0 | 0.16±0.53 | 0.15±0.48 | 0.15±0.44 | 0.17±0.39 | ns | ns | ns |
| C17:1 | 0.12±0.04 | 0.15±0.03 | 0.13±0.04 | 0.15±0.02 | ns | ns | ns |
| C18:0 | 11.00±0.95 | 9.15±1.26 | 11.23±1.40 | 9.53±1.37 | ns | *** | ns |
| C18:1n9 | 44.40±2.01 | 47.40±2.87 | 44.96±2.43 | 46.5±4.02 | ns | *** | ns |
| C18:2n6 | 10.38±0.83 | 9.90±2.27 | 11.11±1.12 | 10.74±1.40 | ns | ns | ns |
| C20:0 | 0.08±0.01 | 0.08±0.03 | 0.07±0.04 | 0.10±0.02 | ns | ns | ns |
| C18:3n3 | 0.32±0.10 | 0.42±0.10 | 0.38±0.08 | 0.48±0.06 | ** | *** | ns |
| C20:1n9 | 0.64±0.10 | 0.71±0.15 | 0.60±0.12 | 0.68±0.20 | ns | ns | ns |
| C20:2n6 | 0.37±0.06 | 0.34±0.06 | 0.39±0.10 | 0.35±0.10 | ns | ns | ns |
| C20:3n3 | 0.02±0.02 | 0.03±0.01 | 0.03±0.03 | 0.04±0.03 | ns | ns | ns |
| C20:3n6 | 0.07±0.06 | 0.06±0.03 | 0.05±0.08 | 0.03±0.02 | ns | ns | ns |
| C20:4n6 | 0.48±0.25 | 0.58±0.44 | 0.10±0.17 | 0.11±0.07 | *** | ns | ns |
| C23:0 | 0.23±0.21 | 0.15±0.14 | 0.04±0.05 | 0.13±0.30 | ns | ns | ns |
| SFA | 36.58±1.34 | 33.82±1.78 | 36.74±1.52 | 34.89±3.74 | ns | *** | ns |
| MUFA | 51.77±1.56 | 54.85±2.94 | 51.18±2.03 | 53.83±3.75 | ** | *** | ns |
| PUFA | 11.65±0.95 | 11.32±2.77 | 12.07±1.39 | 11.77±1.55 | ns | ns | ns |
| n-6 PUFA | 10.94±0.93 | 10.53±2.65 | 11.27±1.30 | 10.89±1.47 | ns | ns | ns |
| n-3 PUFA | 0.35±0.11 | 0.44±0.11 | 0.41±0.10 | 0.52±0.07 | † | *** | ns |

²T= tissue; ³Typ: Typology;

Probability ^oStatistical significance at $P<0.05$, ^(*) Statistical significance at $P<0.01$, ^(**) Statistical significance at $P<0.001$, ^(†) = $P<0.10$

Previous studies conducted in heavy pigs (PASTORELLI *et al.*, 2003) (160±10 kg of BW) and in light pigs (SANTOS *et al.*, 2008) showed that the fatty acid composition of dry cured ham depends on the dietary fatty acid composition. Both studies observed an increase in ALA content in dry-cured ham obtained from pigs fed diets enriched in n-3 PUFA.

The increase of linolenic acid and monounsaturated fatty acids content, in “Nero di Parma ham” is certainly positive considering the indications provided by human diet for the important role of monounsaturated fatty acids and fatty acids of the omega 3 series. A trend was noted for n-3 PUFA in the two tissues analysed (Table 1).

As far as linolenic acid is concerned, the content is higher in adipose tissue than in muscle (0.43 vs 0.37), according to MUSELLA *et al.* (2009) and as expected.

In contrast, eicosapentaenoic acid (EPA) and docosapentaenoic acid (DPA) are preferentially stored in the organs or muscle rather than in the adipose tissue. In the present work, these fatty acids have not been quantified. No significant effect has been found for tissue x typology. Typology did not affect ($P>0.05$) linoleic acid (C18:2n6) in any of analysed tissue. Regarding the curing process of meat and in order to obtain adequate fat quality, adipose tissue should contain no more than 12% of C18:2n-6 and exceed 12% of C18:0 (MOUROT and HERMIER, 2001). Adipose tissues studied in the present research were within those ranges.

The nature and proportion of individual fatty acids, especially SFA to PUFA, is important in assessing the quality and nutritional value of fats. The proportions of these fatty acid groups have been used to calculate the very important risk factors for atherogenic index (AI) and thrombogenic index (TI). A lower AI value indicates a lower proportion of saturated to unsaturated acids, which reduces ability of endothelium of blood vessels to attach lipids and plaque formation. The TI at its lower index indicates a lower risk of occurrence of disturbance of the blood coagulation process and blood clotting. Both these indices in the present study were at an appropriate low level in both typologies of ham, close to that observed in wild boar meat (RAZMAITE *et al.*, 2012). Both AI (0.42 *vs* 0.45) and TI (1.00 *vs* 1.20) indices were significantly lower in “Nero di Parma” ham than Parma ham. Our results are consistent with those obtained by CEBULSKA *et al.* (2018), who reported an average value of 0.40 and 1.07 for AI and TI respectively in pork meat originating from pigs of polish native pure breeds. A significant reduction of the nutritional indexes has been reported in cow’s milk (CAROPRESE *et al.*, 2010), ewe’s milk (CIESLAK *et al.*, 2010; CAROPRESE *et al.*, 2011), and rabbit meat (PEIRETTI and MEINERI, 2010) after linseed feeding.

CIESLAK *et al.* (2010) showed reduction of the atherogenic index from 1.4 to 0.5 and thrombogenic index from 0.8 to 0.4. OKROUHLÁ *et al.* (2013) reported a thrombogenic index (1.33 and 1.28 *vs* 0.80 and 0.85) in meat of barrows and gilts.

According to previous studies (LORENZO *et al.*, 2012, FRANCO *et al.*, 2006) that found the effect of carcass location on the fatty acid profile, we investigated the effect of location in three different locations of the ham. Fatty acid composition differences in relation to location were found. In particular, they were identified for the following fatty acids: C18:0, C18: 1n9, C20: 0, C20: 3n3, C20: 4n6 with consequent effect on SFA ($P = 0.007$), MUFA ($P < 0.001$) and n-6 PUFA that showed just a trend ($P = 0.075$). In particular, it is noted that SFA exhibit a higher concentration in the initial part (36.73), the MUFAs in the final part (54.99) and the PUFA in the central part (12.49) of the sampled hams (Fig. 2).

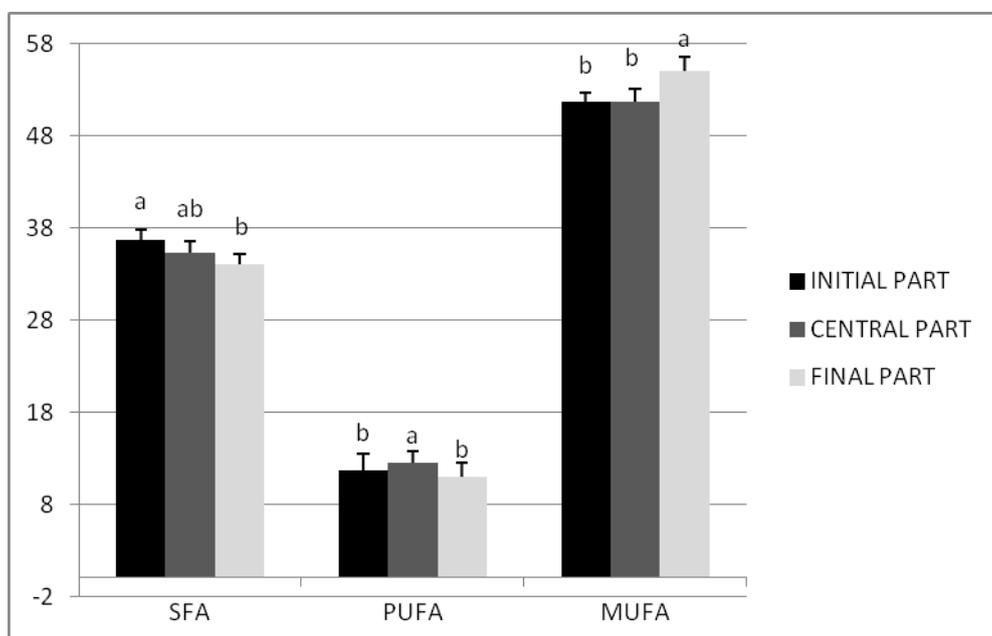


Figure 2. Effect of sampling location on Saturated fatty acids (SFA), Polyunsaturated fatty acids (PUFA) and Monounsaturated fatty acids (MUFA) content.

The highest content of MUFA in the final part agrees with results of CAVA *et al.* (2000) who found higher percentages of oleic acid and MUFA in a deeper muscle than in superficial one.

SFA are mainly located in the initial part corresponding to a location with higher adipose accumulation.

The nutritional value of adipose tissues is related to high values of PUFA/SFA, MUFA/SFA ratios and low values for n-6/n-3 ratio. In the present study all cited ratios were significantly improved in "Nero di Parma" ham.

3.1. Sensorial analysis

There are various kinds of dry-cured hams in Mediterranean countries, distinguished by the origin and the quality of raw material. Dry-cured hams can be categorized into two types: (1) originating from traditional breeds, usually accompanied by extensive outdoor rearing systems and (2) originating from modern lean breeds, raised under intensive systems (ČANDEK-POTOKAR and ŠKRLEP, 2012). Consumer demand regarding the sensory quality of dry cured ham varies according to the region and local habits. Many highly regarded traditional products are based on the exploitation of natural resources like acorn pastures in the current case or in the case of the Iberian pig.

Taste is the key factor affecting consumer satisfaction with dry-cured ham (RESANO *et al.*, 2011). However, familiarity with a product affects quality expectations and perceptions of consumers, which explains why different dry-cured ham characteristics are appreciated in different countries.

The least square means of the different attributes for the samples of dry cured ham are reported in the spider plot (Fig. 3). The panelist effect was significant ($P < 0.01$) for all descriptors; this statement is very common in sensory evaluation because of a different use of scores and disagreement within the assessment of sample (LEA *et al.*, 1997). No effect for replicates and no interaction between panelists \times replicates and samples \times replicates were found except brightness ($P = 0.018$) and sweetness taste ($P = 0.024$). These results underline the excellent reproducibility of scores given by the panelists and excellent homogeneity of samples during repetitions.

Typology \times replication interaction was not significant; this result would therefore seem to indicate that the mean scores for each sample given by the panelists for each descriptor are satisfactory estimates of the sensory profile of Parma and "Nero di Parma" ham. ANOVA of the sensory data showed a significant effect in the following descriptors: redness, marbling, oily, brightness, aged odor, rancid both in odor and flavor, sweetness, bitter and dryness. Numerical values of the considered descriptors of Parma ham are comparable with literature (LAUREATI *et al.*, 2014).

Redness descriptor was higher in "Nero di Parma" (7.4 *vs* 5.88) than Parma ham. This result is consistent with those previously reported by (ESTÉVEZ *et al.*, 2003, 2006) who described a higher a^* value, chroma and iron content in muscles from rustic pig breeds than in those from selected ones. In addition to the breed effect, the characteristics of the Iberian pigs' livestock farming could have influenced since the pigments and iron concentrations and the red colour of the muscles increase with the animal age and the physical exercise (LAWRIE, 1998).

This descriptor is linked to the sensory perception of meat color: consumers consider bright red meat as fresh and are adverse to brown meat.

In addition, the highest oiliness appearance of "Nero di Parma" agrees with values of Montanera ham (JURADO *et al.*, 2007) due to a high fat content of "ham as underlined by CT. The highest value of oiliness produced the highest brightness value in "Nero di Parma" (5.27 *vs* 4.22).

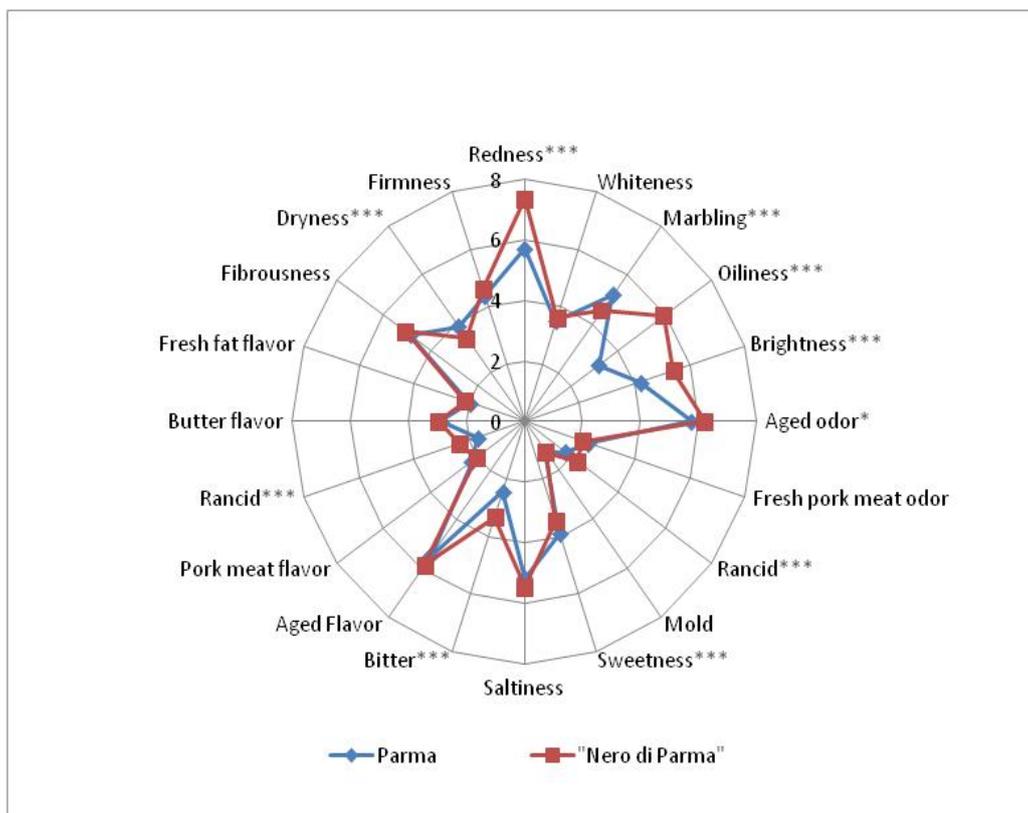


Figure 3. Sensory analysis results: mean values for each sensory descriptor by Parma and "Nero di Parma" ham. For each descriptor the relevant significance is reported. (***significant at $P < 0.001$, **significant at $P < 0.01$, *significant at $P < 0.05$).

In addition, the fat unsaturation affects dryness of ham meat resulting higher in Parma ham according to results of RUIZ *et al.* (2002) obtained in meat.

However, an high fat content is associated with the phenomena of oxidation; the panel, both aroma and odor evaluation, found a greater value of rancid in the "Nero di Parma" ham ($P < 0.001$ and $P < 0.003$) than Parma ham. This attribute is often present in long-matured products, such as ham, and it is also reported in the Iberian typology (GARCIA-GONZALEZ *et al.*, 2006; RUIZ *et al.*, 2002). Rancidity is considered as a defective note of the product if present in high density. However, in contrast to the negative effect of lipid oxidation in pork, the formation of volatile lipid oxidation components during ripening/fermentation is important for the oxidative flavour note of Parma ham. It is well known that the typical ham aroma is related to intramuscular lipid composition and to the extent of lipolysis and oxidation of lipids during processing (BERDAGUÈ, *et al.*, 1993; BUSCAILHON *et al.*, 1994).

In fact, muscle and adipose tissue lipids are subject to intense lipolysis by the action of lipases, generating free fatty acids that, at a second stage, are transformed to volatiles as a result of oxidation. Sensory profiles of dry cured ham are strongly affected by these enzymatic reactions (TOLDRA *et al.*, 1997).

"Nero di Parma" also showed the most intense aged odor according to the prolonged seasoning period (30 *vs* 24 months). As for marbling, a significant difference was obtained between the two types, higher in Parma than in "Nero di Parma" ham (5.13 *vs* 4.53). It must be emphasized that marbling score is not only affected by the total fat area of fat

flecks, but also by the distribution of fat (CHENG *et al.*, 2015). The total lipid content of muscle was equal to an average value of 7.1% (s.e. 0.88) and 10.2% (s.e. 1.26) ($P = 0.65$) in Parma ham and “Nero di Parma ham” respectively. This result agrees with CT analysis as described below.

Taste descriptor related to sweetness, a typical characteristic of Parma ham, highlighted in Parma ham higher values (3.93 *vs* 3.43) than “Nero di Parma ham”. In contrast, “Nero di Parma ham”, characterized by a lower sweetness, resulted more bitter (3.18 *vs* 2.28); this attribute could be caused by a greater presence of myoglobin. Higher myoglobin levels in bull meat have been indicated as leading to greater sensations of metallic, liver, and bitter flavors. As recently reported, native pig breeds are characterized by the highest redness and the higher content of heme pigments (CEBULSKA *et al.*, 2018).

In order to satisfy the requirements of the modern meat industry, it is important to develop some non-destructive, accurate, and rapid techniques for assessing meat quality and safety as recently reviewed (XIONG *et al.*, 2017). Computerized tomography has been used mostly in medicine for diagnostic purposes. Nevertheless, it has also been proven to be useful in other fields and its application has been extended to palaeontology, geology and also to food technology and the meat science field. Application of computed tomography (CT) in meat science is based on the different X-ray attenuations that different tissues produce.

It has been demonstrated to be useful in the estimation of body composition in animals and to measuring lean percentage in pig carcasses (PICOUET *et al.*, 2010).

In the present paper Hounsfield Units (HU), transformed by the software as cm^3 , were then expressed as a percentage; the different distribution of lean and fat can be appreciated from the images reported in Fig. 4.

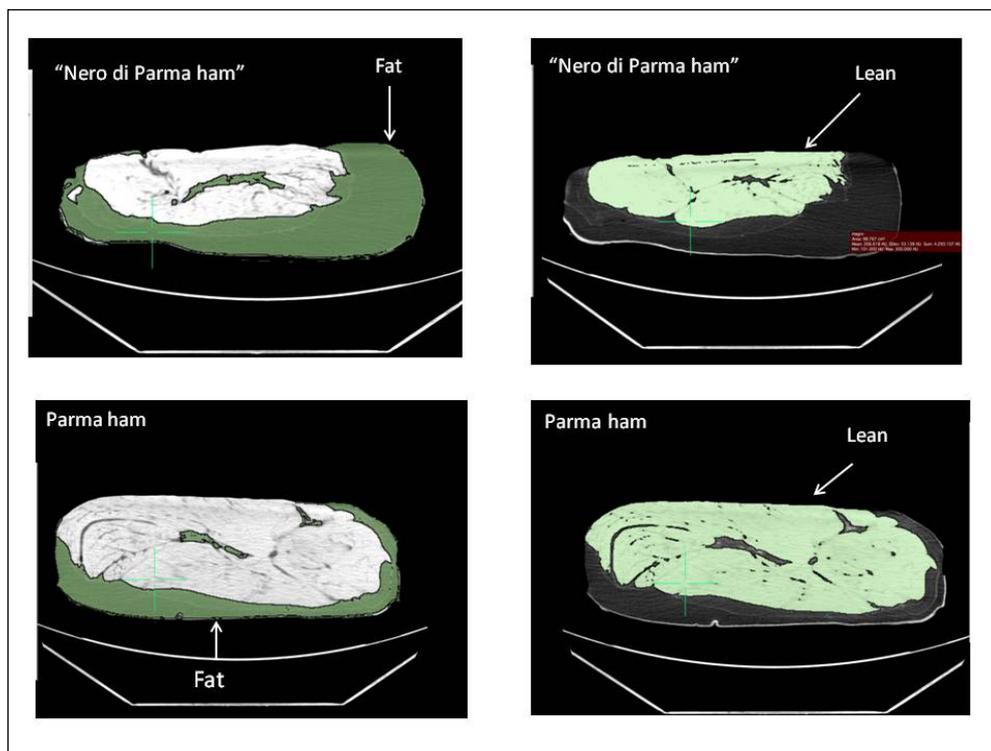


Figure 4. Distribution of fat and lean tissue in Parma ham and “Nero di Parma ham”.

As graphically presented in Fig. 5 the opposite content of lean and fat component in the two types of analyzed hams (“Nero di Parma” 39% and 55%, Parma: 59% and 34%) could be noted respectively. Surprisingly, connective content is similar between the two types. MONZIOLS *et al.* (2006) evaluating by magnetic resonance imaging the proportion of different carcass cuts reported a value of 62% (st. dev. 7.3) and 20.2% (st. dev. 6.3) in muscle and fat of ham respectively. The percentage of muscle overlaps the values found in Parma ham.

The highest fat content of “Nero di Parma ham” is due to an adaptive mechanism to the environment, which is known as thrifty genotype and which was firstly described in humans (NEEL, 1962) and also in Iberian pigs (GARCIA-CONTRERAS *et al.*, 2018).

The thrifty genotype facilitates accommodation to seasonal cycles of feasting and famine because the ability to store fat in excess during food abundance enables survival during periods of scarcity.

An higher fat content implicates a longer ripening process from which depends all chemical and physical changes affecting volatile compounds during processing.

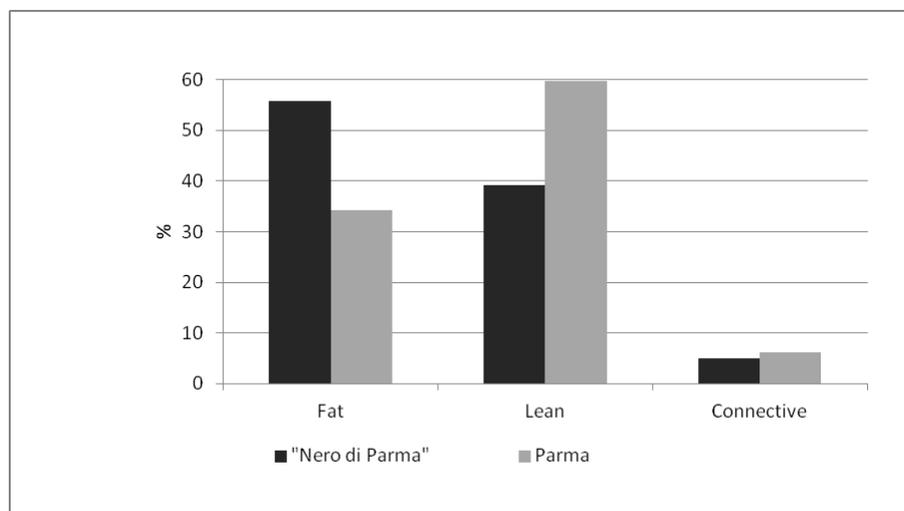


Figure 5. The lean, fat, and connective tissue surface ratio in “Nero di Parma” ham and Parma ham.

The connective tissue content of meat varies with species, chronological age, state of nutrition of the animal and muscle fiber characteristics (KLONT *et al.*, 1998). Meat texture is directly related to the size of muscle fiber and the amount of connective tissue (JOO *et al.*, 2013). Moreover, connective tissue also undergoes morphological changes during meat-aging (BAILEY and LIGHT 1989; NISHIMURA 2015). The results of CT are consistent with the evaluation of the sensory analysis carried out on the ham; in this study no difference was found in texture also in accordance with the study of NISHIMURA (2010).

4. CONCLUSIONS

In conclusion, the results of the quality tests conducted on raw cured ham from the “Nero di Parma” pig emphasize high processing value and nutritional value of the meat of these animals. The profile of fatty acids and the proportions of individual fatty acids expressed in the form of disease risk indices (AI, TI) allow us to characterize the “Nero di Parma”

ham as a product with health value. "Nero di Parma" ham with the high monounsaturated and omega-3 fatty acids content, could play an important role for human health; moreover, the omega6/omega3 ratio was improved in "Nero di Parma" ham more than in Parma ham.

The present study provides additional data on Parma PDO ham with regard to the fatty acid composition, and sensory analysis, confirming literature and the positive evaluation of this product.

The sensorial profile of a typical product is the starting point for a strategy to enhance the typicality. The results of this preliminary study indicated that "Nero di Parma" ham, for which sensory investigations are not known, highlighted some descriptors such as oiliness, brightness, redness significantly different from Parma ham, and useful to define the sensorial profile of a typical product.

This study is only a first approach from which further investigations can emerge. The numbers will have to be expanded in order to reach a definitive sensorial profile and to characterize the "Nero di Parma" ham for the entire nutritional label.

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