Physical, chemical and technological traits of dry-cured ham of Cinta Senese pigs reared outdoors and indoors

Carolina Pugliese¹, Oreste Franci¹, Anna Acciaioli¹, Riccardo Bozzi¹, Gustavo Campodoni¹, Francesco Sirtori¹, Gustavo Gandini²

¹Dipartimento di Scienze Zootecniche. Università di Firenze, Italy
²Dipartimento di Scienze e Tecnologie Veterinarie per la Sicurezza Alimentare. Università di Milano, Italy

Corresponding author: Dr. Carolina Pugliese. Dipartimento di Scienze Zootecniche. Università di Firenze. Via delle Cascine 5, 50144 Firenze, Italy - Tel. +39 055 3288263 - Fax: +39 055 321216 - Email: carolina.pugliese@unifi.it

Paper received February 17, 2006; accepted April 29, 2006

ABSTRACT

The effects of rearing system on technological and physical-chemical traits of Cinta Senese hams were investigated. Forty-three pigs were reared under two different farming conditions, outdoors and indoors, and slaughtered at 130 kg of live weight. Hams were processed according to the dry-curing method for Tuscan ham. Outdoor pigs showed higher salting losses (4.2 vs 2.0%) and lower seasoning losses (26.7 vs 29.0%). On sample-slice, pigs reared outdoors showed higher percentages of subcutaneous fat (40.5 vs 37.4%) and lower percentages of Semimembranosus (Sm) and Semitendinosus (St) muscles (23.8 vs 26.0% and 6.4 vs 7.0%, respectively). Outdoor pigs had higher values of chroma and lower values of hue in all analysed muscles (Biceps Femoris (BF), Sm and St) and their subcutaneous fat showed lower chroma (5.0 vs 7.0) and higher hue values (0.939 vs 0.627). BF of outdoor pigs had higher percentages of intramuscular fat (6.4 vs 4.9%) and lower percentages of crude protein (27.4 vs 30.9%). Subcutaneous fat of outdoor pigs showed lower SFA contents (32.1 vs 35.9%) and higher percentages of PUFA n-3 (1.23 vs 0.30%) and PUFA n-6 (11.8 vs 7.66%). Outdoor pigs had a higher PUFA/SFA ratio (0.41 vs 0.22).

Key words: Cinta Senese pigs, Outdoors, Dry-cured ham, Meat quality, Fatty acids composition.

RIASSUNTO

CARATTERISTICHE FISICO, CHIMICHE E TECNOLOGICHE DEL PROSCIUTTO DI SUINI CINTA SENESE ALLEVATI AL CHIUSO E AL BRADO

Scopo del presente lavoro è stato quello di valutare l'effetto del sistema di allevamento sulle caratteristiche fisico, chimiche e tecnologiche del prosciutto di suini di Cinta Senese. Sono stati allevati 43 suini Cinta Senese in due diverse condizioni di allevamento: intensivo (indoors) e al pascolo (outdoors) e macellati al peso vivo medio di 130 kg. Le cosce sono state stagionate secondo il metodo previsto per il prosciutto Toscano. I suini outdoor hanno fatto registrare le più alte perdite di salagione (4,2 vs 2,0 %) e le più basse perdite di stagionatura (26,7 vs 29,0 %). Per quanto riguarda la composizione della fetta i suini outdoor hanno fornito la più elevata percentuale di grasso sottocutaneo (40,5 vs 37,4 %) e la più bassa di Semimembranosus (Sm) e Semitendinosus (St), (23,8 vs 26,0 % e 6,4 vs 7,0 % rispettivamente). I suini outdoor hanno fatto registrare i più alti valori di croma in tutti e tre i muscoli indagati [Biceps Femoris (BF), Sm e St], mentre, per il grasso sottocutaneo, si sono distinti per i più bassi valori di croma (5,0 vs 7,0) e per i più alti di tinta (0,939 vs 0,627). Il BF dei suini outdoor ha fatto registrare le più alte percentuali di grasso intramuscolare (6,4 vs 4,9 %) e le più basse di proteina grezza (27,4 vs 30,9 %). Per quanto riguarda la composizione acidica del
Introduction

The Tuscan dry-cured ham is a traditional pork meat product from Central Italy with a Protected Denomination of Origin (PDO) registration. Nowadays an increasing number of Tuscan hams is produced with local Cinta Senese pigs and consumers confer to these hams a consistent added value (Franci, 2004).

The development of a specific PDO label and commercial brands is under investigation.

Additionally, the characterisation of meat from the extensive rearing system of the local breed could be exploited to increase the commercial value of the ham, similarly to the Iberian pig experience (Lopez-Bote, 1998). As reviewed by Edwards and Casabianca (1996), several Authors have studied the effects of the outdoor production system on quality of pork products of the Mediterranean area and have underlined links between pasture and lipid composition of the meat. Antequera et al. (1992) and Cava et al. (2000) reported in the Iberian ham high concentrations of oleic acid supported by acorn pastures that, together with the typical marbling of the meat, are considered essential for appropriate ripening and flavour development of dry-cured products.

The effects of rearing system on carcass composition and on raw meat quality of Cinta Senese pigs were investigated in previous works (Franci et al., 2003; Pugliese et al., 2005), but no information is available on dry-cured ham.

In this paper the technological and physical-chemical traits of Tuscan dry-cured ham from Cinta Senese pigs reared outdoors and indoors are investigated.

Material and methods

Animals

Forty-three hams, belonging to as many Cinta Senese pigs, were used. Animals were reared under two different farming conditions: outdoors on woodland pastures characterised by holm oak, turkey oak, durmast and chestnut trees; indoors in pens, housed according to sex and fed commercial feed-stuff. For more details on the experimental design, see previous works (Acciaioli et al., 2002; Franci et al., 2003; Pugliese et al., 2005). Pigs were slaughtered at a target live weight of about 130 kg. Weight at slaughter was 136 kg for indoor pigs and 128 kg for outdoor pigs, with a corresponding age of 312 and 510 days, respectively.

Technological properties and sensory analysis

At slaughtering, thighs were removed from the right half-carcasses and processed according to the dry-curing method of Tuscan ham (Table 1). After each stage of processing, hams were weighed and relative losses were computed. At the end of the seasoning period hams were judged on a 4-point scale, by a technician of the curing factory, for globosity and fatness (very low – very high), then they were deboned. A sample slice, about 3 cm thick, was taken transversally from the caudal portion of ham in the middle of the area where the femur was removed, and immediately vacuum-packed.

Seven sensory attributes on the sample slice were assessed by a trained panel of 5 members, on a scale of 1-4, the extremes being "very low" and "very high." Attributes were assigned for firmness, redness, colour uniformity and marbling of lean, for exten-
REARING SYSTEM ON CINTA SENESSE HAM TRAITS

Physical-chemical analysis

On sample slice, colour parameters, L*, a*, b* were determined with a colorimeter Minolta Chromameter CR-200, for subcutaneous fat and for Biceps femoris (BF), Semimembranosus (Sm) and Semitendinosus (St) muscles. Slices were dissected into subcutaneous and internal fat, BF, Sm and St muscles and other lean. The following analyses were carried out on BF and Sm muscles:
1) moisture, by lyophilising to constant weight, determined on minced samples of 50 g; 2) intramuscular fat (IMF), by ether extraction in a Soxhlet apparatus (AOAC, 1990), on lyophilised sample; 3) shear force measurements, by Warner-Bratzler Instron 1011 apparatus (WB), on cylindrical cores of 2.54 cm of diameter.

Fatty acid analysis

The following analyses were carried out on the subcutaneous fat dissected from the sample slice, separately for the outer and the inner layers: 1) moisture; 2) total lipids extracted according to Folch et al. (1957); 3) fatty acid profile of total lipids. Fatty acid methyl esters were prepared by esterification in presence of sulphuric acid (Morrison and Smith, 1964), and were analysed by gas chromatography, using a DANI 86.10 apparatus equipped with a flame ionisation detector (FID). Fatty acids were separated on a capillary column coated with FFAP-TPA stationary phase (30 m length; 0.32 mm internal diameter; 0.25 mm film thickness). Temperature of the column started at 160°C and reached 220°C, with 2°C/min. increase. Temperature of the detector was set at 260°C. Methyl esters were identified by their retention time and expressed as percentage of total detected methyl esters.

Statistical analysis

Data were analysed with the following linear model (SAS, 1996):

\[ Y_{ijk} = \mu + R_i + S_j + b_i X_{ijk} + e_{ijk}, \]

where \( Y_{ijk} \) is the \( k \)th observation of the \( i \)th rearing system (i=1,2) and of the \( j \)th sex (i=1,2), \( \mu \) is the overall mean, the \( b_i \) term is the regression coefficient on trimmed ham weight (X), \( e_{ijk} \) is the random error.

Repeated data were analysed by MIXED procedure (SAS, 1996). In addition to rearing system, sex and covariate, the model included the fixed effect judge (for subjective assessment), or muscle (for muscle traits), or fat layer (for acidic composition).

Table 1. The dry-curing process of Tuscan ham.

| Stage      | Characteristics                                                  |
|------------|------------------------------------------------------------------|
| Trimming   | Ham is defatted and trimmed by leaving 10 cm of lean beyond the femur knob. In the hams of Cinta Senese, foot is not removed. |
| Salting    | Ham is covered with salt and placed in a salting cellar for 18-21 days, at 4°C and 90% relative humidity.             |
| Resting    | Ham is first brushed to remove superficial salt, then it is kept for 40 days in a chamber with a temperature between 2-4°C, 60% relative humidity. |
| Seasoning  | Ham is kept in a cellar for a minimum of 250 days. The conditions in the cellar are highly constant: temperature varies between 17-18°C, 60% relative humidity. |
Results

Overall, no relevant differences were found between sexes, thus the relative comparison was not tabulated.

Rearing system significantly affected losses during the different processing periods (Table 2). Hams of outdoor pigs registered higher trimming and salting losses, subsequently they showed lower losses throughout the resting and seasoning periods. Overall losses during the whole cured process were lower in outdoor pig hams.

With regard to outward appearance (Table 3), hams from outdoor pigs scored highest for fatness (+30%). When the assessment was carried out on the sample slice, rearing system affected marbling and fat extension, with higher values in the hams of outdoor pigs. Firmness of lean was significantly lower (~10%) in the outdoor pigs. As regards redness and colour uniformity, no effect of rearing system was found.

Concerning sample slice composition (Table 4), outdoor pigs showed the highest incidence of subcutaneous fat (+8%) and the lowest percentages of Sm ad St muscles; no difference between rearing systems was found for intermuscular fat, BF and other lean percentages.

For chemical-physical traits of lean,
some significant interactions between muscle and rearing system emerged; consequently, the means of the specific combinations are shown separately (Table 5). As far muscle influence is concerned, in both rearing systems BF was moister, fatter and tougher, and contained more ashes and less protein than Sm muscle. On the contrary, in regard to rearing system effects, the main differences were found in BF muscle where outdoor pigs showed the highest values of moisture and ether extract and the lowest of crude protein. In regard to colorimetric parameters, outdoor pigs showed the lowest values of L* in St muscles. The outdoor system induced the highest value of a* in the BF and St muscles. No rearing differences were registered for b* values. Marked differences were observed among the three muscles: generally in both rearing systems Sm showed the lowest value of L*, BF the highest of a*.

Fat colour (Table 6) showed differences only for the a* parameter, with values almost twice as high in hams of indoor pigs with respect to outdoor pigs.

The effect of rearing system on chemical composition of backfat (Table 7) was relevant. Outdoor pigs had less moisture, lower contents of C14:0, C16:0, C18:0, C16:1, and higher contents of C18:2, C18:3 and C20:2 than indoor animals, and consequently, they showed the highest PUFA/SFA ratio. As regards the layer effect, outer-layer showed lower C16:0, C18:0 and C16:1 percentages, higher contents of C18:1, C18:2, C20:2 and a higher PUFA/SFA ratio.

The effect of seasoning on fatty acid composition of subcutaneous fat (outer layer only) is reported in Table 8 combining the
results of previous trial on the fresh fat of the same animals (Pugliese et al., 2005). Interaction between factors has been detected. In fat of indoor pigs the curing process induced a marked decrease of SFA and PUFA and consequently, an increase of MUFA. In the outdoor system only a significant variation in PUFA was shown, decreasing the PUFA n-6 as the curing process proceeded.

Discussion

The effects of rearing system on ham weight losses during the dry-curing process can be related to carcass composition and meat characteristics. Higher trimming losses of outdoor pig hams can be explained by their higher adiposity (Franci et al., 2003) and higher salting losses in based on the lower water holding capacity observed in their fresh meat (Pugliese et al., 2005). The differences in weight losses recorded in the resting period and in the seasoning process have opposite signs with respect to those recorded at salting stage. Probably the higher adiposity of outdoor pig hams reduced water losses, confirming the reports of Buscailhon and Monin (1994), and Gou et al. (1995), which showed that the rate of desiccation during processing of dry cured hams can be inversely related to backfat thickness.

The higher adiposity of hams from outdoor pigs, scored both as overall fatness and as an extension of subcutaneous fat on sample slice, is in agreement with their higher carcass adiposity (Franci et al., 2003). However, no difference between rearing systems was found in the visual assessment of inner fat knob, which is an important aspect for Italian consumers who appreciate ham with limited amounts of internal fat. The evaluation of the lean portion of the sample slice penalized outdoor pigs because of the lowest firmness and the highest marbling scores. The latter result is confirmed by intramuscular fat contents of BF and Sm muscles. On the contrary, Cava et al. (2000) reported no differences in marbling value of hams between free-ranging and confined Iberian pigs, in spite of the highest intramuscular fat contents of the former.

Composition of the ham sample slice was in general agreement with composition of the fresh sample joint (loin) of the same animals (Pugliese et al., 2005): outdoor pigs showed a lower lean percentage and higher fatness, but no differences were observed for intermuscular fat content contrary to the results on fresh loin-joint.

Table 4. Sample-slice composition.

| Rearing system  | Outdoor | Indoor | RSD   |
|-----------------|---------|--------|-------|
| Slice weight g  | 381.63  | 357.86 | 51.31 |
| Subcutaneous fat % | 40.47\(\text{a}\) | 37.41\(\text{b}\) | 3.47  |
| Intermuscular fat % | 4.04    | 3.92   | 1.21  |
| Biceps femoris % | 20.79   | 21.81  | 1.76  |
| Semimembranosus % | 23.78\(\text{a}\) | 25.96\(\text{b}\) | 2.59  |
| Semitendinosus % | 6.42\(\text{a}\) | 7.03\(\text{b}\) | 0.82  |
| Other lean %    | 4.16    | 3.68   | 0.83  |

\(\text{a, b within criterion means different (P< 0.05)}\)
The higher fatness of outdoor pigs was also evident for intramuscular fat both in Biceps femoris and in Semimembranosus confirming the results obtained in the fresh Longissimus lumborum (Pugliese et al., 2005). The absence of differences between rearing systems in intermuscular fat agrees with the results of the visual assessment of the fat knob. Therefore, intermuscular fat seems to be a poor predictor of overall carcass adiposity.

The effect of rearing system on a* parameter on BF and St muscles was in agreement with the results obtained on fresh Longissimus lumborum (Pugliese et al., 2005). The outdoor rearing system caused more redness in both fresh and seasoned meat confirming the findings of Carrasco et al. (2004), who compared free-ranging with intensively reared pigs. However, the older age of these outdoor pigs may also be the reason for their high value of a*. In fact, as reported by Majoral et al. (1999), myoglobin concentration in pig muscle increases with ageing.

Colour differences among muscles, redness in particular, are probably linked to variation in the level of heme pigments

### Table 5. Chemical-physical traits of muscles.

| Muscle (M) | Rearing system (R) | Significance¹ | RSD |
|-----------|--------------------|---------------|-----|
|           | outdoor | indoor | R | M | RxM |
| Moisture % | BF      | 55.36** | 52.97** | ns | * | * | 2.31 |
|           | Sm      | 49.01v  | 49.50v  |     |   |   |     |
| Crude protein | BF  | 27.28** | 30.83** | *  | *  | *  | 2.69 |
|           | Sm      | 35.54v  | 36.62v  |     |   |   |     |
| Ether extract | BF  | 6.35**  | 4.97**  | *  | *  | ns | 0.96 |
|           | Sm      | 5.00v   | 3.38v   |     |   |   |     |
| Ash       | BF      | 10.60v  | 10.82v  | ns | *  | ns | 0.52 |
|           | Sm      | 9.31v   | 9.74v   |     |   |   |     |
| Shear force kg | BF  | 19.61v  | 20.90v  | ns | *  | ns | 3.92 |
|           | Sm      | 16.81v  | 15.36v  |     |   |   |     |
| L*        | BF      | 37.95v  | 38.02v  | ns | *  | *  | 1.90 |
|           | Sm      | 32.65v  | 32.81v  |     |   |   |     |
|           | St      | 37.15v  | 39.16v  |     |   |   |     |
| a*        | BF      | 17.75** | 15.86** | *  | *  | *  | 1.13 |
|           | Sm      | 14.36v  | 14.35v  |     |   |   |     |
|           | St      | 14.11v  | 13.27v  |     |   |   |     |
| b*        | BF      | 6.10v   | 6.04v   | ns | *  | ns | 0.81 |
|           | Sm      | 5.30v   | 5.94v   |     |   |   |     |
|           | St      | 6.02v   | 6.60v   |     |   |   |     |

¹ ns = not significant , * P≤ 0.05  
** different letters represent significant differences between rearing systems, within muscle (P≤ 0.05)  
*** Different letters represent significant differences among muscles, within rearing system (P≤ 0.05)
among fibre populations of different muscles (Leseigneur-Meynier and Gandemer, 1991), and to pigment concentration. It has been suggested that the latter is linked to the dehydratation processes, more intense in the superficial muscle Sm than in deeper muscle BF (Campo-Fernández et al., 1992). Our results agree with those of García-Esteban et al. (2003), which reported higher values for colour parameters in BF of dry-cured ham than in Sm.

Muscular differences in physical-chemical composition, moisture in particular, can also be explained by muscle location. BF muscle, because of its deep position, adsorbs salt by slow diffusion and gradually loses moisture. For these reasons it is considered the most representative muscle of the ham (Diaferia and Baldini, 1994). The BF muscle was more influenced by rearing conditions than Sm, the latter showing differences for intramuscular fat only. Intramuscular fat contributes to organoleptic properties of fresh meat with effects on juiciness, flavour and tenderness (Beattie et al., 1999). However, fat amount can affect dry ham quality in different ways: the higher intramuscular fat in outdoor pig hams induced a high marbling score that is not appreciated by Italian consumers.

The effects of rearing system and/or of diet composition on fatty acids pattern have been investigated by several Authors for the characterisation of dry cured ham (Cava et al., 1999; Timón et al., 2001; Lebret et al., 2002; Carrapiso et al., 2003; Pastorelli et al., 2003). In contrast to our results, Carrapiso et al. (2003) and Cava et al. (1999) found lower contents of SFA and higher of MUFA in pigs reared on oak plantations with respect to animals fed concentrate. Significant enrichment in MUFA and PUFA in hams from pigs raised extensively with free availability of acorn and pasture has been reported by Flores et al. (1988). Their results are in agreement with our study only for the higher PUFA percentage.

The expected decrease of PUFA during the dry-curing process has been observed only in indoor pigs; this result is probably due to lower stability of their fat with respect to outdoor pigs.

In fact, as reported by Daza et al. (2005), outdoor pigs, with respect to indoor pigs, fed a diet with different MUFA/PUFA ratios and α-tocopheryl acetate, show a higher resistance to oxidation, probably due to the presence of γ-tocopherol and/or other antioxidants identified in acorn, such as gallic acid derivatives, even if there is no evidence that these substances are absorbed and accumulated in animal tissues. The characterisation of dry-cured ham of Cinta Senese pigs in relation to feeding regimes seems more arduous than in other situations of the Mediterranean area, such as Dehesa for the Iberian pig, which are more standardised (Lopez-Bote, 1998).

Table 6. Colour parameters of subcutaneous fat.

| Rearing system | RSD | Outdoor | Indoor |  |
|----------------|-----|---------|--------|---|
| L*             | 72.77 | 72.85 | 1.54 |
| a*             | 2.99 | 5.64 | 0.94 |
| b*             | 3.99 | 4.04 | 0.49 |

a, b within criterion means different (P < 0.05)
Difficulties are in fact associated with the wide variability of the composition of the woods where Cinta Senese pigs are reared. The animals of this trial pastured on mixed woods, feeding on both chestnuts and acorns that are known to have different fatty acid compositions. It is possible that the higher PUFA level of outdoor pig hams was due to feeding on chestnuts and grass that have high level of these fatty acids (Pugliese and Bozzi, 2004; Cava et al., 1999).

The lack of significant difference in the fat firmness score (Table 3) seems contradictory with the difference in total PUFA. However, it should be noted that the level of total PUFA, also in seasoned fat, was below the threshold value of 15% above which fat consistency and oxidative stability can be negatively affected (Warnants et al., 1996).

### Table 7. Fatty acid composition of subcutaneous fat.

| Rearing system | Layer | RSD |
|----------------|-------|-----|
|                |       |     |
| Outdoor        |       |     |
| Indoor         |       |     |
| Outer          |       |     |
| Inner          |       |     |
| Moisture %     |       |     |
| Lipids         |       |     |
| Fatty acids %  |       |     |
| C14:0          |       |     |
| C16:0          |       |     |
| C18:0          |       |     |
| C16:1          |       |     |
| C18:1          |       |     |
| C18:2          |       |     |
| C18:3          |       |     |
| C20:1          |       |     |
| C20:2          |       |     |
| SFA            |       |     |
| MUFA           |       |     |
| PUFA n-3       |       |     |
| PUFA n-6       |       |     |
| PUFA/SFA       |       |     |

* a, b within criterion means different (P< 0.05)
* Other fatty acids (< 0.2%) determined: C12:0; C17:0; C20:0; C16:3; C20:3; C20:4

**Conclusions**

The extensive rearing system can be exploited to characterise the products of Cinta Senese pigs, since it significantly affects the property of fat and meat of cured hams. The higher percentage of intramuscular fat, which is well known to be positively correlated with organoleptic traits, the more intensive colour of meat and the higher content of PUFA, represent an indubitable advantage to typify dry cured ham. Some aspects, such the highest level of PUFA, could negatively affect the technological traits of fat in outdoor pigs, but the lack of difference in fat firmness score confirms that their level is not problematic. Moreover, the differences in fatty acid composition between rearing systems could rep-
Table 8. Changes in chemical composition of outer layer of subcutaneous fat during the seasoning process, according to rearing system.

| Rearing system (R) | Stage of curing (S) | Significance | RSD |
|--------------------|---------------------|--------------|-----|
|                    | fresh               | seasoned     | R  | S  | RxS |
| Moisture           | Outdoor             | 5.44<sup>a</sup> | 1.77<sup>y</sup> | *  | *  | *  | 1.02 |
|                    | Indoor              | 6.53<sup>x</sup> | 1.71<sup>y</sup> |    |    |    |     |
| Lipids             | Outdoor             | 82.34<sup>a</sup> | 77.98<sup>y</sup> | ns | *  | ns | 3.31 |
|                    | Indoor              | 81.42<sup>x</sup> | 77.30<sup>y</sup> |    |    |    |     |
| Fatty acids<sup>2</sup>: | Outdoor | C14:0 | 0.97<sup>a</sup> | 1.19<sup>xy</sup> | *  | *  | ns | 0.04 |
|                    | Indoor              | 1.29<sup>x</sup> | 1.49<sup>xy</sup> |    |    |    |     |
|                    | Outdoor             | C16:0 | 20.93<sup>a</sup> | 20.55<sup>y</sup> | *  | *  | *  | 0.43 |
|                    | Indoor              | 24.04<sup>x</sup> | 23.26<sup>xy</sup> |    |    |    |     |
|                    | Outdoor             | C18:0 | 9.24<sup>a</sup>  | 9.11<sup>y</sup> | *  | *  | *  | 0.59 |
|                    | Indoor              | 10.51<sup>x</sup> | 9.69<sup>xy</sup> |    |    |    |     |
|                    | Outdoor             | C18:1 | 1.43<sup>a</sup>  | 2.04<sup>y</sup> | *  | *  | *  | 0.15 |
|                    | Indoor              | 1.99<sup>x</sup> | 2.82<sup>xy</sup> |    |    |    |     |
|                    | Outdoor             | C18:2 | 52.57<sup>a</sup> | 52.23<sup>y</sup> | *  | *  | *  | 1.05 |
|                    | Indoor              | 50.26<sup>x</sup> | 52.46<sup>y</sup> |    |    |    |     |
|                    | Outdoor             | C18:3 | 9.51<sup>x</sup>  | 7.78<sup>xy</sup> |    |    |    |     |
|                    | Indoor              | 9.51<sup>x</sup> | 7.78<sup>xy</sup> |    |    |    |     |
|                    | Outdoor             | C20:1 | 0.90<sup>a</sup>  | 1.11<sup>xy</sup> | *  | *  | *  | 0.05 |
|                    | Indoor              | 0.32<sup>x</sup> | 0.28<sup>xy</sup> |    |    |    |     |
|                    | Outdoor             | C20:2 | 0.89<sup>a</sup>  | 1.19<sup>y</sup> | ns | *  | *  | 0.06 |
|                    | Indoor              | 0.98<sup>x</sup> | 1.21<sup>y</sup> |    |    |    |     |
|                    | Outdoor             | SFA   | 31.49<sup>a</sup> | 31.24<sup>y</sup> | *  | *  | *  | 1.00 |
|                    | Indoor              | 36.17<sup>x</sup> | 34.75<sup>xy</sup> |    |    |    |     |
|                    | Outdoor             | MUFA  | 54.89<sup>a</sup> | 55.46<sup>y</sup> | ns | *  | *  | 1.11 |
|                    | Indoor              | 53.23<sup>x</sup> | 56.48<sup>xy</sup> |    |    |    |     |
|                    | Outdoor             | PUFA n-3 | 1.06<sup>a</sup> | 1.25<sup>xy</sup> | *  | *  | *  | 0.08 |
|                    | Indoor              | 0.39<sup>x</sup> | 0.34<sup>xy</sup> |    |    |    |     |
|                    | Outdoor             | PUFA n-6 | 12.37<sup>a</sup> | 11.77<sup>xy</sup> | *  | *  | *  | 0.53 |
|                    | Indoor              | 10.02<sup>x</sup> | 8.21<sup>xy</sup> |    |    |    |     |
|                    | Outdoor             | PUFA/SFA | 0.43<sup>a</sup> | 0.43<sup>y</sup> | *  | *  | *  | 0.02 |
|                    | Indoor              | 0.29<sup>x</sup> | 0.25<sup>xy</sup> |    |    |    |     |

<sup>1</sup> ns = not significant, * P ≤ 0.05
<sup>2</sup> Different letters represent significant differences between rearing systems (within stage of curing) (P ≤ 0.05)
<sup>x,y</sup> Different letters represent significant differences between stages of curing (within rearing system) (P ≤ 0.05)
<sup>3</sup> Other fatty acids (< 0.2%) determined: C12:0; C17:0; C20:0; C16:3; C20:3; C20:4
resent, for Cinta Senese products, a useful method of alimentary traceability which is an indubitable advantage either for consumers who are protected against fraud and imitations, or for producers who in this way could have products with high added value.

The authors wish to thank the managerial and technical staff of the Corpo Forestale dello Stato (ex- ASFD administration) of Siena and the Bezzini farm in Sovicille (Siena, Italy).

**REFERENCES**

AOAC, 1990. Official Methods of Analysis. 15th ed. Association of Official Analytical Chemists, Washington, DC, USA.

ACCIAIOLI, A., PUGLIESE, C., BOZZI, R., CAMPODONI, G., FRANCI, O., GANDINI, G., 2002. Productivity of Cinta Senese and Large White x Cinta Senese pigs reared outdoor on woodlands and indoor. 1. Growth and somatic development. Ital. J. Anim. Sci. 1:171-180.

ANTEQUERA, T., LOPEZ-BOTE, C.J., CÓRDOBA, J.J., GARCÍA, C., ASENSIO, M.A., VENTANAS, J., 1992. Lipid oxidative changes in the processing of the Iberian pig hams. Food Chem. 45:105-110.

BEATTIE, V.E., WEAHTHRUP, R.N., MOSS, B.W., WALKER, N., 1999. The effect of increasing carcass weight of finishing boars and gilts on joint composition and meat quality. Meat Sci. 52:205-211.

BUSCAILHON, S., MONIN, G., 1994. Déterminisme des qualités sensorielles du jambon sec. 2ème partie. Viandes et Prod. Carnés 15:39-48.

CAMPO-FERNÁNDEZ, A.D., PÉREZ-ÁLVAREZ, J.A., SAYAS, M.E., ARANDA-CATÁLA, V., 1992. Spanish dry-cured ham: physical and physicochemical study. Page 471 in Proc. 38th Int. Congr. of Meat Science and Technology (ICoMST), Clermont-Ferrand, France.

CARRAPISO, A.I., BONILLA, F., GARCÍA, C., 2003. Effect of crossbreeding and rearing system on sensory characteristics of Iberian ham. Meat Sci. 65:623-629.

CARRASCO, A., TÁRREGA, R., RAMÍREZ, M.R., MINGOARRANZ, F.J., CAVA, R., 2004. Colour and lipid oxidation in dry-cured loins from free-range reared and intensively reared pigs as affected by ionizing radiation dose level. Meat Sci. 69:609-615.

CAVA, R., RUIZ, J., VENTANAS J., ANTEQUERA, T., 1999. Oxidative and lipolytic changes during ripening of Iberian hams as affected by feeding regime: extensive feeding and alpha-tocopheryl acetate supplementation. Meat Sci. 52:165-172.

CAVA, R., VENTANAS, J., RUIZ, J., ANDRÉS, A.I., ANTEQUERA, T., 2000. Sensory characteristics of Iberian ham: influence of rearing system and muscle location. Food Sci. Technol. Int. 6:235-242.

DAZA, A., REY, A.I., RUIZ, J., LOPEZ-BOTE, C.J., 2005. Effects of feeding in free-range conditions or in confinement with different dietary MUFA/PZFA ratios and α-tocopheryl acetate, on antioxidants accumulation and oxidative stability in Iberian pigs. Meat Sci. 69:151-163.

DIAFERIA, C., BALDINI, P., 1994. Influenza della temperatura di prestagionatura e del tempo di stagionatura sulle caratteristiche chimico-fisiche e sensoriali di prosciutti crudi di tipo Veneto. Ind. Conserve 69:91-95.

EDWARDS, S.A., CASABIANCA, F., 1996. Perception and reality of product quality from outdoor pig system in Northern and Southern Europe, pp 145-156 in Proc. 4th Int. Symp. Livest. Farm. Syst., Foulum, Denmark.
FLORES, J., BIRON, C., IZQUIERDO, L., NIETO, P., 1988. Characterisation of green hams from Iberian pigs by fast analysis of subcutaneous fat. Meat Sci. 23:253-262.

FOLCH, J., LEES, M., SLOANE-STANLEY, G.H., 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226:497-509.

FRANCI, O., CAMPODONI, G., BOZZI, R., PUGLIESE, C., ACCIAIOLI, A., GANDINI, G., 2003. Productivity of Cinta Senese and Large White x Cinta Senese pigs reared outdoors in woodlands and indoors. 2. Slaughter and carcass traits. Ital. J. Anim. Sci. 2:59-65.

FRANCI, O., 2004. Generalità storiche e produttive. In: O. Franci (ed.) La Cinta Senese. Gestione Attuale di una razza antica. ARSIA Regione Toscana, Firenze, Italy, pp 19-31.

GARCÍA-ESTEBAN, M., ANSORENA, D., GIMENO, O., ASTIASARÁN I., 2003. Optimization of instrumental colour analysis in dry-cured ham. Meat Sci. 63:287-292.

GOU, P., GUERRERO, L., ARNAU, J., 1995. Sex and crossbreed effects on the characteristics of dry-cured ham. Meat Sci. 40:21-31.

LEBRET, B., MASSABIE, P., GRANIER, R., JUIN, H., MOUROT, J., CHEVILLON, P., 2002. Influence of outdoor rearing and indoor temperature on growth performance, carcass, adipose tissue and muscle traits in pigs, and on the technological and eating quality of dry-cured hams. Meat Sci. 62:447-455.

LESIGNEUR-MEYNIER, A., GANDEMER, G., 1991. Composition of pork muscle in relation to the metabolic type of the fibres. Meat Sci. 29:229-241.

LOPEZ-BOTE, C.J., 1998. Sustained utilization of the Iberian pig breed. Meat Sci. 49:17-27.

MAYORAL, A.I., DORADO, M., GUILLÉN, M.T., VIVO, J.M., VAZQUEZ, C., RUIZ, J. 1999. Development of meat and carcass quality characteristics in Iberian pigs reared outdoors. Meat Sci. 52:315-324.

MORRISON, W.R., SMITH, L.M., 1964. Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron fluoride methanol. J. Lipid Res. 5:600-608.

PASTORELLI, G., MAGNI, S., ROSSI, R., PAGLIERINI, E., BALDINI, P., DIRIK, P., VAN OPSTAELE, F., CORINO C., 2003. Influence of dietary fat, on fatty acid composition and sensory properties of dry-cured Parma ham. Meat Sci. 56:571-580.

PUGLIESE, C., BOZZI, R., 2004. Qualità dei prodotti. In: O. Franci (ed.) La Cinta Senese. Gestione Attuale di una razza antica. ARSIA Regione Toscana, Firenze, Italy, pp 109-140.

PUGLIESE, C., BOZZI, R., CAMPODONI, G., ACCIAIOLI, A., FRANCI, O., GANDINI, G., 2005. Performance of Cinta Senese pigs reared outdoors and indoors. 1. Meat and subcutaneous fat characteristics. Meat Sci. 69:459-464.

SAS, 1996. User’s Guide Statistics. Version 6.12. SAS Institute, Inc., Cary, NC, USA.

TIMÓN, M.L., VENTANAS, J., CARRAPISO, A.I., JURADO A., GARCÍA, C., 2001. Subcutaneous and intermuscular fat characterisation of dry-cured hams. Meat Sci. 58:85-91.

WARNANTS, N., VAN OECHEL, M.J., BOUCQUÉ, CH.V., 1996. Incorporation of dietary polyunsaturated fatty acids in pork tissues and its implications for quality of end products. Meat Sci. 44:125-144.