Invited lecture
COBISS: 1.06
Agris category code: L02, Q01

# FEEDING STRATEGIES FOR LOCAL BREEDS IN VIEW OF PRODUCT QUALITY

Carolina PUGLIESE [1, 2], Francesco SIRTORI [1], Oreste FRANCI [1]

**ABSTRACT**

The effect of quantitative-qualitative modulation of diet on quality of meat and cured product in pig local breeds is reviewed, focusing on the effect on intramuscular fat (IMF) which is the most important of the meat traits. IMF does not develop the last among fat depots, so high level of feeding in advanced age favours subcutaneous fat deposition, whose commercial destination is often problematic also for the local pig. The compensatory growth, as consequence of re-alimentation after feeding restriction, attains better to local breeds than to conventional ones, because of the longer rearing period and the exploitation of natural resources in sylvo-pastoral system. This practice in Cinta Senese produces meat with higher cooking loss, fatter, less tender, darker and redder and subcutaneous fat richer in MUFA and PUFA n-3. However, the compensatory effect seems to depend also to the age when fattening starts. Knowledge on protein requirements in the local breeds is less available but researches on Iberian and Cinta Senese pig highlighted that only very low dietary protein content (below 9%) produced significant effect on overall fatness and on some meat traits. On other hand, that protein content is usual in the diet of sylvo-pastoral feeding system, based on grass and acorn without any aminoacidic integration.

**Key words:** local pig / feed restriction / dietary proteins / intramuscular fat / meat quality

## 1 INTRODUCTION

Strategies for feeding pig have a great importance in the determination of chemical, physical and sensorial characteristics of meat (fatty depots included) and of processed products. The literature refers largely to conventional and improved breeds but, from those general rules, it is possible to obtain indication which, *mutatis mutandis*, can also be useful for the management of local breeds, even if these genotypes are to be reared according to the systems more congenial in form of compliance of the specification required by the marks of origin. The recent review of Lebret (2008) examined extensively the link between feeding/rearing system and the quality of carcass and meat in pigs, with particular emphasis to the conventional breeds. The feeding strategies can be categorised according the following points: 1) feeding restriction; 2) feeding restriction and re-alimentation (and, consequently, compensatory growth); 3) dietary level of protein (or lysine): energy ratio. The analytical, physical and sensorial traits, considered to define the quality of pig products, are largely influenced by the fat components, both by that portion indissolubly linked to meat (IMF) and by the subcutaneous and intermuscular depots, which, although mechanically separable from the muscle, ultimately participate directly to the cured products as a whole piece (i.e. ham) or as sausages (i.e. salami). So, the quantitatively and qualitatively variation of fat, largely dependent to the diet, is to be considered primarily in the relationship between feeding strategy and products quality. However, even the muscular component, participates in the definition of quality parameters through the relations between stromatic and fibrillar proteins, the proportion of the various types of muscle

1 DiSPAA, Animal Science Section. University of Firenze, Via delle Cascine, 5. 50144 Italy
2 Corresponding author, e-mail: carolina.pugliese@unifi.it

fibers and the process of post-mortem acidification (pH fall). The latter is perhaps the main factor affecting water holding capacity (WHC) and the tenderness of the meat. The influence of feeding on the muscular component is well recognised in the review of Andersen *et al.* (2005), where particular emphasis to muscle protein turnover and energy level in conventional pig is made. The present review is focused on influence of feeding strategy on adipose depots, as main responsible of the characteristics of the products of local pig of the Mediterranean area.

## 2 FAT DEPOTS

IMF represents the inseparable component of the meat and its proportion is generally associated with the improved sensory traits of meat (Fernandez *et al.,* 1999; Wood *et al.,* 2004) to the point that Wood *et al.* (1986) stated that particularly low IMF content may not assure desirable organoleptic properties. Moreover, IMF plays a major role in the quality of dry-cured meat products, as Iberian ham, since it strongly influences the technological feasibility and the sensory quality of the final products (Lopez-Bote, 1998). IMF content is higher in local pigs than in the "improved" ones, as reviewed by Pugliese and Sirtori (2012) and as found in some direct comparisons between the two genotypes (Franci *et al.,* 2005; Labroue *et al.,* 2000; Serra *et al.,* 1998). The fat content in *Longissimus* muscle of local pigs is generally higher than 3% but can exceed also 20% in Iberian pig that exhibited the highest variability for this trait. Moreover, studying the relationships among various fat depots, Franci *et al.* (2001) pointed out that IMF was only partially linked to overall fatness and this relative independence was mainly due to breed differences. This finding was confirmed by Wood *et al.* (2004) which indicated: low IMF and subcutaneous fat (SF) content in Large White, high percentage of both fats in Berkshire, low SF and high IMF in Duroc, high SF and low IMF in Tamworth. Also in some Mediterranean local pigs there are differences between IMF and carcass fat content (Table 1), but the comparison should be conducted in the same experiment to achieve scientific evidence. However it seems important to report the findings of Wood *et al.* (2004) that the composition of the IMF are influenced not by the IMF content but by the overall body fatness which definitively controls the fatty acid profile. In this context, the allometric growth of the various fat depots is to be examined. According to Lee and Kauffman (1974), IMF develops later than the other fat depots and then it is more sensitive to the environmental and nutritive manipulation during the fattening. Anyway this finding was relative to very light pig. Results concerning a wide weight range, inclusive of high weights usual in the pig production of the Mediterranean area (Table 2), highlight that IMF is late developing tissue, but not the latest among the fat depots because this record is mainly attributable to subcutaneous/intermuscular fat. This pattern implies that nutritional manipulation performed in the late fattening in order to increase the IMF deposition and, consequently, to improve the meat quality and characterize the cured product, involves in a considerable increase of the subcutaneous depot, whose commercial destination is often problematic.

## 3 FEED RESTRICTION

Studies on the improved pig breeds demonstrated that feed restriction, in comparison to *ad libitum* feeding, particularly during the growing-fattening period, reduces the growth rate and, consequently, leads to leaner carcasses (Quiniou *et al.,* 1995; Lebret *et al.,* 2001). This is due to the fact that the relative growth rate of adipose tissue increases with the age, whereas the protein deposition remains rather constant and priority; hance, the fat deposition appears more sensitive to a reduction of energy intake during the fattening period. Lebret *et al.* (2001) demonstrated that a restriction of 25% in feeding allowance decreases the growth rate for 27% and reduces the overall carcass fatness and the IFM deposition in *Longissimus*. This confirms previous research (i.e. Quiniou *et al.,* 1995; Čandek-Potokar *et al.,* 1998), where

***Table 1:*** *Comparison of fat content in carcass and in Longissimus muscle of some local breeds*

| Breed | Body weight (kg) | Age (days) | Total fat cuts (%) | IMF (%) | Author |
|---|---|---|---|---|---|
| Casertana | 200 | 494 | 39.5 | 4.7 | Fortina *et al.,* 2005 |
| Mora Romagnola | 193 | 514 | 44.7 | 6.1 | Fortina *et al.,* 2005 |
| Nero Siciliano | 102 | 448 | 39.4 | 3.3 | Pugliese *et al.,* 2004 |
| Cinta Senese | 136 | 312 | 37.1 | 3.2 | Franci *et al.,* 2005 |
| Cinta Senese | 154 | 430 | 33.5 | 6.0 | Sirtori *et al.,* 2011 |
| Iberian | 152 | 482 | ~56* | ~10* | Mayoral *et al.,* 1999 |

* Adaptation of original data

***Table 2:*** *Allometric coefficients (b ± se) of fat depots*

| Author | Franci *et al.* (2001) | De Pedro-Sanz (1987) | Geri *et al.* (1984) |
|---|---|---|---|
| Breed | conventional | Iberian pig | conventional |
| Live weight range (kg) | 124–183 | 50–175 | 20–200 |
| Part of reference | carcass | Ham | total carcass fat |
| Subcutaneous fat | 1.34 ± 0.08 | 1.70 ± 0.03 | 1.06 ± 0.01 |
| Intermuscular fat | 1.47 ± 0.14 | 1.41 ± 0.06 | 0.68 ± 0.04 |
| IMF | 1.26 ± 0.22 | 1.04 ± 0.04 | 0.81 ± 0.03 |

the feeding restriction did not affect the meat quality (pH, reflectance, drip loss). On the contrary, Blanchard *et al.* (1999) found that a restriction of 0.8% of *ad libitum* diet produced less tender and juicier meat and Bee *et al.* (2006) stated that feeding restriction had detrimental impact on meat quality, with lower water holding capacity and tenderness. These general principles can be applied also on the local pig breeds, characterised by low protein deposition and high body fatness. Actually, in these breeds, the feeding system is extremely variable and produces different weight gain, as demonstrated by Crovetti *et al.* (2012) on Cinta Senese which, according to the different systems, reached the slaughter weight of 150 kg at ages from 12 until 24 months. Unfortunately, in the extensive conditions, the reduction of growth rate is consequence both of feeding allowance restriction and of use of natural resources, as pasture on grass; so, it is impossible to evaluate the true effect of feeding restriction on the quality of the products. On other hand, on the Italian local breeds there is no experimental trial on this topic but it is possible to extrapolate some indications comparing different studies where weight gain is the discriminating factor. Hence, comparing the findings of Franci *et al.* (2005) and Pugliese *et al.* (2003), emerged that in Cinta Senese the 15% decrease in growing rate determines a lower percentages of fat cuts and IMF and also lower WHC. Similar tendency can be achieved reprocessing data of Sirtori *et al.* (2011) on Cinta Senese reared indoors and outdoors.

## 4 FEED RESTRICTION AND RE-ALIMENTATION

This topic has been well reviewed by Lebret (2008) in relation to the conventional breeds. This feeding strategy is applied to encourage the compensatory growth, an accelerated the rate of weight gain due to *ad libitum* feeding subsequent to a period of limited food supplied. Compensatory growth was firstly defined by McMeekan (1940) and, thereafter extensively studied by many authors. Normally this strategy allows to localise the high energy supply when the pig is older, because of the limited growth in the previous phase, and the biological rhythm should favour the fat deposition, both in the subcutaneous and muscular depot. According to Kristensen *at al.* (2004), the compensatory growth should improve meat tenderness, as it can favour the muscle protein turnover. On the contrary, Lebret *et al.* (2007) and Heyer and Lebret (2007) found that 28 or 34 days of re-feeding period had no positive effect on the IMF content of *Longissimus* and on meat eating quality. Similar results were achieved on light pigs (up to six months of age) by other authors with analogous experimental design (Skiba, 2010; Oksbjerg *et al.,* 2002; Wiecek *et al.,* 2011).

In conclusion, increase of the IMF level and improvement of meat quality might depend from the onset and duration of the restriction and re-alimentation period, the rate of reduction of growth during the restriction and from the age at the re-feeding. However, the positive effect of compensatory growth on the increase of IMF seems to be difficult to achieve in the conventional pig breeds and in the intensive pig production where the increase of age or weight at slaughter is to be avoid. On the contrary, the compensatory growth is well suitable in the rearing scheme of the local pig in the Mediterranean regions where natural feeding resources are widely used in a sylvo-pastoral system and where pigs are slaughtered at high weight and/or age with the aim to enhance the quality of processed products. The best example of such feeding strategy is the one used in the rearing of Iberian pig (Lopez-Bote, 1998). Also recently, other local breeds of the Mediterranean area have been studied in relation to the extensive system, as Alentejano in Portugal (Neves *et al.,* 2007; Tirapicos Nunes, 2007); Corsican pig in France (Secondi *et al.,* 2007); Nero Siciliano and Cinta Senese in Italy (Pugliese *et al.,* 2004 and 2005). Normally, the extensive system, particularly linked to the availability of natural resources, *per se* determined the feeding restriction and re-alimentation but in some rearing systems, as the one of Iberian pig (Lopez-Bote, 1998), the feeding restriction during the growth is deliberately practiced to exalt the weight gain during the final period of *Montanera*. The shape of the growth curve in

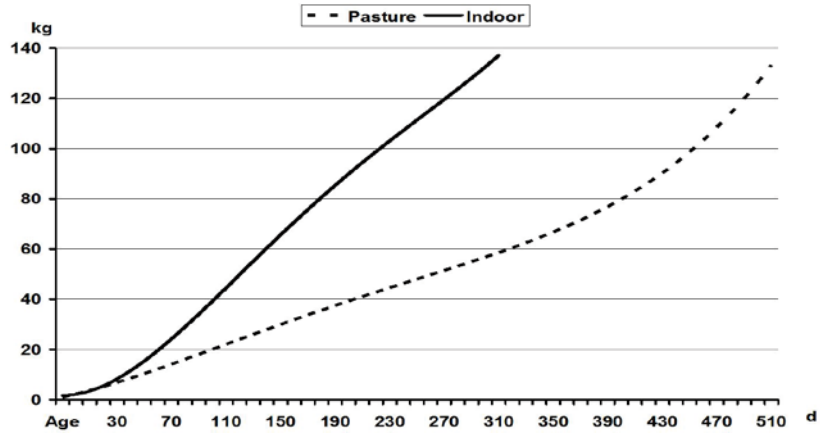


***Figure 1:*** *Trend of growth in Cinta Senese pig according to rearing system (Acciaioli et al., 2002)*

free-range system, in comparison with that of the intensive system, is well represented in Fig. 1, relative to Cinta Senese pig. The consequence of this pattern on carcass and meat composition is reported in Table 3. Free-range pigs had more IMF, but also higher fat cuts percentage, and they produced meat with higher cooking loss, less tender, darker and redder. Subcutaneous fat was richer in MUFA and PUFA, including the PUFA n-3. It is difficult to attribute all these characteristics exclusively to the compensatory growth, given the differences in the diet composition. However, the study of Mayoral *et al.* (1999) on Iberian pig, during the traditional management system with fattening on acorns and pasture, highlighted that, following a growth pattern analogous to that shown for Cinta Senese in Fig. 1, IMF of *Longissimus* increased up to 10%, water loss decreased continuously, total collagen did not vary but insoluble collagen increased from 7 to 77% of total collagen. Unfortunately, the carcass fat increased markedly during the last 80 days reaching the value of 56% of the carcass weight. The effect of *Montanera* pasture on fat quality characteristics of Iberian pig was less pronounced in pigs starting the fattening with 8 months than in pigs starting with 12 an 14 months (Daza *et al.,* 2007a), whereas a severe reduction of the feeding level before the fattening in Montanera did not produced compensatory growth and resulted in only a small improvement in fatty acid profile of SF (Daza *et al.,* 2008). Other works in Iberian pigs reared in intensive system, allows better understanding of the effects of the compensatory growth on meat and fat traits avoiding confusion with other factors such as the different diet composition present in the abovementioned researches. Daza *et al.* (2007b) found that the re-alimentation on *ad libitum* level, following feed restriction, did not modify the backfat thickness and the IMF content but increased the oleic content in the subcutaneous fat (about 2%) whereas Serrano *et al.* (2009) found the same results for carcass traits and IMF content but higher content of oleic acid in backfat of pigs feed continuously *ad libitum*.

***Table 3:*** *Performances of Cinta Senese pig according to rearing system, as in Fig. 1 (Pugliese et al., 2005)*

| | Indoor | Pasture |
|---|---|---|
| Slaughter weight (kg) | 136.2[a] | 127.7[b] |
| Age (days) | 312[a] | 510[b] |
| Total fat cuts (%) | 36.7[a] | 41.0[b] |
| IMF (%) | 3.3[a] | 4.0[b] |
| Cooking loss (%) | 26.6[a] | 30.3[b] |
| Shear force on cooked meat (N) | 105[a] | 151[b] |
| L* | 50.13[a] | 45.78[b] |
| a* | 11.77[a] | 14.95[b] |
| In subcutaneous fat (% of FAs) | | |
| MUFA | 53.3[a] | 55.08[b] |
| PUFA n-3 | 0.39[a] | 1.02[b] |
| PUFA n-6 | 10.05[a] | 12.30[b] |

a, b; $P < 0.05$

## 5 PROTEIN LEVEL AND QUALITY

The protein requirements of the improved pig breeds have been widely studied (see review of Whittemore *et al.,* 2001) also in terms of the growth and feeding efficiency (Campbell *et al.,* 1984; Hansen and Lewis, 1993). But only a limited number of studies have addressed the effect of the dietary protein or lysine levels on the carcass composition and, in particular, on the meat quality. A summary of the studies on conventional breeds (Lebret, 2008) reports, that unbalanced diets (with insufficient ratio of protein or lysine to energy contents) in-

creased IMF content and improved tenderness and juiciness of meat. The knowledge on protein requirements in the local breeds is less available and, in particular, studies that define the composition of ideal protein ratio at different stages of growth are few. Only on Iberian pig a wide research has been conducted to study the effects of different dietary levels of ideal protein on protein and energy retention (Barea *et al.,* 2007; Nieto *et al.,* 2012) and on carcass characteristics (Nieto *et al.,* 2003; Barea *et al.,* 2006). In detail, Barea *et al.* (2006) observed that a diet with 6.2% of protein (0.42% of Lys) produced at 100 kg of live weight a higher percentage of dissectible fat in the ham and shoulder compared with other three diets with 8.4 (0.57), 10.6 (0.72), 12.8 (0.87) % of protein (Lys), which behaved in similar manner. Unfortunately, information on specific influence on meat and cured products quality is not available.

Similar results on overall body fatness have been found in Cinta Senese by Sirtori *et al.* (2013) that also shows the influence of dietary protein content on meat quality (Table 4). It emerged that the diet at 8% of protein is well distinguishable from the others as it resulted in greater fatness of the carcass and in meat with higher IMF, cooking loss, lightness and redness. It is noticeable that the three other diets, at higher protein content, had the same behaviour, confirming the picture found also for the *in vita* performance (Sirtori *et al.,* 2010). This result demonstrates the low protein requirements of this breed and justifies the use of a diet at 10% of protein, without any aminoacidic integration. On other hand, the integration of amino acids into the diet is prohibited by the rules of an organic system or of the "Cinta Senese" PDO label, to which many breeders of Cinta Senese adhere. Finally, it is evident that, the lowest protein contents tested in the researches of Barea *et al.* (2006) and Sirtori *et al.* (2013), are difficult to implement in a conventional pig productive system as they are lower than protein content of cereals, but are usual in the diet of sylvo-pastoral feeding system. In fact, Rodriguez-Estevez *et al.* (2009) demonstrated that Iberian pig, reared in the Dehesa, intakes daily about 3.6 kg of acorn endocarp and 0.4 kg of grass (as dry matter) with a dietary protein content of 6.5% (on dry matter basis). So the results on meat quality obtained indoors with the diet at a lower protein content, can be realistic in animal reared in free-range on natural pasture.

## 6 CONCLUSION

This review limits its examination to some aspects of the feeding strategy related to quantitative and qualitative modulation of the diet, focusing on changes in the IMF that is considered the main responsible for the quality of meat and cured products. It turns out that researches on the developmental pattern of fat deposits for many local breeds in the Mediterranean would be useful, since it is not appropriate to generalize, given the evident differences in fat partitioning among genotypes. In fact the local breeds are slaughtered at high weights and ages and have better chances to feel the effects of compensatory growth linked to dietary restrictions for energy and/or protein. However, this tool must be properly calibrated to avoid excessive development of fat deposits of problematic commercial value. This principle must be kept in mind also in consideration of the fact that for many of these breeds the niche market of products requires the respect of breeding systems which ensure also the image of naturalness and healthiness, in the respect of specific

***Table 4:*** *Effect of dietary protein content on traits of Longissimus l. muscle in Cinta Senese pig (Sirtori et al., 2013)*

| | Protein content of diet (%) | | | | |
|---|---|---|---|---|---|
| | 8 | 10 | 13 | 16 | rsd |
| Dietary Lysine (%) | 0.21 | 0.37 | 0.57 | 0.79 | |
| Total fat cuts (%) | 37.16[a] | 32.92[b] | 33.95[b] | 33.30[b] | 1.98 |
| Cooking loss (%) | 20.90[a] | 16.26[b] | 16.51[b] | 18.32 | 4.64 |
| WB shear force on cooked meat (kg) | 9.70 | 10.32 | 10.93 | 9.60 | 2.18 |
| IMF (%) | 6.58[a] | 4.18[b] | 3.78[b] | 4.07[b] | 1.24 |
| Protein (%) | 21.36[a] | 22.78[b] | 23.52[b] | 23.23[b] | 1.17 |
| Colour parameters | | | | | |
| - L* | 48.47[a] | 45.75[b] | 44.85[b] | 45.38[b] | 2.62 |
| - a* | 11.33 | 10.55 | 11.00 | 10.94 | 1.46 |
| - b* | 3.59[a] | 2.90[b] | 2.52[b] | 2.74[b] | 0.79 |

[a, b] Within row, means assigned with different letter differ significantly ($P < 0.05$)

regulations that prevent integration with synthetic substances.

## 7 REFERENCES


Acciaioli A., Pugliese C., Bozzi R., Campodoni G., Franci O., Gandini G. 2002. Productivity of Cinta Senese and Large White × Cinta Senese pigs reared outdoor on woodlands and indoor. 1. Growth and somatic development. Italian Journal of Animal Science, 1: 171–180

Andersen H.J., Oksbjerg N., Young J.Y., Therkildsen M. 2005. Feeding and meat quality – a future approach. Meat Science, 70: 543–554

Barea R., Nieto R., Aguilera J.F. 2007. Effect of the dietary protein content and the feeding level on protein and energy metabolism in Iberian pigs growing from 50 to 100 kg live weight. Animal, 1: 357–365

Barea R., Nieto R., Lara L., Garcia M.A., Vìlchez M.A., Aguilera J.F. 2006. Effect of dietary protein content and feeding level on carcass characteristics and organ weights of Iberian pigs growing between 50 and 100 kg live weight. Animal Science, 82: 405–413

Bee G., Calderini M., Biolley C., Guex G., Herzog W., Lindemann M.D. 2006. Changes in the histochemical properties and meat quality traits of porcine muscles during the growing-finishing period as affected by feed restriction, slaughter age, or slaughter weight. Journal of Animal Science, 85: 1030–1045

Blanchard P.J., Ellis M., Warkup C.C., Hardy B., Chadwick J.P., Deans G.A. 1999. The influence of rate of lean and fat tissue development on pork eating quality. Animal Science, 68: 477–485

Campbell R.G., Taverner M.R., Curic D.M. 1984. Effect of feeding level and dietary protein content on the growth, body composition and rate of protein deposition in pigs growing from 45 to 90 kg. Animal Production, 38: 233–240

Čandek-Potokar M., Žlender B., Lefaucheur L., Bonneau M. 1998. Effects of age and/or weight at slaughter on longissimus dorsi muscle: biochemical traits and sensory quality in pigs. Meat Science, 48: 287–300

Crovetti A., Sirtori F., Esposito S., Pugliese C., Acciaioli A., Franci O. 2012. The link between breed, territory and product quality: the case of the Cinta Senese. Option Méditerranéennes, series A, 101: 125–132

Daza A., Lopez-Bote C.J., Olivares A., Menoyo D., Ruiz J. 2007a. Age at the beginning of the fattening period of Iberian pigs under free-range conditions affects growth, carcass characteristics and the fatty acid profile of lipids. Animal Feed Science and Technology, 139: 81–91

Daza A., Lopez-Bote C.J., Olivares A., Menoyo D., Ruiz J. 2008. Influence of a severe reduction of the feeding level during the period immediately prior to free-range fattening on performance and fat quality in Iberian pigs. Journal of the Science of Food and Agriculture, 88: 449–454

Daza A., Rey A.I., Menoyo D., Bautista J.M., Olivares A., Lopez-Bote C.J. 2007b. Effect of level of feed restriction during growth and/or fattening on fatty acid composition and lipogenic enzyme activity in heavy pigs. Animal Feed Science and Technology, 138: 61–74

De Pedro-Sanz E.P. 1987. Estudio de los factores sexo y peso de sacrificio sobre las caracteristicas de la canal del cerdo Iberico. PhD tesis, Universidad de Cordoba.

Fernandez X., Monin G., Talmant A., Mourot J., Lebret B. 1999. Influence of intramuscular fat content on the quality of pig meat – 1. Composition of the lipid fraction and sensory characteristics of m. longissimus lumborum. Meat Science, 53: 59–65

Fortina R., Barbera R., Lussiana C., Mimosi A., Tassone S., Rossi A., Zanardi E. 2005. Performances and meat quality of two Italian pig breeds fed diets for commercial hybrids. Meat Science, 71: 713–718

Franci O., Bozzi R., Pugliese C., Acciaioli A., Campodoni G., Gandini G. 2005. Performance of Cinta Senese pigs and their crosses with Large White. 1 Muscle and subcutaneous fat characteristics. Meat Science, 69: 545–550

Franci O., Pugliese C., Bozzi R., Acciaioli A., Parisi G. 2001. The use of multivariate analysis for evaluating relationship among fat depots in heavy pigs of different genotypes. Meat Science, 58: 259–266

Geri G., Franci O., Zappa A., Campodoni G. 1984. Accrescimento relativo e distribuzione del grasso in suini maschi e castrati e femmine da 20 a 200 chilogrammi di peso vivo. Zootecnica e Nutrizione Animale, 10: 365–380

Hansen B.C., Lewis A.J. 1993. Effect of dietary protein concentration (Corn:soybean meal ratio) on the performance and carcass characteristics of growing boars, barrows, and gilts: mathematical description. Journal of Animal Science, 71: 2122–2132

Heyer A., Lebret B. 2007. Compensatory growth response in pigs: effects on growth performance, composition of weight gain and carcass and muscle levels, and meat quality. Journal of Animal Science, 85: 769–778.

Kristensen L., Therkildsen M., Aaslyng M.D., Oksbjerg N., Ertbjerg P. 2004. Compensatory growth improves meat tenderness in gilts but not in barrows. Journal of Animal Science, 82: 3617–3624

Labroue F., Goumy S., Gruand J., Mourot J., Neelz V., Legault C. 2000. Comparison au Large White de quatre races locales porcines françaises pour les performances de croissance, de carcasse et de qualité de la viande. Journées Recherche Porcine en France, 32: 403–411

Lebret B. 2008. Effects of feeding and rearing system on growth, carcass composition and meat quality in pigs. Animal, 2: 1548–1558

Lebret B., Heyer A., Gondret F., Louveau I. 2007. The response of various muscle types to a restriction-re-alimentation feeding strategy in growing pigs. Animal, 1: 849–857

Lebret B., Juin H., Noblet J., Bonneau M. 2001. The effect of two methods of increasing age at slaughter on carcass and muscle traits and meat sensory quality in pigs. Animal Science, 72: 87–94

Lee Y.B., Kauffman R.G. 1974. Cellular and enzymatic changes with animal growth in porcine intramuscular adipose tissue. Journal of Animal Science, 38: 532–537

Lopez-Bote C. J. 1998. Sustained utilization of the Iberian pig breed. Meat Science, 49: 17–27

Mayoral A.I., Dorado M., Guillén M.T., Robina A., Vivo J.M., Vazquez C., Ruiz J. 1999. Development of meat and carcass quality characteristics in Iberian pigs reared outdoors. Meat Science, 52: 315–324

McMeekan C.P. 1940. Growth and development in the pigs, with special references to carcass quality characters. III. Effects of plane of nutrition on the form and composition of bacon pig. Journal of Agricultural Sciences, 30: 511–569

Neves J., Freitas A., Martins J., Nunes J. 2007. Alpha-tocopherol content on the semimembranosus muscle of Alentejano pigs reared in intensive and extensive conditions. In: Ed. Nanni Costa L., Zambonelli P., Russo V. Proceedings of 6th International Symposium on the Mediterranean Pig, Messina, Capo d'Orlando, Italy. 165–167

Nieto R., Lara L., Garcia M.A., Vilchez M.A., Aguilera J.F. 2003. Effect of dietary protein content and food intake on carcass characteristics and organ weight of growing Iberian pigs. Animal Science, 77: 47–56

Nieto R., Lara R., Garcia-Valverde R., Aguinaga M.A., Conde-Aguilera J.A., Aguilera J.F. 2012. Response analysis of the Iberian pig growing from birth to 150 kg body weight to changes in protein and energy supply. Journal of Animal Science, 90: 3809–3820

Oksbjerg N., Soerensen M.T., Vestergaard M. 2002. Compensatory growth and its effect on muscularity and technological meat quality in growing pigs. Acta Agriculturae Scandinavica, Section A – Animal Science, 52: 85–90

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 Science, 69: 459–464

Pugliese C., Calagna G., Chiofalo V., Moretti M., Margiotta S., Franci O., Gandini G. 2004. Comparison of the performances of Nero Siciliano pigs reared indoors and outdoors: 2. Joints composition, meat and fat traits. Meat Science, 68: 523–528

Pugliese C., Campodoni G., Badii M., Pianaccioli L., Franci O. 2003. Cinta Senese and Large White × Cinta Senese raised on pasture in wood: sample join composition and meat quality. Italian Journal of Animal Science, 2 (suppl. 1): 397–399

Pugliese C., Sirtori F. 2012. Quality of meat and meat products produced from southern European pig breeds. Meat Science, 90: 511–518

Quiniou N., Noblet J., van Milgen J., Dourmad J.Y. 1995. Effect of energy intake on performance, nutrient and tissue gain and protein and energy utilization in growing boars. Animal Science, 61: 133–143

Rodriguez-Estevez V., Garcia A., Pena F., Gomez A.G. 2009. Foraging of Iberian fattening pigs grazing natural pasture in the dehesa. Livestock Science, 120: 135–143

Secondi F., Gandemer G., Casabianca F. 2007. Finishing period and accumulation of intramuscular fat for the Corsican pig. In: Proceedings of the 5th International Symposium on the Mediterranean Pig, Tarbes, France, 16–19 November 2004. Audiot A., Casabianca F., Monin G. (eds.). Zaragoza, CIHEAM / INRA / SEAE, 2007, Options Méditerranéennes, Serie A, 76: 165

Serra X., Gil F., Pérez-Enciso M., Oliver M.A., Vasquez J.M., Gispert M., Diaz I., Moreno F., Latorre R., Noguera J.L. 1998. A comparison of carcass, meat quality and histochemical characteristics of Iberian (Guadyerbas line) and Landrace pigs. Livestock Production Science, 56: 215–223

Serrano M.P., Valencia D.G., Fuentetaja A., Lazaro R., Mateos G.G., 2009. Influence of feed restriction and sex on growth performance and carcass and meat quality of Iberian pigs reared indoors. Journal of Animal Science, 87: 1676–1685

Sirtori F., Acciaioli A., Pugliese C., Bozzi R., Campodoni G., Franci O. 2010. Effect of dietary protein level (as substitution of maize with soybean meal) on growth and feed efficiency of Cinta Senese pig in the growing-fattening period. Italian Journal of Animal Science, 9: 157–162

Sirtori F., Crovetti A., Acciaioli A., Pugliese C., Bozzi R., Campodoni G., Franci O. 2013. Effect of dietary protein level on carcass traits and meat properties of Cinta Senese pigs (submitted)

Sirtori F., Crovetti A., Meo Zilio D., Pugliese C., Acciaioli A., Campodoni G., Bozzi R., Franci O. 2011. Effect of sire breed and rearing system on growth, carcass composition and meat traits of Cinta Senese crossbred pigs. Italian Journal of Animal Science, 10: 188–194

Skiba G. 2010. Effects of energy or protein restriction followed by realimentation on the composition of gain and meat quality characteristics of *Musculus longissimus dorsi* in pigs. Archives of Animal Nutrition, 64: 36–46

Tirapicos Nunes J.L. 2007. Livestock management to optimise carcass and meat characteristics in farming systems using natural resources. In: Proceedings of the 5th International Symposium on the Mediterranean Pig, Tarbes, France, 16–19 November 2004. Audiot A., Casabianca F., Monin G. (eds.). Zaragoza, CIHEAM / INRA / SEAE, 2007, Options Méditerranéennes, Serie A, 76: 73–82

Whittemore C.T., Green D.M., Knap P.W. 2001. Technical review of the energy and protein requirements of growing pigs: protein. Animal Science, 73: 363–373

Wiecek J., Rekiel A., Batorska M., Skomial J. 2011. Effect of restricted feeding and realimentation periods on pork quality and fatty acid profile of *M. longissimus thoracis*. Meat Science, 87: 244–249

Wood J.D., Jones R.C.D., Francombe M.A., Whelehan O.P. 1986. The effects of fat thickness and sex on pig meat quality with special reference to the problems associated with overleaness. 2 Laboratory and trained taste panel results. Animal Production, 43: 535–544

Wood J.D., Nute G.R., Richardson R.I., Whittington F.M., Southwood O., Plastow G., Mansbridge R., da Costa N., Chang K.C. 2004. Effects of breed, diet and muscle on fat deposition and eating quality in pigs. Meat Science, 67: 651–667