



The production of the heavy pig for high quality processed products

Paolo Bosi, Vincenzo Russo

Dipartimento di Protezione e Valorizzazione agroalimentare. Università di Bologna, Italy

Corresponding author: Prof. Paolo Bosi. DIPROVAL. Università di Bologna. Via F.lli Rosselli 107, 42100 Reggio Emilia, Italy - Tel. + 39 0522 290522 - Fax: +39 0522 290523 - Email: paolo.bosi@unibo.it

Paper received February 22, 2004; accepted May 26, 2004

ABSTRACT

The review discusses the topics presented below, with experimental data and more evidence for some aspects which are problematic for the pig producer. To obtain high quality processed pig products, heavy pig production in Italy is subjected to rules fixed by several Consortia, on the basis of the experience of producers and the results from scientific research. Slaughter animals of at least 9 months of age and 160 kg live weight are required to provide heavy cuts with excellent meat. Breeds are limited to Italian Large White and Landrace, selected for specific parameters such as loss at 1st salting of the ham, and their crosses. Crosses with Duroc and hybrids can be used if obtained from selection and crossing schemes that fit the objectives of Italian selection. Backfat thickness must be "sufficient" to obtain retailed fresh hams with fat cover ranging from 20 to 30 mm, depending on ham weight, and the content of linoleic acid in ham fat cover cannot exceed 15%. Fat quantity and quality in feeds should be carefully controlled to satisfy the quality of fat in the ham. The feeding level is also relevant, due to the imposed minimum age at slaughter. Feed restriction is a necessary practice to respect the rules for ham production. For castrate males of medium genetic value, the restriction should reduce fat deposition, but the diet composition can be adapted to maintain the maximum growth of protein. For strains with high lean deposition potential and particularly for gilts, protein deposition should also be limited to maintain a sufficient fat cover of ham.

Key words: Pig feeding, Carcass quality, Ham quality, Fat quality, Ham processing.

RIASSUNTO

LA PRODUZIONE DEL SUINO PESANTE PER PRODOTTI TRASFORMATI DI ALTA QUALITÀ

La rassegna discute gli aspetti di seguito riportati, argomentandoli con dati sperimentali ed evidenziandone gli elementi più problematici per i produttori. Per ottenere prodotti trasformati di suino d'alta qualità, la produzione italiana del suino pesante è sottoposta a regole fissate dai Consorzi, sulla base dell'esperienza dei produttori e dei risultati della ricerca scientifica. Sono richiesti soggetti da macello di almeno 9 mesi di età e 160 kg di peso vivo, per fornire tagli pesanti con carni eccellenti. Sono permessi solo soggetti di razza Large White Italiana e Landrace, Italiana, selezionati per parametri specifici, quale il calo di prima salatura del prosciutto, oppure provenienti dal loro incrocio. I prodotti d'incrocio con il Duroc e gli ibridi commerciali possono essere usati se ottenuti con schemi di selezione ed incrocio che rientrino negli obiettivi della selezione italiana. Lo spessore del lardo deve essere "sufficiente" per ottenere prosciutti rifilati con una copertura adiposa nell'intervallo di 15 - 30 mm, in funzione del peso del prosciutto, ed il contenuto di acido linoleico nella copertura adiposa del prosciutto non deve essere superiore al 15%. La quantità e la qualità dei mangimi devono essere attentamente controllate per soddisfare la qualità del prosciutto. Il livello nutritivo scelto è ugualmente importante, vista l'imposizione di un'età minima alla macellazione. Una restrizione alimentare è una pratica necessaria per rispettare le

regole per i prosciutti tipici. Per i maschi castrati di medio valore genetico, la restrizione deve essere calibrata per limitare la deposizione di grasso, mentre le caratteristiche della dieta debbono essere adeguate per mantenere la deposizione di proteine. Per i ceppi ad elevato potenziale di crescita, soprattutto nel caso delle femmine, bisogna spesso limitare anche la deposizione di proteine per rispettare i vincoli di età e nel contempo mantenere una sufficiente copertura adiposa del prosciutto.

Parole chiave: Alimentazione del suino, Qualità della carcassa, Qualità del prosciutto, Qualità del grasso, Trasformazione del prosciutto

Introduction

The production of the Italian heavy pig aims essentially to provide thighs for the production of dry-cured hams having protected origin designation, such as Parma and San Daniele. For such high quality production, meat with an excellent aptitude for salting and seasoning is needed.

Generally speaking, this aptitude can be defined as the capacity of the thighs to achieve high technological yield and ideal sensorial characteristics at the end of the process of transformation at least 12 months long.

Programs of genetic improvement, rearing techniques, and feeding of heavy pigs evolved from an approach that was more empirical to one that is more scientific, in order to obtain meat and cuts with such characteristics. In fact, for whole salted products, such as Parma ham, the quality of raw materials is of fundamental importance, because the production technology (based simply on the addition of salt and on the control of ambient temperature and humidity) does not enable the correction of severe shortages or original defects.

The relevance of the quality of raw material is underlined by the fact that the Consortia of protection of Parma and San Daniele hams not only indicated the required characteristics for the fresh thigh (Table 1), but also dictated rules for the genotypes (breeds and crosses) that are allowed, the age and the slaughtering weight of pigs, and the feed that can be used.

Genetic types

For the production of the Italian heavy pig, Consortia for the protection of Parma and San Daniele admit only some purebred subjects, or hybrids obtained from some breeds.

As purebred, only individuals from the Italian Large White and Italian Landrace breeds can be used. In addition, the crosses with the Italian Duroc breed are permitted. Subjects of the same breeds coming from other countries or subjects of other breeds can be used for the production of crossed pigs, provided they are obtained by selection programs with objectives not inconsistent with those of the Italian selection. These results

Table 1. Characteristics of thighs for the production of Parma ham.

Item	Minimum	Maximum	Optimum	
Weight of trimmed fresh thighs	kg	10	-	12-14
Fat thickness ¹ of thighs for:				
7-9 kg dry-cured weight		15	-	20
>9 kg dry-cured weight		20	-	30
Fat quality				
Iodine number		-	70	-
Linoleic acid content	% on total FA		15	
Thighs of pigs with PSE, DFD and other defects				Not utilized

¹ At the level of the head of femur.

Table 2. Seasoning loss in Parma hams obtained from different pig breeds reared in the same condition¹.

Breed	Seasoning loss (%)
Pietrain	32.1
Belgian Landrace	29.2
Italian Large White	27.0
Italian Landrace	26.7
Duroc	25.6
Cinta Senese	25.2

¹ Baldini *et al.* 1989

were reached by a prevalently empirical approach and validated by a limited number of studies.

Baldini *et al.* (1989), comparing different breeds reared under the same conditions (Table 2), observed remarkable differences in seasoning loss, confirming the unsuitability of Pietrain and Belgian Landrace for Parma ham production. The greater seasoning loss observed in dry-cured hams from these breeds may be due to the greater percentage of lean meat and to the very high frequency of the halothane susceptibility gene. In fact, the gene for halothane susceptibility clearly shows a negative effect on seasoning loss (Russo and Nanni Costa, 1995).

Also as regards sensorial characteristics, differences have been observed between genetic types. Parolari *et al.* (1988) by means of subjective evaluation observed adverse effects on the color, flavor and firmness of Parma hams obtained from

purebred Duroc or Duroc x Large White, and Duroc x Landrace crosses, compared with Landrace x Large White crosses.

Other studies reviewed by Russo and Nanni Costa (1995) showed that the hams obtained from Large White and Landrace breeds and from their crosses are better than other genetic types.

On the whole the effect of genetic types on quality of hams may be explained, at least partially, by the different frequency of the negative halothane gene and the different degree of adiposity of the carcass of different breeds.

In fact, a greater content of lean meat on the carcass corresponds to a higher seasoning loss and a worsening of sensorial characteristics of dry-cured ham (Russo and Nanni Costa, 1995; Gallo *et al.*, 1999).

The breeding program for Italian heavy pig

The Italian breeding programme is based on the selection of breeds Large White, Landrace, Duroc and on their crossing. The Italian selection scheme follows the same objectives of other countries (reproductive efficiency, growth rate, feed efficiency and carcass characteristics), but it is characterised by how it bears on meat quality, especially for the dry-cured ham production.

In Table 3 the objectives and the selection criteria for meat quality are shown.

Contrarily to other countries that try to exploit the positive aspect of the allele for halothane sensitivity by crossing, the objective of the Italian selection is to remove this gene since it has been observed that the dry-cured ham quality is worse

Table 3. Selection for meat quality on Italian breeds used for heavy pig production.

OBJECTIVES	CRITERIA
- PSE elimination	→ Mutation C->T at the CRC gene
- Preventing the increase on seasoning loss	→ Salting loss → Backfat thickness
- Improving organoleptic characteristics	→ Backfat thickness
- Reducing "grassinatura" defect (only in Duroc breed)	→ Visible intramuscular fat

Table 4. Effect of halothane gene and PSE on the seasoning loss (%) (From Russo and Nanni Costa, 1995).

Authors	Comparisons	Differences and statistical significance
Sellier <i>et al.</i> (1985)	Hal ⁺ vs Hal ⁻ ⁽¹⁾	1.2 P<0.01
Santoro and Lo Fiego (1987)	Hal ⁺ vs Hal ⁻ ⁽¹⁾	1.2 ns
Maggi and Oddi (1988)	PSE vs Normal ⁽²⁾	3.9 -
Russo <i>et al.</i> (1994)	NN vs Nn ⁽³⁾	1.0 P<0.08

⁽¹⁾ Halothane test.

⁽²⁾ Objective and subjective muscles evaluation.

⁽³⁾ Genotypes determination at the DNA level by PCR of mutation C->T at the CRC gene.

Table 5. Variations of genic and genotypic frequencies at the halothane locus (CRC ¹) in pig breeds reared for the production of Italian heavy pig.

	Italian Large White		Italian Landrace		Duroc	
	1995	2002	1995	2002	1995	2002
Genic frequencies:						
N (C)	96.56	99.17	94.00	99.47	91.46	98.67
n (T)	3.44	0.83	6.00	0.53	8.54	1.33
Genotypic frequencies:						
NN (CC)	93.12	98.35	88.00	98.94	84.81	97.35
Nn (CT)	6.88	1.65	12.00	1.06	13.29	2.65
nn (TT)	-	-	-	-	1.90	-

¹ In brackets, genes and genotypes are indicated with nucleotidic bases of the gene CRC: C=cytosine, T= thymine.

when both heterozygous and homozygous pigs thighs are used. In fact, the literature on the effects of the halothane gene points out that also heterozygous pigs, compared to the negative homozygous animals, produce meat with lighter colour, lower pH45 values and a lower water holding capacity (Russo *et al.*, 1989). Moreover the few researches carried out have shown the negative effect of the allele for the halothane sensitivity on seasoning loss (Table 4) and on the organoleptic characteristics of Parma ham.

The selection, made at first by the halothane test and subsequently by the PCR-RFLP test on DNA, is close to reaching the aim of the elimination of the unfavourable allele from the breeds that are used for the Parma ham production (Table 5).

To prevent the increase on seasoning loss, two

selection criteria are used: the salting loss and backfat thickness.

Since the parameters for the evaluation of fresh meat are not fully adequate to evaluate the suitability of meat for salting, a new parameter has been identified: the salting loss during the first 7 days of salting. The salting loss may be considered as a measure of water-holding capacity under the salting condition. This criterion has shown a coefficient of phenotypic correlation of 0.57 (Russo *et al.*, 1991) and of genetic correlation of 0.65 with the seasoning loss (Buttazzoni *et al.*, 1993). Moreover, on the basis of research data from Buttazzoni *et al.* (1993) and Carnier *et al.* (1999) and also considering data supplied by the Ufficio Tecnico Centrale of ANAS, the heritability of seasoning loss is in the range of 0.30-0.61.

Because of the positive genetic correlation ($r_g = 0.7$) between salting loss and weight of lean cuts, the salting loss reduction implies a reduction of lean cuts weight. Consequently, to avoid a great decrease of genetic progress for lean cuts, the selection objective is to maintain a constant salting loss.

Another important objective that distinguishes the selection for the heavy pig is to maintain a constant backfat thickness in order to satisfy the fat covering of ham fixed by the rules of the Consortia of Parma and San Daniele ham (Table 1). Indeed, an insufficient fat covering of the thigh causes an increase of the seasoning loss and a lowering of the organoleptic characteristic of the dry-cured ham.

The objective to maintain the backfat thickness constant represents a choice aimed at improving the attitude of the meat to salting and seasoning, but it reduces genetic progress that could be obtained for the increasing lean cuts, since there is a high negative genetic correlation between backfat thickness and lean cuts.

The visible intramuscular fat (GIV) is another original selection criterion set up and utilised by the Italian pig breeder association (ANAS) in order to reduce, in the Duroc breed, the frequency of the so-called "grassinatura" defect due to an excessive presence of inter and intramuscular fat in thighs (Ufficio Tecnico ANAS, 2003). GIV is evaluated subjectively on visible thigh muscle. The genetic index for the GIV indicates the genetic value of the boars for the probability of transmitting this defect.

Relevance of weight and age at slaughtering

Research data showed a reduction of seasoning loss with the increase of thigh weight (Quadri *et al.*, 1981; Bergonzini *et al.*, 1985; Russo *et al.*, 1989; Russo *et al.*, 1991). Some aspects concerning the effects of weight on organoleptic quality of hams were discussed by Russo and Nanni Costa (1995). Thus, to obtain thighs of the required weight, slaughter weight should be around 160 kg.

Studies on factors affecting seasoning loss have shown that a sufficient fat covering is also important to reduce the loss of hams during the

dry-curing period. Simple correlations between backfat thickness and seasoning loss were in the range between -0.79 and -0.50 (Bosi *et al.*, 1984; Lo Fiego *et al.*, 1989; Nanni Costa *et al.*, 1989; Virgili and Domiano, 1999). Genetic correlations between backfat thickness and curing loss after salting are also in the same range (Carnier *et al.*, 1999). In multiple correlations, backfat thickness was also more important than ham weight (Bosi *et al.*, 1984) or carcass weight (Nanni Costa *et al.*, 1989). The reasons for the effect of ham covering on seasoning loss are quite inductive. Adipose tissue contains less water than muscular tissue (5-15% vs 70-75%) and hampers exchanges between muscle and external environment.

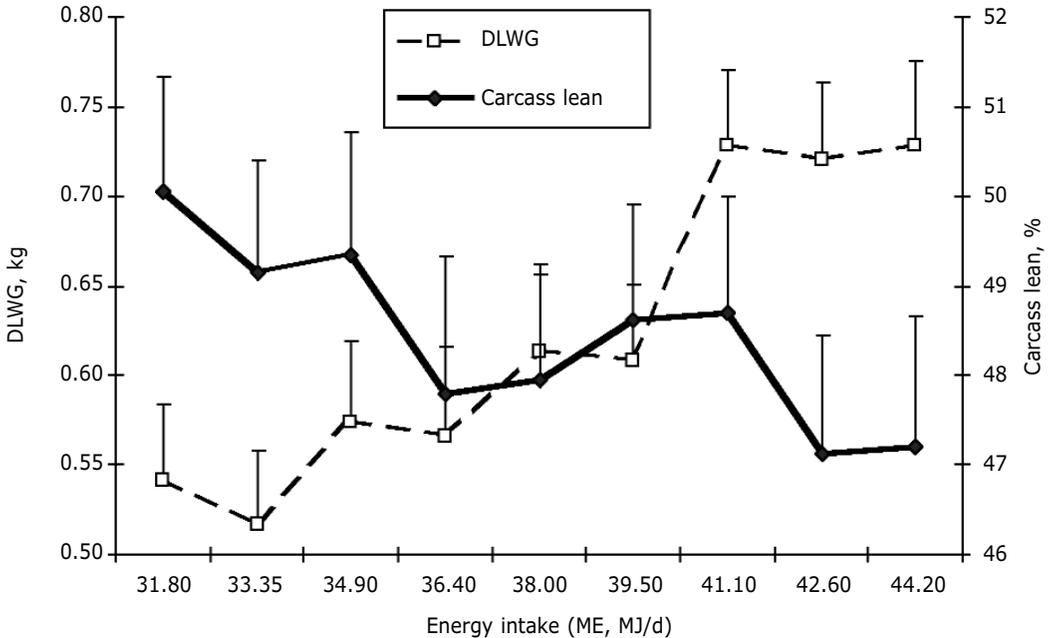
The degree of maturity and the age of the pig are generally associated with live weight. However, selection and improved feeding and breeding techniques have significantly increased the growth rate of modern genetic types. As a consequence, the relationship between maturity and weight is weaker. That is why the Consortia empirically introduced a limit on the age at slaughtering of at least 9 months. This raises a question: could younger subjects with an optimal fat covering be suitable for the typical production? Until now no experimental data for the heavy pig have been available to compare the seasoning loss of genetically similar subjects reared on different feeding planes in order to produce subjects of different ages, but similar fat covering.

The importance of the presence of fat is not limited to subcutaneous fat. The presence of more intermuscular and intramuscular fat can reduce the seasoning loss, as well. In fact, hams from subjects fed at a high energy level had higher separable fat and intramuscular fat, but also improved seasoning yields, compared to hams from pigs fed with a medium energy level (Zappa *et al.*, 1991).

Feeding strategies for the Italian heavy pig.

For traditional subjects used in the Italian heavy pig production, when a base diet supplies adequate quantities of protein and micronutrients, it is possible to modulate growth, carcass lean contents and backfat thickness, by changing the amount of additional energy.

Figure 1. Effect of energy intake from 92 kg to slaughtering on daily live weight gain (DLWG) and carcass lean percentage of Italian heavy pig. Different energy intake in different groups was obtained by adding from 0 to 0.8 kg of corn starch (17.2 ME MJ/kg DM) in 0.1 kg intervals to 2.6 kg base diet (Cacciavillani and Bosi, 1996).



As an example, Figure 1 presents the effect of energy intake from 92 kg to slaughtering on daily live weight gain and carcass lean percentage of Italian heavy pig. Different energy intake in different groups was obtained by adding from 0 to 0.8 kg of cornstarch (17.2 ME MJ/kg D.M.) in 0.1 kg intervals to a 2.6 kg base diet (Cacciavillani and Bosi, 1996). The daily live weight gain increased with energy intake, while lean carcass percentage decreased to nearly 47%, because the surplus energy was mainly allocated to fat deposition.

Practical experience and early trials have made it clear that feed restriction needs to be imposed on heavy pigs. However, the age to start the restriction and its entity can vary, and it should be considered that a minimum degree of carcass fatness is required to maintain the quality of products. Furthermore, modern genotypes can attain very fast growth and it is possible that a more severe dietary restriction should be applied

to maintain the limit of 9 months of age, and that also protein deposition should be limited.

To test this hypothesis, a very simple exercise of calculation was set up, where the entire cycle from birth to slaughtering is considered. The achievement of the maximum protein deposition is fixed as a priority.

The statements used for the prediction of the effect of fixed age at slaughter (9 months) on the protein deposition and on the required feeding level of Italian heavy pigs of different sex/genotypes are presented in Figure 2. In synthesis, daily protein growth was calculated by the Gompertz equation according to Whittemore *et al.* (2001), from birth to 270 days (9 months), using the values of protein weight at maturity and of maturing rate reported by Whittemore *et al.* (2001), for commercial gilts and castrate males and for improved gilts. They are summarized in Table 6. The age for the slaughtering at 165 kg was fixed at 270 days.

Figure 2. Statements used for the prediction of the effect of fixed age at slaughter (9 months) on the protein deposition and on the required feeding level of Italian heavy pigs of different sex/genotype.

<i>Starting point (birth)</i>
1) Live weight: 1.5 kg 2) Body protein content: 0.17 kg (calculated from de Passile <i>et al.</i> , 1979; Shield <i>et al.</i> , 1983)
<i>Daily protein deposition</i>
1) No dietary restriction to attain maximum predicted daily protein growth 2) No depressive effect of weaning (or a compensatory growth after) 3) Daily body protein growth (Kg/d) = $B \times P \times \ln(P_m/P)$ where P is the protein mass at a given time (kg), P _m (kg) is protein weight at maturity, and B (d ⁻¹), is rate of maturing (Whittemore <i>et al.</i> , 2001):
<i>Total protein mass in a given day (P)</i>
By adding daily protein deposition of a given day to total protein mass of the preceding day
<i>Final point (slaughtering, 270 days of age, 165 kg LW)</i>
1) Calculation of total protein mass iterated for 270 days (9 months) 2) Final total defatted body mass (kg): P+Water+Ash, where Water (kg) = $3.04 \times (P_m)^{0.145} \times P^{0.85}$, and Ash (kg) = $0.21 \times P$ (Whittemore, 1994) 3) Carcass lean (kg) = $2.24 \times P$, for females, and = $2.27 \times P$, for castrated males (Tullis, 1982) 4) Final empty body (kg) = 165×0.95 5) Fat to be deposited to reach final weight (kg) = final empty body - final total defatted body weight

Table 6. Values of protein weight at maturity (P_m), and of rate of maturing (B) used in the calculations for commercial castrate males and gilts, and for improved gilts (Whittemore *et al.*, 2001).

Sex and genotype	P _m (kg)	B (d ⁻¹)
Castrate male, commercial	37.5	0.0105
Gilt, commercial	40.0	0.0110
Gilt, improved	45.0	0.0120

The weight for the slaughtering was fixed at 165 kg. Then the final body composition was estimated. Fat to be deposited was calculated as the difference between empty body and final total defatted body weight.

The results of the calculations presented in Table 7 show that for commercial type castrate

males, growth can be modulated in order to maintain the maximum protein deposition permitted by their genotype, and to deposit a sufficient amount of fat. Estimated lean percentage in the carcass is 47% - an acceptable value. Also for commercial gilts, which have more lean deposition compared to castrates, it is possible to feed up to

Table 7. Results of the calculations of the predicted effect of the production at fixed age (9 months) on the protein deposition and the carcass performance of Italian heavy pigs of different sex/genotype.

	Castrate male, commercial	Gilt, commercial	Gilt, improved
Predicted final total defatted body mass kg	119.6	131.9	156.9!!
Estimated carcass lean (including 3 % intramuscular fat)	" 63.3	69.5	Not calculated
Pre-fixed live weight at 9 months ¹	" 165.0	165.0	165.0
Empty body	" 156.7	156.7	156.7
Fat to be deposited (Empty body - Predicted final total defatted body mass) ¹	" 37.1	24.9	-0.2
Carcass weight (Live weight X 0.82)	" 135.3	135.3	Not calculated
Carcass lean percentage	" 47.0	51.4	Not calculated
Average daily live weight gain	" 0.607	0.607	Not calculated

¹ It is assumed that enough energy is supplied to sustain protein deposition and that, after this use, the residual dietary energy for growth is used for fat deposition.

the maximum lean deposition, but in this case fat deposition could be near the minimum quantity required for a sufficient ham covering. For improved gilts, the predicted final total defatted body mass results paradoxically close to the overall pre-fixed body weight, if no restriction is imposed on protein deposition. Furthermore, considering also the average gut content, the weight of fat should be close to zero. This clearly contrasts not only with the goals for heavy pig production, but also with the biological laws of growth (Emmans and Kyriazakis, 1999). In conclusion, this simple exercise demonstrates that general requirements for the heavy pig cannot be formulated, but specific requirements should be tuned to each genotype (and sex). In the case of improved genotypes, a restriction on protein supply may be required, in addition to energy restriction. Substantially, this is a practice that is somewhat inefficient in nutritional terms.

Research data confirm that the percentage of well-balanced protein required for the Italian heavy pig is quite low, particularly in the finishing period (Manini *et al.*, 1997; Bosi *et al.*, 1999; Bonomi *et al.*, 2002). Furthermore, a correct approach to the diet formulation can reduce

nitrogen excretion. Table 8 shows the results of a trial for the finishing period, considering the effect of two different dietary crude protein percentages (CP). In addition to the equal performance, the 9.5% CP diet reduced blood urea at 135 kg live weight. Consequently the nitrogen excretion with urine was reduced, with a favorable effect of low CP diet to reduce the pollution from heavy pig.

To reduce the environmental impact of heavy pig production, phosphorus requirements were also revised. Bosi *et al.* (1997) concluded that a diet containing 1.7 g/kg digestible P, reached with the inclusion of 0.6% mineral P, maximizes *in vivo* performances and bone mineralization, even in lean fast growing strains. This same dietary P level leads to a 13% decrease in P excretion when compared to the typical P feed content used in the finishing heavy pig diets.

A valid tool for the calculation of requirements specific to each genotype is the modelization of growth. Recently the ASPA Commission "Nutrient requirements of heavy pig" (2003) proposed, for the heavy pig, a methodology based on the assumption of the Edinburgh group (Emmans and Kyriazakis, 1999; Whittemore *et al.*, 2001).

Table 8. Effect of well-balanced crude protein percentage in the finishing diet on growth and carcass performance of Italian heavy pigs (Bosi *et al.*, 1999).

Parameters		9.5 % CP	12 % CP	SEM
Starting LW	kg	85.6	88.1	1.6
Final LW	"	166.4	167.9	1.4
Daily LW gain	g	771	778	2.1
Feed intake	kg	3.18	3.23	0.03
Feed to gain		4.16	4.21	0.11
Carcass weight	"	138.4	138.6	1.26
Carcass lean	%	47.50	47.23	0.46
Daily gain of carcass lean	g	291	285	1.0
Blood urea				
- at 135 kg ^a	mmol/l	3.80	4.65	0.16
- at 165 kg	"	4.85	5.22	0.23

^a $P < 0.01$.

Effect of diet on fat quality in the ham

Thighs are acceptable for Parma or San Daniele production when the content of linoleic acid in thigh subcutaneous fat is lower than the value fixed in the rules set by the two Consortia. Now this value is 15% of total FA. This parameter for fat composition was introduced to limit the content of polyunsaturated fatty acids that can affect the composition and the consistence of fats in the ham and increase their oxidability. Alternatively, the Consortia consider the iodine number that is related with the presence of unsaturated fatty acids and their degree of unsaturation. Baldini *et al.* (1983) and Micossi *et al.* (1996) presented high positive correlations between iodine number, linoleic acid percentage, degree of unsaturation and peroxidability index in subcutaneous fat from hams of heavy pigs.

So, fat quantity and quality in feeds should be carefully controlled to satisfy the quality of fat in the ham. The possibility of manipulating the fatty acid composition of backfat by diet is well established for the light pig (Madsen *et al.*, 1992; Morgan *et al.*, 1992) and was reviewed by Mordenti *et al.* (1994) for the heavy pig. The addition of sources of fat can be attractive when these materials can provide cheap net energy, but the

effects on qualitative parameters of fat (linoleic acid or iodine number) should be considered.

In Figure 3, the linoleic acid contents on dry matter of different experimental diets for the Italian heavy pig are plotted against the linoleic acid contents observed on total fatty acids of subcutaneous fat. It is generally observed that when the level of linoleic acid in the diet is over 2% of dietary dry matter, the threshold value for subcutaneous fat is usually passed. These results justify the limit of 2% linoleic acid in the dietary dry matter of finishing heavy pigs that was imposed by the Consortia. In addition, data show the risk of the use of vegetal oils, as all the groups of heavy pigs with more than 15% linoleic acid in fat covering received dietary supplementation with these fat sources.

Other studies set out to test eventual effects of dietary fats on other qualitative parameters of Parma or San Daniele hams. The addition of vegetal oils (corn or rapeseed) to the diet of Italian heavy pigs, only slightly changed the profile of saturated and unsaturated aldehydes and the sensory evaluation of the Parma hams (Pastorelli *et al.*, in press). With respect to controls, Parma hams produced from pigs fed diets including a vegetal source of monounsaturated fatty acids (high oleate sunflower oil) had only small variations in fatty acid profile of intramuscular polar and neutral

lipids (Bosi *et al.*, 2000). The same experimental diet did not change the oxidative stability of fat from Parma hams, evaluated by TBARS and cholesterol oxides (Zanardi *et al.*, 2000).

Can a well-chosen withdrawal of fat supplementation reduce the negative drawbacks on ham quality due to the clearance rate of fatty acids in the depots and to their dilution with the increasing thickness? Corino *et al.* (1997) tested the effect of different times of withdrawal of dietary lard addition on growth and carcass performance of Italian heavy pigs. In Figure 4 the variation of the iodine number in the two layers of thigh subcutaneous fat attributed to different times of withdrawal is presented. Although the difference between diets did not reach statistical significance, the data are in the same trend of what has been observed for the light pig, supporting the indication that 2 months of withdrawal can be advisable to be sure that thighs are acceptable. The criteria of suspension have not been directly considered in the rules for heavy pigs. The Consortia allow the addition of fats up to 2% dry matter, but, substantially, oils are not permitted. Indeed, the melting point of permitted fat sources is over 36 °C and 40 °C, respectively, for diets of pigs up to 80 kg live weight and for finishing pigs.

Other specific ingredients of the diet for Italian heavy pigs

Cereals, milk whey and by-products of the milling industry are the traditional local sources used for the typical production. With the evolution of feeding systems and the availability of other raw materials, the Consortia defined the list of permitted feedstuffs and their proportion in the diet for the growth phase (30-80 kg l.w.) and for the finishing phase (80-160 kg l.w.). The criteria were mainly based on the contribution of each source to the lipid composition of the diet, but also other factors were considered, such as the contents of pigments, or the nature of the source industrial processes of by-products. Experiments to exclude negative effects on growth performance or attitude for dry-cured ham production with Italian heavy pigs are required to introduce new feedstuffs in the positive list. This was the case of cassava

(Russo *et al.*, 1985) and ensiled beet pulp (Scipioni and Martelli, 2001). Other specific studies were addressed to test meat soup (Russo *et al.*, 1995) and milk whey (Mordenti *et al.*, 2002).

Conclusions

Heavy pig production is a system driven by the rules fixed by the Consortia to guarantee the high quality of the dry-cured ham. Most of these rules originated from empirical observations, but are effective to preserve the high standard of the product. Some of these indications are confirmed by studies on Italian heavy pigs. For other aspects, improvements in the production could be suggested by more research data.

Part of this paper was first presented at the 54th Meeting of the European Association of Animal Production, 31 August – 3 September 2003, Rome, Italy.

REFERENCES

- ASPAC COMMISSION "NUTRIENT REQUIREMENTS OF HEAVY PIG", 2003. A methodological approach to assess nutrient requirements of heavy pigs in Italy. *Ital. J. Anim. Sci.* 2:73-87.
- BALDINI, P., PALMIA, F., PEZZANI, G., LAMBERTINI, L., 1983. Indagine sulla composizione del grasso superficiale di prosciutti freschi destinati alla produzione del prosciutto di Parma. *Ind. Conserve* 58: 219-222.
- BALDINI, P., BELLATI, M., RIVALDI, P., SPOTTI, E., LIONELLI, C., 1989. La tecnologia di preparazione del prosciutto di Parma: un esempio di valorizzazione della qualità del suino pesante. Printed for Proc. 1st Colloquy on Production porcine en Europe Méditerranéenne: quelles stratégies pour le porc méditerranéen, Ajaccio, France.
- BERGONZINI, E., ROSI, M.A., FABBRI, R., 1985. Stagionatura dei prosciutti in funzione dell'epoca d'inizio, del peso e dell'adiposità. *Ann. Ist. Sperim. Zootec.* 18 (1): 25-42.
- BONOMI, A., BONOMI, B.M., QUARANTELLI, A., SABBIONI, A., SUPERCHI, P., SUSSI, C., VIRGILI, R., FUSARI, A., 2002. La produzione del suino pesante in rapporto ai tipi genetici e all'impiego di diete ipoproteiche integrate con lisina. *Riv. Suinicolt.* 43 (4): 198-204.
- BOSI, P., RUSSO, V., SANTORO, P., 1984. Calo di stagionatura del prosciutto rifilato e qualità della carcassa

- sa e della carne. Proc. 38th Nat. Congr. SISVet., Rimini, Italia, 38: 487-489.
- BOSI, P., MACCHIONI, P., RUSSO, V., 1997. Dietary means to reduce phosphorus pollution from finishing heavy pigs. *Pig News Inf.* 18: 117N-121N.
- BOSI, P., MATTUZZI, S., CACCIAVILLANI, J.A., CASINI, L., 1999. Urea in the diet of finishing Italian heavy pigs. In: G. Piva, G. Bertoni, F. Masoero, P. Bani, L. Calamari (eds.) *Recent Progress in Animal Science. I.* FrancoAngeli, Milano, pp 546-548.
- BOSI, P., CACCIAVILLANI, J.A., CASINI, L., LO FIEGO, D.P., MARCHETTI, M., MATTUZZI, S., 2000. Effects of dietary high-oleic acid sunflower oil, copper and vitamin E levels on the fatty acid composition and the quality of dry cured Parma ham. *Meat Sci.* 54: 119-126.
- BUTTAZZONI, L., GALLO, M., BAIOTTO, C., CARCHEDI, C., 1993. La selezione per la qualità della carne suina destinata alla trasformazione. *Riv. Suinicolt.* 34(4): 139-145.
- CACCIAVILLANI, J.A., BOSI, P., 1996. Effect of energy intake at constant protein intake on the performance of pigs slaughtered at 160 kg lw. Page 421 in Proc. 14th IPVS Congr., Bologna, Italy.
- CARNIER, P., CASSANDRO, M., KNOL, E., PADOAN, D., 1999. Genetic parameters for some carcass and fresh ham traits of crossbred Goland pigs. In: G. Piva, G. Bertoni, F. Masoero, P. Bani, L. Calamari (eds.) *Recent Progress in Animal Science. I.* FrancoAngeli, Milano, pp 221-223.
- CORINO, C., GIORNI, P., PASTORELLI, G., 1997. Differenti tempi di sospensione della somministrazione di diete grassate nel suino pesante in fase finale di ingrasso. *Zoot. Nutr. Anim.* 23: 329-339.
- DELLA CASA, G., FABBRI, R., BERGONZINI, E., GIGLI, S., ROSI, M.A., 1991. Soia integrale fioccata nell'alimentazione del suino pesante. 3. Caratteristiche del grasso sottocutaneo e stagionatura dei prosciutti. *Riv. Suinicolt.* 32(3): 87-92.
- DELLA CASA, G., PANCIROLI, A., CAVUTO, S., FAETI, V., POLETTI, E., CALDERONE, D., MARCHETTO, G., 1999. Effects on pig fat quality of partially hydrogenated lard fed to growing-finishing heavy pigs. *Zoot. Nutr. Anim.* 25: 51-62.
- EMMANS, G.C., KYRIAZAKIS, I., 1999. Growth and body composition. In: I. Kyriazakis (ed.) *A quantitative biology of pig.* CABI publishing, Oxon, UK, pp 181-197.
- GALLO, L., PADOAN, D., BONDESAN, V., PENZO, N., 1999. Effect of some carcass and fresh ham traits on curing loss of hams from crossbred Goland pigs. In: G. Piva, G. Bertoni, F. Masoero, P. Bani, L. Calamari (eds.) *Recent Progress in Animal Science. I.* FrancoAngeli, Milano, pp 689-691.
- LEBRET, B., JUIN, H., NOBLET, J., BONNEAU, M., 2001. The effects of two methods of increasing age at slaughter on carcass and muscle traits and meat sensory quality in pigs. *Anim. Sci.* 72: 87-94.
- LO FIEGO, D.P., SANTORO, P., NANNI COSTA, L., BOSI, P., 1989. Relazione tra composizione acidica, spessore del lardo e caratteristiche tecnologiche del grasso di copertura del prosciutto. *Selez. Vet.* 30: 1689-1695.
- MADSEN, A., JAKOBSEN, K., MORTENSEN, H., P. 1992. Influence of dietary fat on carcass fat quality in pigs. A review. *Acta Agric. Scand. A.* 42: 220-225.
- MANINI, R., PIVA, A., GRANDINI, A., MORDENTI, A., PIVA, G., DOURMAD, J. Y. 1997. Protein retention in Italian heavy pigs: Development of a factorial approach for the determination of lysine requirement. *Livest. Prod. Sci.* 47: 253-259.
- MORDENTI, A., MARTELLI, G., PACCHIOLI, M.T., 2002. Il siero di latte nell'alimentazione del suino pesante. *Latte.* 27(2): 126-136.
- MORDENTI, A., PIVA, G., DELLA CASA, G., 1994. Nutrition and fat quality in the heavy pig. *Ital. J. Food Sci.* 6: 141-155.
- MORGAN, C. A., NOBLE, R. C., COCCHI, M., MC CARTNEY, R., 1992. Manipulation of the fatty acid composition of pig meat lipids by dietary means. *J. Sci. Food Agric.* 58: 357-368.
- MICOSSI, E., TUBARO, F., MAGNABOSCO, P., CIANI, F., URINI, F., 1996. Analisi della insaturazione degli acidi grassi del tessuto adiposo del maiale. *Riv. Suinicolt.* 37(3): 97-101.
- NANNI COSTA, L., LO FIEGO, D.P., BOSI, P., RUSSO, V., 1989. Relazione tra qualità della carcassa, qualità della carne e calo di stagionatura del prosciutto nel suino pesante da salumificio. *Riv. Suinicolt.* 30(2): 63-67.
- PANTALEO, L., MOUROT, J., CONTEMPO, V., SALVATORI, G., PASTORELLI, G., MOUNIER, A., CORINO, C., 2000. Effet de la nature lipidique des regimes sur la composition en acides gras du jambon chez le porc lourd. 32^{èmes} Journées de la Recherche Porcine en France, Paris, France, 32: 311-317.
- PAROLARI, G., RIVALDI, P., LEONELLI, C., BELLATI, M., BOVIS, N. 1988. Colore e consistenza del prosciutto crudo in rapporto alla materia prima e alla tecnica di stagionatura. *Ind. Conserve.* 63: 45-49.
- PASSILLE, A.M.B.DE, HARTSOCK, T.G., 1979. Within- and between-litter variation of proximate composition in newborn and 10-day-old Landrace swine. *J. Anim. Sci.* 49: 1449-1457.
- PASTORELLI, G., MAGNI, S., ROSSI, R., PAGLIERINI, E., BALDINI, P., DIRINK, P., VAN OPSTAELE, F., CORINO, C., 2004. Influence of dietary fat, on fatty composition and sensory properties of dry-cured Parma ham. *Meat Sci.* (In press).
- PIVA, G., MORLACCHINI, M., GRANDINI, A., CERIOLO, C., FUSARI, A., 1994. Effetto dei grassi salificati sulle performances produttive e sulla qualità del grasso di deposito in suini pesanti. *Riv. Suinicolt.* 35 (11): 53-62.
- PIVA, G., MORLACCHINI, M., GRANDINI, A., CERIOLO, C., FUSARI, A., 1994. L'impiego dei grassi idrogenati

- nell'alimentazione del suino pesante. Riv. Suinicolt. 37(4): 157-164.
- QUADRI, G., BERGONZINI, E., ZULLO, A., COSENTINO, E., MATASSINO, D. 1981. Studio di alcuni tipi genetici di suini "da salumificio" allevati con un piano alimentare "medio". IV Aspetti quantitativi ed economici del prosciutto stagionato. Riv. Suinicolt. 22(5): 21-49.
- RUSSO, V., BOSI, P., SANTORO, P., MARCHINI, R., 1985. Effetti dell'impiego di manioca sulla qualità delle carcasse e della carne del suino pesante. Riv. Suinicolt. 26(5): 57-61.
- RUSSO, V., LO FIEGO, D.P., BIGI, D., NANNI COSTA, L., PIGNATTI, M., 1989. Relationship between carcass lean content and the technological and commercial characteristics of Parma ham. Page 273 in Book of Abstr. 40th Ann. Meet. EAAAP, Dublin, Ireland.
- RUSSO, V., NANNI COSTA, L., LO FIEGO, D.P., DE GROSSI, A., 1991. Early estimation of seasoning loss in Parma ham production. pp 926-929 in Proc. 37th Int. Congr. of Meat Science and Technology, Kulmbach, Germany.
- RUSSO, V., NANNI COSTA, L., DALL'OLIO, S., DAVOLI, R., DE GROSSI, A., LO FIEGO, D.P., ZAMBONELLI, P., 1994. Effect of the Halothane gene in heterozygote pigs on ham meat quality. Paper S-IVA.03 in Proc. 40th Int. Congr. of Meat Science and Technology, The Hague, Netherlands.
- RUSSO, V., NANNI COSTA, L., 1995. Suitability of pig meat for salting and the production of quality processed products. Pig News Inf. 16: 17N-26N.
- RUSSO, V., BOSI, P., CASINI, L., COVI, P., DE GROSSI, A., LO FIEGO, D.P., LOSA, R., MACCHIONI, P., 1995. Impiego di broda di carne nella produzione del suino pesante. Zoot. Nutr. Anim. 21: 85-95.
- SCIPIONI, R., MARTELLI, G., 2001. Consequences of the use of ensiled sugar beet-pulp in the diet of heavy pigs on performances, carcass characteristics and nitrogen balance: a review. Anim. Feed Sci. Technol. 90: 81-91.
- SHIELDS, R.G. JR., MAHAN, D.C., CAHILL, V.R., 1983. A comparison of methods for estimating carcass and empty body composition in swine from birth to 145 kg. J. Anim. Sci. 57: 55-65.
- TULLIS, J.R., 1982. Protein Growth in Pigs. PhD Diss., University of Edinburgh, Scotland.
- UFFICIO TECNICO ANAS, 2003. Il contributo della selezione italiana alla filiera del suino pesante. Inf. Agr. 59 (13, suppl.): 7-8.
- VIRGILI, R., DOMIANO, L., 1999. Quality of meat to be processed into typical dry-cured products. In: G. Piva, G. Bertoni, F. Masoero, P. Bani, L. Calamari (eds.) Recent Progress in Animal Science.1. FrancoAngeli, Milano, pp. 613-625.
- WHITTEMORE, C.T., 1994. Growth and simulation of animal responses. In: D.J.A. Cole, J Wiseman, M.A. Varley (eds.) Principles of pig science. Nottingham University Press, Loughborough, UK, pp 55-73.
- WHITTEMORE, C.T., GREEN, D.M., KNAP, P.W., 2001. Technical review of the energy and protein requirements of growing pigs: protein. Anim. Sci. 73: 363-373.
- ZANARDI, E., NOVELLI, E., GIRETTI, G.P., CHIZZOLINI, R., 2000. Oxidative stability of lipids and cholesterol in salame Milano, coppa and Parma ham: dietary supplementation with vitamin E and oleic acid. Meat Sci. 55: 169.
- ZAPPA, A., FRANCI, O., POLI, B.M., CAMPODONI, G., PARISI, G., GERI, G., 1991. Influenza dell'alimentazione e del sesso sulle caratteristiche del prosciutto stagionato. pp 831-842 in Proc. 9th Nat. Congr. ASPA, Roma, Italy.