EFFECTS OF NUTRITION AND SELECTION ON MEAT QUALITY

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ABSTRACT

Nutrition and selection are both factors which mainly affect rabbit carcass and meat quality. Effects of feeding level and of dietary fibre, dietary fat and fat quality and protein quality are summarised. Four ways of studying the effects of selection for growth rate on rabbit carcass and meat quality are also reviewed.

Key words: Rabbit, Nutrition, Selection, Growth, Meat quality

INTRODUCTION

Two of the productive factors, which have great effects on rabbit carcass and meat quality, are nutrition, specially the dietary fat inclusion and fat source, and selection programmes (DALLE ZOTTE, 2002) that mainly affect the growth rate.

As carcass weight and correlatively live weight are determined for the demand of customers, the age at slaughter is also regionally fixed and, as a consequence, carcass composition, meat to bone ratio, chemical composition of meat, texture, water holding capacity and flavour are affected. Nutrition can also affect carcass fattening, the percentage of lipids on meat and its composition in different fatty acids; it can also affect fat stability and the possibility of meat conservation, protein content of meat and its amino acid composition.

Effects of nutrition on rabbit meat quality have already been object of excellent reviews OUHAYOUN (1998) or XICCATO (1999), and also MAERTENS (1998) wrote a specific review on effects of fat in rabbit nutrition. Now, in this paper, only the main effects of nutrition and the effect of selection for growth rate on meat quality will be commented.

NUTRITION EFFECTS

Nutrient requirements of intensively reared rabbits are now well established (DE BLAS and MATEOS, 1998) and only little variations are possible because if changes are big digestive disorders can easily appear. However, some recent studies are conducted on increasing the age at slaughter with feed restriction (LARZUL *et al.*, 2004) or by organic production (COMBES *et al.,* 2003). Increasing diets in n-3 fatty acids are also interesting nowadays, (DAL BOSCO *et al.,* 2004). These topics should be reviewed.

Effect of feeding level

Nutrition can modify growth by changing the energy intake either by feed restriction or by adding fat to the diet. If digestive energy concentration of the diet is higher than 9 to 9.5 MJ/kg there is a chemiostatic regulation of ingestion (LEBAS *et al.*, 1984) but when diet is lesser than 0.85 of the *ad libitum* intake, growth rate slows down and feed efficiency is decreased.

As rabbits are usually slaughtered at a fixed commercial liveweight, a slow growth enhances early maturing tissues and decreases late-maturing tissues. The skin, the digestive tract and the bones are more developed on slowly growing rabbits. The muscles and specially the adipose tissue, which are late-maturing tissues, had a poorer development.

Works related to the effects of feed restriction on growth and carcass composition are numerous and as OUHAYOUN *et al.,* (1986) showed, the carcasses of restricted rabbits are less fatty, have a lesser meat to bone ratio and a lower slaughter yield. Chemical body composition is richer in water and ash and has less fat and protein. The slaughter yield is also decreased because (i) there is a higher retention time of feed in the digestive tract and as a consequence, it increases the weight of the full digestive tract (ii) the decrease in growth rate enhances the relative growth of early-maturing organs as the digestive tract (OUHAYOUN, 1998). XICCATO (1999) highlighted that feed restriction could be detrimental for the juiciness and flavour of the meat, but LARZUL *et al.,* (2004) did not find significant unfavourable effects on sensory traits even though muscular fat content was largely decreased.

Effect of dietary fibre content

A decrease on DE intake plays a similar role to feeding restriction, limiting the growth and lowering the dressing proportion. This is the case when diets have a high fibre and low-energy content. Carcasses are less fattened, the skeleton is more developed and the lipid content of the carcass is very low, but the water and protein content seems to be high (PARIGI BINI *et al.*, 1994). Moreover there is not evidence that crude fibre or fibre fraction play a specific effect on carcass and meat quality apart from their role in the modification on energy concentration (XICCATO, 1999).

Effect of dietary fat content

Increasing the fat content of the diet improves the energy level of the diet and results in higher DE intake. Growth and feed efficiency are also higher (CASTELLINI and BATTAGLINI, 1992; FERNÁNDEZ *et al.*, 1994) and this fat supplementation is possible in case of an early weaning because of the high lipase activity of kits (GIDENNE and FORTUNE-LAMOTHE, 2002).

If fat addition is low or moderate (2-6%), only a moderate reduction of feed intake is produced and the digestive use of the entire diet or single nutrients may be improved (SANTOMÁ *et al.*, 1987; XICCATO *et al.*, 1998), the dressing percentage is increased (CASTELLINI and BATTAGLINI, 1992), liver is reduced and carcasses are fatter (FERNÁNDEZ and FRAGA, 1996).

When fat is present in the diet at high levels (more than 9%), the dressing percentage is increased, carcasses are fatter, the carcass length to circumference ratio is reduced, and the fat content of hind leg meat is increased, while water and protein content is reduced (PLA and CERVERA, 1997). In some studies (CASTELLINI and BATTAGLINI, 1992), however, different feeding plans and fat enriched diets do not show different chemical composition of the *longissimus dorsi* muscle.

Fat quality

Vegetable or animal source of added fat seemed not to affect the main carcass traits (FERNÁNDEZ and FRAGA, 1996; PLA and CERVERA, 1997), but lipid composition and flavour of rabbit meat were different (OLIVER *et al.*, 1997) and influenced on juiciness (GONDRET, 1998) and on technological characteristics (BERNARDINI *et al.*, 1996).

It has usually been considered that lipids on rabbit meat are rich on unsaturated and polyunsaturated fatty acids. The origin of these fatty acids are not endogenous as OUHAYOUN *et al.,* (1987) noted, but it is the result of diet. Cereals, particularly, and oil seed meal provides linoleic acid (C18:2, n-6) and lucerne provides linolenic acid (C18:3, n-3). Supplementing a basal diet with lipids prevents rabbit endogenous production and the composition and the storage of lipids are modified.

Furthermore, as the fat ingested by rabbits is mainly absorbed in the small intestine before being transformed by the cecal flora, the final composition of stored lipids is considerably influenced by the dietary fatty acid composition. Enriching the diets of rabbits with soya, sunflower oils or soya beans increases the proportion of unsaturated FA when comparing to those obtained using conventional diets (COBOS *et al.*, 1993). When rabbit diets were supplemented with animal fat (A) or vegetable oil (V), the perirenal fat was higher (67%) than in control fed animals (C) but also its PUFA proportion was increased. Perirenal fat of group A was richer in oleic acid (41%) than in rabbits of group V. The P:S ratio was higher in group V (2.45) than in group A (0.53) or in group C (0.42) (OLIVER *et al.*, 1997).

Different FA added has diverse metabolic comportment. In fact, the short and medium-chain fatty acids are mainly catabolized as energy sources, while the long-chain FA are more likely to be deposited directly in the adipose tissue (GONDRET, 1998; XICCATO, 1998). As GONDRET *et al.,* (1998) note, the reason could be that the exogenic FA can modify the lipogenic enzyme activity. This influence seems to be more pronounced on dissectible lipidic deposits than on intramuscular fat. Finally, the FA profile of rabbit meat and fat deposits do not exactly reflect the FA profile of the dietary source of fat (COBOS *et al.*, 1993; GONDRET *et al.*, 1998).

The FA composition of adipose tissue strongly influences the carcass aspect and the organoleptic properties of meat. If rabbits are fed with a diet containing 5% of olive oil, rich in oleic acid, the carcass looks shiny and the perirenal tissue is soft and translucent. If a 5% of copra oil (coconut), rich in lauric acid, is added, the carcass has a pleasant appearance and the perirenal fat is hard and white and seems beef tallow; however meat has a soapy taste, which makes it unfit for consumption. Conversely, when olive oil is incorporated into the diet, the carcasses of rabbits are unappealing but the meat is acceptable. Adding linseed oil and soybean oil, both give an unpleasant flavour to meat because of the high content of polyunsaturated fatty acids, especially linoleic acid which easily peroxidices. If the fat added is cocoa butter (rich in stearic acid), the rabbit meat has a high organoleptic quality. (OUHAYOUN *et al.*, 1987)

OLIVER *et al.,* (1997) also reported significant differences in the organoleptic characteristics of the loin meat of rabbits fed with enriched-fat diets. Meat juiciness was increased and the meat from rabbits fed with animal fat diets (A) was considered to have more "liver" taste, while vegetable fat provided an "aniseed" or "grass" flavour. No differences were observed between diets for the other texture parameters. The addition of vegetable and animal fat to the diet affected fat colour significantly, giving diet V a lower lightness. Softer consistency meat of these rabbits was less pale than those giving diets C and A. Water holding capacity and pH of *longissimus dorsi* muscle of rabbits fed fat-enriched were also higher (PLA and CERVERA, 1997).

Recent recommendations for human diets (BRITISH NUTRITION FOUNDATION, 1993) suggest increasing the n-3 PUFA consumption and decreasing the n-6:n-3 ratio to =6:1. The n-6:n-3 ratio of fat of leg rabbit meat is about 11 and in perirenal rabbit fat is 8.5 aproximately (RAMÍREZ *et al.,* in press). So, the possibility of improving the n-3 PUFA content of meat by dietary supplementation is really interesting.

Supplementing rabbit diets with fish sources or other ingredients containing linolenic acid, BERNARDINI *et al.,* (1999) and TASSINARI *et al.,* (2001) have obtained an increase in the n-3 PUFA content in meat. Moreover, different experiments have been carried out on improving tissue oxidative stability by feeding animals with high levels of antioxidants (LOPEZ-BOTE *et al.,* 1997; CASTELLINI *et al.*, 2001, LO FIEGO *et al.*, 2004). DAL BOSCO *et al.,* (2004) found that proximate composition of the fresh meat was not significantly affected by the dietary antioxidant treatment; the sensory quality of the fresh and stored muscle was slightly affected and that of the experimental diet showed significantly higher scores.

Protein quality

The effects of protein on the diet should be studied both for the relation DP/DE and for presence of some amino acids.

If dietary DP/DE is low and the total protein ingestion does not cover the daily protein requirements, the growth is impaired and the slaughter yield is reduced (LEBAS and OUHAYOUN, 1987). If DP/DE is lower than the optimal daily quantity, the fat deposition on the carcass can be high because of a sub-optimal muscular protein accretion. When DP/DE is higher than the optimal value of 10.5-11 g of DP MJ^{-1} DE (LEBAS, 1989), the muscular protein synthesis reaches its maximum potential and the protein in excess is used as an energy source. In this case, the body gain composition can remain constant (XICCATO, 1999) and the fat deposition can suffer a slight reduction (MAERTENS *et al.*, 1988). If DP/DE is very high (more than 14 g MJ^{-1}) daily gain and feed conversion are deteriorated, the perirenal fat is reduced and mortality can be increased (KJAER and JENSEN, 1997).

Protein content of the diet also affects meat composition. If low-protein diets are supplied during post-weaning, the growth is impaired and a compensatory growth appears in the last period of fattening, delaying the fat deposition (LEBAS and OUHAYOUN, 1987). When diets with different DP/DE ratios are given during the fattening period, the results seem not to be conclusive. OUHAYOUN and DELMAS (1983) comparing *longissimus dorsi* muscle of rabbits fed diets differing from 10 to 17 g protein $MJ^{-1}DE$ found that the growth rate increased, the LD muscle had a better relative development, a higher nitrogen mainly in sarcoplasmic fraction and a more glycolitic enzyme activity. However, XICCATO *et al.,* (1993) found that carcass and meat composition were not modified.

Possibly, more studies are needed, but OUHAYOUN (1998) forwards an interesting model: With a diet low on DP/DE that decreases growth rate, the meat quality is enhanced because the development of glycolitic metabolism is limited, the intramuscular lipid content is increased, and the fall of the pH during the processing of the muscle into meat is restricted and this meat has a better water-holding capacity.

The composition of dietary proteins in essential amino acids can affect the growth rate and as a consequence, the body components and the slaughter yield are affected too. But these changes in growth rate are generally lesser than 10% when comparing with control. The muscle to bone ratio and the dissectible carcass fat are not significantly affected (OUHAYOUN, 1998). No effect has been yet shown in rabbits when the variation of amino acid supply does not modify the growth rate (XICCATO, 1999). A discussion on the importance of different amino acids can be found in the review of OUHAYOUN (1998).

EFFECTS OF SELECTION ON CARCASS AND MEAT QUALITY

One of the most important objectives of rabbit producers is to improve feed efficiency, because this trait has one of the highest economic values in rabbit production (ARMERO and BLASCO, 1992). Increasing post weaning daily gain is an indirect form of improving feed efficiency, because of its high negative genetic correlation. Using males of high adult weight is a way of improving daily gain and there are a number of studies on the influence of males of different breeds as terminal sires (OUHAYOUN, 1978; DAVID *et al.*, 1990). Actually, the most common practice in meat rabbit production for improving feed efficiency is to use sire lines selected for growth rate in terminal crosses (ROCHAMBEAU *et al.*, 1989; ESTANY *et al.*, 1992).

Traits of commercial carcasses are modified when using different breeds as terminal sires (LUKEFAHR *et al.,* 1983; PERRIER and OUHAYOUN, 1993) and also meat quality traits are affected (BERNARDINI BATTAGLINI *et al.*, 1994; DALLE ZOTTE and OUHAYOUN, 1998). When using selected animals as terminal sires, the changes on carcass and the meat traits are also expected because the accelerated growth rate obtained through selection conduces to an earlier slaughter and could stimulate glycolitic metabolism in muscular tissue. Theoretically, this has an adverse effect on water retention and on flavour on the meat (OUHAYOUN, 1992).

At least four ways have been used to study the effects of selection for growth rate on carcass traits and meat quality

Comparing lines selected for different objectives

When comparing two rabbit lines at a same age, DELTORO and LÓPEZ (1986) found that carcasses of rabbits of line selected for growth rate were less fatty, they had higher head percentage and lesser percentage of lean content of loin than those of line selected for maternal characters. Meat composition as fresh matter has less percentage of fat (3.87 *vs.* 4.02) and a little more protein one (20.43 *vs.* 20.24) (DELTORO and LÓPEZ, 1987).

At a same slaughter weight of 2 kg, rabbits of line R of Valencia, selected for daily gain, had a more developed liver, a lesser hind part, a more developed thoracic cage and lesser dissectible fat (2.5 vs. 3.1%) than rabbits of line V, selected for sitter size. The meat content of carcass, the meat to bone ratio and the fat content of meat were lesser in the R line; the muscular pH on the *Biceps femoris* and on *Longissimus lumborum* muscles and the meat colour did not show differences (PLA *et al.,* 1996). Differences on carcass composition seemed to be about the same sense in PLA *et al.,* (1998) when comparing the dam lines A, V selected on litter size, and line R, but in this case pH was higher in R line than in A and V, the meat of the R line had less fat and loosed more water when cooked. Initial yield force and maximum shear force were also higher in line R than in line A, being line V closer to line R.

When comparing carcasses and meat of rabbit lines selected for growth rate with others selected for different objectives, the differences which were found are of the same sense as those when comparing breeds of high or lower adult weight at a same live weight. But as a method for studying the effects of selection, this form of comparison has, at least, two limitations: (i) Lines selected for different objectives do not necessarily had the same origin and could be very different at the beginning of the selection process. (ii) When differences are found they are not necessarily consequence of selection on growth rate; in fact, BRUN and OUHAYOUN (1994) showed that selection on prolificacy resulted in a decrease in growth rate, in carcass fatness and in hindleg fraction of the carcass when a selected line for litter size (1077) is compared with a control line (9077) that remained unselected.

Comparing the characteristics of a line selected for growth rate with those of the same line some time afterwards.

BLASCO *et al.* (1990) compared the characteristics of rabbits of the California breed selected for 10 generations with those corresponding to a former unselected group and estimated the adult weight from weights until 20 weeks. Adult weight seems to increase from 3031 to 4210, but no changes on allometric coefficients of muscular tissue were found. The authors consider that some changes in maturity could take place due to selection on growth rate.

There is not information on meat quality in this experiment and there are no more references about experiments with this objective. But an objection to this form of comparison may be made: feed and/or other ambient conditions could be very different and the results found are not necessarily consequence of effects of the selection.

Comparing rabbits differently selected for growth rate.
In a recent experiment in the INRA in France, two groups of rabbits of a same genetic origin have been selected divergently for higher (HW) or lower (LW) growth rate (LARZUL *et al*., 2000).

Slaughtering rabbits at 63 days of age, differences in body weight, but not in perirenal fat percentage were found after 3 generations of selection and ultimate pH in *longissimus lumborum* muscle was higher in the HW line (LARZUL *et al.*, 2000). When comparing rabbits of the 3rd and 5th generations, LARZUL *et al.* (2001) found a difference of 16% on live weight, while on carcass weight the difference is about 14%; in this case, the carcasses of rabbits of HW group were 23% fatter.

When comparing the *Semitendinosus muscle,* this muscle was a 13% heavier and its section was 8% higher in rabbits of HW group, but no differences on myofibers were found (GONDRET *et al.*, 2001). Shear force was 20 and 8% higher, respectively, in *semitendinosus* an *longissimus lumborum* muscles in HW rabbits when compared with LW line, the result that is in concordance with the observation of PLA *et al.* (1998) in the sense that *Longissimus lumborum* of rabbits selected for growth rate had higher shear force than those selected for maternal characters. In the INRA experiment no effects of selection were found on pH values of both muscles considered or in intramuscularly fat content of ST muscle (GONDRET *et al.*, 2002).

The divergent selection for growth rate has been efficient after 6 generations and the difference between selected lines was 450 g for body weight. Furthermore, the variation in weight was symmetric in the two lines when comparing with a control line, constituted with frozen embryos from the first generation (LARZUL *et al.*, 2003-a). Effects on carcass traits were variable and the line selected for high weight had lower skin and higher perirenal fat percentages. Ultimate pH of LL muscle was not modified but meat of this muscle had higher lightness and lower yellowness in the HW line (LARZUL *et al*., 2003-b). Differences in weight and size of *semitendinosus* muscle are maintained, being lower in the slow-growing line. Moreover, after six generations of selection there is a difference of 16% in lipid content of this muscle, which was lower in the LW line (GONDRET *et al.,* 2003).

Comparing rabbits of different generation of selection simultaneously
This is the case of the experiment of Valencia where frozen embryos of a line (R) selected for growth rate corresponding to an old generation of selection are unfrozen and implanted in recipients does. The offspring of the born rabbits constituted the control group and are compared in a same ambient with rabbits belonging to a posterior generation of selection of the same line.

When the difference in selection was of 6 generations, BLASCO *et al.* (1996) found that selected rabbits had a 10% higher live weight at 70 days. The adult weight estimated from Gompertz curves was also a 7% higher in this group (BLASCO *et al*., 2003). When two groups of rabbits of 63 days, differing 7 generations, were compared, animals of the selected group were heavier and had a more developed liver, kidney and thoracic viscera, but their dissectible fat deposits (scapular and perirenal) were lighter. Meat to bone ratio was not affected by selection process. Raw meat of selected rabbits had lesser water holding capacity (2.1%) and cooked meat loosed more water (3.31%). Edible meat of a hind leg had less fat (0.37%) (PILES *et al.*, 2000).

Comparing two groups differing 11 generations and slaughtering rabbits of 9 and 13 weeks, HERNÁNDEZ *et al.* (submitted) did not find relevant negative effects of selection on carcass characteristics. Selected rabbits had less fat and improved meat to bone ratio. Effects of selection on meat quality are also small and meat of *longissimus lumborum* muscle retains a little less water (1.45%) but its metabolism does not seem affected; meat of hind legs has more water (0.48%) and less protein (0.18%) and fat (0.29%).

In a posterior experiment, when difference on selection was of 14 generations, selected rabbits were heavier at 63 days, carcasses differing 118 g had better conformation and were fatter (PASCUAL *et al.,* 2004). Although the differences are not relevant yet, their meat retained less water and showed a more glycolitic metabolism. As RAMIREZ *et al.,* (2004) show, effects of selection on instrumental texture properties of meat are also lightly negative and meat seems harder and with higher shear firmness, chewiness and gumminess. Conversely, these differences were not appreciated by a trained jury, but this found that meat of selected rabbits with a higher metallic-liver (1.38 v 1.13) and a lighter aniseed flavours (0.62 vs. 1.21); aniseed aroma of LL meat of S animals was also lighter in S group (HERNÁNDEZ *et al.*, 2004).

Selection could also affect the fatty acid composition of meat, but when analysing the fatty acid composition of extracted lipids on the meat of whole hind leg, indices related to human health were only slightly modified by selection. The highest change was a 10% of reduction of the polyunsaturated: saturated fatty acids ratio (less than a 1% of change per generation) and slightly improved ratio n6:n3 fatty acids. From this point of view, selection for growth rate does not damage the quality of meat until now (RAMIREZ *et al.*, in press).

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