REVIEW

PHYSICAL CHARACTERISTICS OF RABBIT MEAT: A REVIEW*

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This review was aimed at assessing of the physical traits in rabbit meat and at summarizing of the main factors which can influence them. To evaluate the meat quality in general it is necessary to account not only the chemical composition of meat, but all quality traits including physical and sensory characteristics. Physical characteristics are often related, so they must be seen as a complex. The pattern of acidification may affect the colour and water holding capacity of the meat. At rigor the extent of contraction of the muscle will determine the textural qualities of the meat after cooking. Preslaughter handling may therefore influence several important quality characteristics. Main attention is devoted to factors of high effect on rabbit meat quality such as the genetic effects (breed, size), biological factors (age, weight), feeding and technological factors.

meat colour and pH; meat tenderness; water holding capacity; oxidative stability

INTRODUCTION

Rabbit meat is well appreciated for its high nutritional and dietetic properties, it is lean and lipids are highly unsaturated (60%), it is rich in proteins (20–21%), its amino acids are of high biological value, low in cholesterol and sodium, and rich in potassium, phosphorus and magnesium (Bielanski et al., 2000). The control and improvement of carcass and meat quality is assuming greater importance in rabbit production. Indeed, the increasing integration of the different sectors of the entire rabbit (production, slaughter, transformation and marketing) makes the quality of the carcass more important and requires that all the production factors should be considered as essential parts of the process and therefore carefully controlled (Xiccato, 1999). During the last ten years, studies on rabbit meat quality have been mainly focused on meat chemical composition, pH and colour (Oliver et al., 1997; Dalle Zotte, Ouhayoun, 1998). In order to understand clearlythe link between these traits and the organoleptic variables, researchers have also investigated several aspects of meat water holding capacity and the measuring of meat tenderness and oxidation stability (Bernardini et al., 1994; Pla, Cervera, 1997). However, relatively little is known about the factors that affect these meat quality traits. Quality of meat is a broad term involving chemical, physical and sensory characteristics. Among the physical characteristics we rank the colour, pH, water holding capacity and meat texture. To evaluate the quality of meat, it is necessary to assess all these traits together, because they are related (Hernández et al., 1998). The first criterion of rabbit meat attractiveness for the traditional consumers is quality *sensu lato* followed by appearance, which is primary given by the colour of meat (Combes et al., 2008). Meat texture or tenderness is an important eating quality criterion for the consumers, because it is connected with the chewness of meat. The histochemical and biochemical characterization and classification of muscle fibres are closely related to colour stability and tenderness, as well as water holding capacity, eating quality and lipid oxidation.

Meat colour

Colour of meat is the visual characteristic of meat that gives the critical first impression. Meat colour can be affected by many factors. One of the most important factor is the content of pigment myoglobin, which is dependent on primary production factors such as species, breed, nutritional status and age of animal. Meat colour varies according to a part of carcass. In addition, meat colour is influenced by many factors. Hernández et al. (2004)

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determined the effect of slaughter age on the intensity of meat colour in *m. longissimus lumborum* muscle, they observed that rabbits at 9 weeks of age had higher values of L*, a* and b* than animals at 13 weeks of age. These lower values in older animals could be a consequence of a decrease in oxidative metabolism in the longissimus muscle during growth. Pre-slaughter period and the slaughter process, stress immediately before and during the slaughtering also affect meat colour (Petracci, Baéza, 2007). Dal Bosco et al. (1997) show the effect of journey time and stocking density during transport on meat colour. They observed darker as well as redder meat in rabbits that had undergone a long transport. Also Lambertini et al. (2006) showed that rabbits who underwent longer transports had significantly darker meat, means lower L* and H° values. The effect of genotype and genotype origin was studied by Dalle Zotte and Ouhayoun (1998). They published a significant effect of genetic origin on meat colour in all colour parameters. The lightest meat was found in INRA strains in comparison with Hy+ rabbits. Also Ristic and Zimmermann (1992) found significant differences in lightness and redness of meat between genotypes. These results are in agreement with Chiericato et al. (1996) who compared 3 breeds in meat colour characteristics, they found significant differences in lightness and redness between the New Zeland White, Grimaud and Provisal Rabbits. The New Zeland White had a higher redness and lightness. The appearance of meat is important for consumers, and therefore the selection should give only small variations in meat colour and knowledge of the effect of different factors may bring stability in this physical meat parameter.

pH measurement

pH gives a good estimate of glycolytic potential of the muscle if measured after a long chilling period (Blasco, Ouhayoun, 1996). The pH of muscle during life is about 7.2. Also immediately after slaughtering, pH value is near to neutrality. Post mortem, the muscle acidifies to values of 6 or less through the accumulation of lactic acid. The lactic acid derives from the post mortem breakdown of glycogen by glycolysis, in the process liberating energy in the form of adenosine-triphosphate. Within a few hours it falls to a stable value, depending on muscle and its energy reserves. The objective of this measuring is the rate and the intensity of the muscle acidification during *post mortem* time.

There is a strong negative correlation between meat colour and pH of meat, which influences the muscle texture and the oxidation of haem pigments. Muscle pH affects both the light reflectance properties of the meat as well as the chemical reactions of the myoglobin. At high pH levels the oxymyoglobin is rapidly turned into dark red coloured reduced myoglobin (Renerre, 1982) and the muscle structure is less reflective because it is less compact. In the extreme, high pH meat is often characterized as being dark, firm and dry (DFD) and the lighter meat as being pale, soft and exudative (PSE). But in general, rabbit meat is not predisposted for these both abnormalities.

In rabbits the pH measured 24 h *post mortem* in the *m. longissimus lumborum* lies around 5.6 – 5.7 (Pla et al., 1998; Fushy et al., 2006) and in *biceps femoris* 5.7 (Pla et al., 1998). The *biceps femoris* is less acid than the *longissimus lumborum* muscle as a consequence of its more oxidative metabolism and low glycolytic potential (Hernández et al., 1997; Pla et al., 1996).

The muscle pH can be influenced by nutrition. Dalle Zotte et al. (2005) showed a significant effect of feed restriction on pH values of the *biceps femoris,* although the effect of nutrition and feeding plans is of minor influence. According to Dalle Zotte et al. (2005) and Tůmová et al. (2006) pH of loin was not affected by feed restriction. Carrilho et al. (2009) tested the effect of diets with different fibre levels. They observed, that pH was not altered with the level of fibre and energy in the diet, concordant with Villena et al. (2008). The effect of journey time and stocking density during transport on pH was studied by Lambertini et al. (2006), who found that longer transport increased pH. pH can be strongly affected by the age of rabbits and with increasing age pH decreases (Dalle Zotte, Ouhayoun, 1995; Dalle Zotte et al., 1996, 2005). Also the muscle and its structure affect significantly the pH values. Usually *longissimus lumborum* has a lower pH than *biceps femoris*. In particular, it depends on the percentages of each fibre types and their energy metabolism. *Psoas major* muscle which contains only αW fibres has a significantly higher pH (5.98) then the *longissimus lumborum* muscle which has also βR and αR fibers (5.83). Hernández and Gondret (2006) observed that in the heavier rabbit muscular energy metabolism is more glycolytic and, correlatively, ultimate pH is lower. The muscle pH can be influenced by genotype. Ristic and Zimmermann (1992) showed a significant effect of genotype on pH values in loin and thigh meat. They published that higher pH in loin was detected in Zika hybrids (5.72) and the lowest in Hyla hybrids (5.42). Also in thigh meat the trend was similar. The effect of different housing systems is unclear. The pH of meat from rabbits in the open-air farming system was lower than those in cages (Cavani et al., 2000). Dal Bosco et al. (2002) found significantly lower pH in the *musculus longissimus lumborum* (MLL) of pen-housed rabbits. These results are in agreement with Pla (2008), who revealed that in conventionally produced rabbits the pH was significantly higher than in organic. From evaluated factors it seems to be visible that pH of rabbit meat is affected mainly by housing system and further research is necessary.

Water holding capacity (WHC)

The water holding capacity represents the ability of meat to retain its liquid during storage, processing and cooking (Petracci, Baéza, 2007). In meat, about 8% of water is closely linked to proteins and is not concerned with exudation, the remainder is more or less linked and its release depends on applied treatment (Ouhayoun, Dalle Zotte, 1996). Water losses originate from volume changes of myofibrils induced by pre-rigor pH fall and the attachment of myosin heads to actin filaments at rigor where myofibrils shrink owing to pH fall. Denaturation of proteins may also contribute to a reduction in WHC particularly in conditions of rapid pre-rigor pH fall. The fluid thus expelled accumulates between fibre bundles. When a muscle is cut, this fluid drains from the surface under gravity if the viscosity of the fluid is low enough and capillary forces do not retain it (Honikel, 1998).

The effect of genotype on WHC was studied by Biguang et al. (1996). They compared 5 pure breeds (Californian, New Zealand White, Danish White, German Giant and Belgian). The highest WHC was measured in the Californian (19.9%), the lowest WHC in the Danish White (13.3%), but the differences between breeds were not significant. Selection for growth rate may also affect the WHC. Piles et al. (2000) showed that WHC of raw meat was generally poorer in growth selected rabbits compared with a control group. Pla et al. (1998) compared 3 rabbit lines selected for growth rate and litter size. They showed that the WHC was not affected by the selection group. Similarly, Arino et al. (2006) did not find differences in water holding capacity between rabbit lines selected for growth rate. Van der Wall et al. (1983) studied the effect of stunning density on the water holding capacity of meat, they did not found any significant effect and they affirmed that the numerous factors which affect meat quality, make it extremely difficult to determine the effect of stunning technique. López et al. (2008) compared the meat quality characteristics between rabbits slaughtered either after electrical stunning or through the halal procedure. They observed that rabbits slaughtered after the hallal procedure had a higher WHC, but the differences were not significant. Dal Bosco et al. (1997) studied the effect of transport time on water holding capacity, drip and cooking loss. They showed that in the longer transported animals the *longissimus lumborum* muscle had a higher moister content and drip loss. The water holding capacity was higher, while the cooking loss was lower. Another factor which can influence the WHC is the effect of season. María et al. (2006) studied the influence of summer and winter time slaughtering on meat quality and they found a significant effect of season on WHC, in rabbits slaughtered in winter the WHC was higher. The effect of housing is described by Liste et al. (2009) who revealed the effect of different positions on the multi-floor cage rolling stand. They found significant differences in the WHC between rabbits housed on the top, middle or bottom of the rolling stand. The highest WHC was determined in the upper floors. D'Agata et al. (2009) did not find the effect of housing system on drip loss, but they determined significant differences between cooking losses, rabbits housed outdoor had a higher cooking loss than rabbits reared in the indoor housing system. WHC is important mainly for products but the indicator is not affected in a wide range.

Meat tenderness

Meat tenderness (texture) is one of the most important physical and sensory characteristic of meat. The meat texture can be determined using a trained taste panel or by physical methods. Tenderness can be instrumentaly measured by Warner-Bratzler (WB) shear device and by the texture profile analysis (TPA; Honikel, 1998). The average WB shear force value of rabbit meat measured in the LL is 3.6 kg/cm^2, firmness 1.7 kg/s cm^2 and the area 5.3–6 kg/s cm^2 (Arino et al., 2006; Pla, 2008). In the TPA test (texture profile analysis) the following variables were obtained: hardness, cohesiveness, springiness and chewiness (kg), which are calculated as hardness x cohesiveness x springiness (Pla, 2008). Arino et al. (2006) showed the average hardness 11.7 kg, cohesiveness 0.5, springiness 0.5 and chewiness 2.7 kg. Meat tenderness depends mainly on the post-mortem changes affecting myofibrillar proteins and on the connective tissue that represents the "backround" toughness (Arino et al., 2006). Meat texture can be also influenced by the quantity of collagen as well as its solubility (Bailey, Light, 1989). Many authors have tried to clarify the relationship between quality of collagen and meat hardness, however, the results are conflicting. It seems that quality of collagen influences meat texture, but a direct correlation was not determined (Combes et al., 2003). Several studies have indicated an influence of the genetic type and selection (Arino et al., 2006; Hernandéz et al., 1998). In many species, selection for improved growth rate generally favors both hyperplasia (increase in total number) and hypertrophy (incerase in cross-section area) of the myofibres (Rehfeldt et al., 2000). Both the number and size of myofibres are though to have an influence on meat tenderness. Arino et al. (2006) described that rabbit lines selected for litter size and growth rate had the most tender meat. These results are in disagreement with Ramírez et al. (2004) who found that the loin meat of growth-selected rabbits was harder than of the controls. Gasperlin et al. (2006) studied the effect of genotype on meat texture. When compared the genotypes SIKA and Hybrid, they did not confirm any significant effect.

A decrease in the water holding capacity is usually related to a decrease in tenderness and texture (Gault, 1985). Ante-mortem stress can change meat texture and the effects of transport and lairage time at the abattoir can sometimes be confounded. Stress cannot only increase ultimate pH and darkness of meat, but also increase tenderness. Raw meat from rabbits after a long lairage (8 h) was significantly tenderer than after a short lairage (2 h; Liste et al., 2009). No effect of sex on meat tenderness was found out by Carrilho et al. (2009) and Pla (2008). Carrilho et al. (2009) showed the effect of housing system on meat tenderness. Rabbits reared in the organic housing system had a higher maximum share force, shear firmness, what indicates the resistance to cutting the meat, and the shear force and total work. These results are in agreement with Combes et al. (2003), who found higher energy, maximum shear force and rigidity in raw meat from organically reared male rabbits. This less tender meat from organic rabbits should be related to the older age of these animals. Increasing interest in sensorial properties of rabbit meat has been shown, and tenderness, particulary the chewiness of meat, is probably one of the most important rating quality attributes of rabbit meat (Dalle Zotte, 2002).

Oxidative stability

The TBARS test is one of the most frequently used methods for malonic dialdehyde quantification in meat and meat products. In this test, the degree of rancidity in fats and meats has traditionally been measured using an assay for the determination of substances which react with thiobarbituric acid.

The susceptibility of muscle tissue to oxidation depends on several factors; the most important is the level of PUFAs present (Gray et al., 1996). Oxidative deterioration in muscles begins with oxidation of the double bonds of the phospholipids present in the cell membranes, leading to the production of free radicals, and manifests as deterioration of flavor, colour, texture, nutritional value and the possible production of toxic substances. Rabbit meat fat comprises mostly saturated fatty acids (SFAs) and polyunsaturated fatty acids (PUFAs), 36.9% and 34.6% of total fatty acids in hind leg, respectively.

Nutrition has the main influence on the oxidative stability of lipid. The dietary manipulation of tissue lipid composition to produce meat with a high content of PUFA could reduce the oxidative stability of the meat-products and have a negative effect on meat quality. For instance, dietary inclusion of 8% of the whole linseed increased lipid peroxidation, so it leaded to impairing of sensory properties of rabbit meat during storage (Bianchi et al., 2003). Cavani et al. (1996) studied the relationship between feeding whole soybeans and lipid peroxidation. The TBARS values seem to confirm the tendency of meat produced with diets containing whole soybeans to be more susceptible to peroxidation and hence more difficult to preserve in time. Lopez-Bote et al. (1997) evaluated the effect of adding different fat sources and vitamin E into the diet on the oxidative stability. They found the significantly lowest lipid peroxidation in all measurements in rabbits fed by a diet with addition of olive-oil and 300 mg/kg of vitamin E. Corino et al. (1999) also investigated the effect of vitamin E supplementation to rabbits during the last 15 days preslaughter on the oxidative stability. Lipid oxidation was significantly lower in the muscle of rabbits fed additional alfa-tocopherol. They also found a significant logarithmic relationship between muscle alfa-tocopherol concentration and TBARS on the first day of storage. These results are in agreement with Castellini et al. (1998), Corino et al. (2007), Oriani et al. (2001) and Lo Fiego et al. (2004). Therefore it is advisable to use high amounts of these antioxidants, because of the strong oxidative stress that the rabbit meat undergoes during processing and storage (Castellini et al., 2000).

CONCLUSION

This review gives a summarized overview about the main physical meat quality traits and factors, which can significantly influence them. Many factors that can negatively affect quality of rabbit meat are associated with the current commercial production of rabbit meat. In fact, hybridisation programmes are selecting the fast growth rates using terminal sires of large size, with the aim to improve feed efficiency and shortening the rearing time. This might also favour a glycolytic energy metabolism in muscle tissue and consequently spoils meat quality, especially tenderness, by reducing the water holding capacity and the ultimate pH. Physical characteristics are often related, so they must be seen as a complex. pH is negatively correlated with meat colour and WHC. Meat texture mainly depends on the post mortem changes and on the structure of the muscle. For the future, it would be appropriate to include also meat quality traits into the selection programmes.

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Fyzikální ukazatele králičího masa: přehled literatury.

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Cílem tohoto článku bylo posoudit fyzikální ukazatele králičího masa a shrnout nejdůležitější faktory, které je mohou ovlivňovat. Kvalita masa je široký pojem, zahrnující nejen chemické složení, ale i fyzikální a senzorické ukazatele. Fyzikální ukazatele jsou mezi sebou velmi často korelovány, je tedy nutné je posuzovat společně. Průběh okyselování svalu může ovlivnit barvu a vaznost masa. Intenzita kontrakcí svalových vláken v rigoru mortis určuje následnou texturu masa. Hlavní pozornost je v článku věnována faktorům, které mají významný vliv na kvalitu králičího masa, jako je například genotyp, výživa, věk nebo porážková hmotnost.

pH a barva masa; textura; vaznost masa; oxidační stabilita

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