THE EFFECT OF FEED RESTRICTION ON MEAT QUALITY OF BROILER RABBITS: A REVIEW

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The aim of this review was to analyze the effect of feed restriction on meat quality. Feed restriction in broiler rabbits is applied mainly due to the limitation of health problems in the period after weaning. Restriction of feed in rabbits affects growth during the time of application, but also during realimentation period. Parameters relevant for meat quality can be affected along with the change of growth rate. Good knowledge of the carcass composition and influencing factors is important for the correction evaluation of the impact of feed restriction on the meat quality parameters. Stronger feed restriction reduces growth and slaughter weight and has a negative effect on dressing percentage, loin share, and meat to bone ratio, but positively effects fat content. A mild restriction does not affect carcass composition. Meat quality is basically described by chemical composition, physical traits including pH value, and meat colour, and one of the most important characteristics is muscle fibre. Higher water and lower lipid contents were detected in restricted rabbits. Feed restriction increases proportion of oxidative fibres in muscles and leads to higher pH value. Meat colour is not influenced by restriction of feed.

rabbit; restriction; slaughter parameters; chemical composition; muscle fibres; pH; colour

Feed restriction

Feed restriction is frequently applied to the rabbit females to avoid excessive fattening, reproduction troubles, and enhance reproductive results (Maertens, Villamide, 2003; Rommers et al., 2004). In fattening rabbits, limited feed intake induces compensatory growth and improves feed efficiency (Tůmová et al., 2002, 2003; Di Meo et al., 2007; Gidenne, Feugier, 2009; Gidenne et al., 2009), reduces fat in carcasses (Perrier, 1998; Gondret et al., 2000; Tůmová et al., 2003, 2007), and sometimes decreases the incidence of post-weaning digestive disorders, such as rabbit epizootic enteropathy (Xiccato, 1999; Dalle Zotte, 2002; Boisot et al., 2003; Di Meo et al., 2007).

The effect of feed restriction on meat quality depends on implementation, i.e. on the intensity of feed restriction, its duration, and age when it is applied. The feed restriction is usually used for 1–5 weeks with intensity of intake limitation from 90 to 40% of the voluntary intake (Dalle Zotte, 2000; Di Meo et al., 2007; Bovera et al., 2008). The limited feed intake decreases growth in the period of restriction. Gidenne et al. (2009) stated that a linear decreasing of growth is about 0.5 g/day per each percentage of feed reduction. Following the restriction, rabbits are fed *ad libitum* (ADL) and it can exhibit in higher daily weight gain typical for compensatory growth (Tůmová et al., 2002, 2003). Therefore, growth curve in restricted rabbits may approach or copy the curve of the *ad libitum* fed animals. Compensatory growth is defined as a physiological process whereby an organism accelerates its growth after a period of feed restriction. The range of compensatory growth may be quantified by the "compensatory index". Compensatory index (I) is the ratio of the difference between weight variation at the end of restricted growth (A) and compensatory growth (B) periods, respectively, relative to the variation at the end of restricted growth: I = (A – B)/A (Hornick et al., 2000; Andersen et al., 2005). Generally, the compensatory index value lies between 50 and 100%. Value of 100% indicates a full recovery of growth (Hornick et al., 2000). Degree of compensation is indicated by previous growth and by intensity of the feed restriction. If the feed restriction is very intensive, then restricted fed animals despite the growth compensation cannot reach a weigh of the *ad libitum* fed ones.

In rabbits, Perrier, Ouhayoun (1996) showed higher daily weight gain in rabbits restricted on 70% in days 35–56 followed by restriction at 90% level between days 56–77 of age than in rabbits with less intensive restriction (80–80% and 90–70%, respectively). Likewise, Perrier (1998) found out lower daily weight gain (39 g/day) in rabbits with more intensive restriction (on 50% of ADL, between days 35–56 of age). Rabbits with restriction of feed on 70% of ADL had also lower daily weight gain than the *ad libitum* fed group. This author showed that despite the presence of compensatory growth, an early feed restriction provoked lower final weight in comparison

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to the *ad libitum* fed group. Gondret et al. (2000) restricted rabbits from 11 to 18 weeks of age on 70% of ADL. They found significantly lower growth rate in rabbits with feed restriction than in the *ad libitum* fed group. Likewise Tůmová et al. (2004) reported significantly reduced daily weight gain in rabbits with restriction between days 42–56 of age (50 + 65 g feed) than in rabbits with restriction on 50 + 75 g applied at the same period and also than in the *ad libitum* fed group. Gidenne, Feugier (2009) stated decreasing daily weight gain with increasing intensity of feed restriction (90, 80, 70 or 60% of ADL) in restriction time (between days 34–56 of age). These authors observed the opposite trend in realimentation period (after 56 days of age), i.e. rabbits with the most intensive restriction (60% of ADL) had the highest average daily weight gain (58.4 g/day), whereas the *ad libitum* fed group had the lowest growth (46.1 g/day).

Compensatory growth is important for live weight of rabbits. Perrier (1998) discovered that the final body weigh decreased with increasing intensity of feed restriction. They stated that restrictively fed rabbits (on 50 or 70% of *ad libitum* feed between days 35–56 of age) had significantly lower weight than the control group. Also Boisot et al. (2003), who applied restriction between days 34–58 of age, established the lowest live weight in rabbits with intensive restriction (60% of *ad libitum* feed). Dalle Zotte et al. (2005a), Gidenne, Feugier, 2009, and Gidenne et al., 2009 applied restriction between days 35–56 and they detected decreasing of live weight with increasing intensity of feed restriction. Moderate restriction (90% of ADL) did not affect live weight. While rabbits with intensive restriction (under 80%) had lower live weight than the *ad libitum* fed group. Gidenne et al. (2009) registered the decrease of 4.5 g the live weight per each percentage of the restriction. Rabbits during the period of feed restriction received a lower amount of feed, which may be subsequently reflected in insufficient intake of nutrients. Lower amount of taken nutrients can lead to reduced growth of rabbits which do not reach the required live weight despite the realimentation period. Consequently, compensatory growth and thus the influencing of live weight depends on intensity and time of application the feed restriction. It seems that rabbits after longer and stronger restriction cannot compensate live weight, but moderate restriction had no effect on live weight.

The effect of feed restriction on dressing percentage is through final weight. The most liberal feed intake (90% of ADL) during the second period of growth (between days 56–77 of age) reduced dressing percentage compared with rabbits restricted stronger (80 or 70%, Perrier, Ouhayoun, 1996). Perrier (1998) detected significantly reduced dressing percentage only in rabbits restricted on 50% of *ad libitum* feed, but group with less intensive restriction (70% of ADL) did not differ from *ad libitum* fed control. Gidenne et al. (2009) revealed significantly reduced dressing percentage in restricted rabbits (between days 34–55 of age) than in the *ad libitum* fed ones, but groups with various intensity of restriction (80, 70, or 60% of ADL) did not mutually differ. The dressing percentage can be affected also by the beginning of feed restriction. Perrier, Ouhayoun (1996) stated that dressing percentage was similar in *ad libitum* and restricted rabbits on day 56 of age. In a case that rabbits were restricted till day 56 of age, dressing percentage was higher in restricted rabbits compared to the *ad libitum* fed ones. Similar results were detected by Tůmová et al. (2003, 2006). Time of restriction did not influence the dressing percentage, if feed limitation was applied on 6 h/day from day 42 for 2, 3, or 4 weeks (Tůmová et al., 2003) and on 8 h/day or skip-a-day feeding for 5 weeks from day 7 after weaning (Yakubu et al., 2007). However, Matics et al. (2008) used the time restriction immediately after weaning, and they found significantly higher dressing percentage in restricted rabbits. The slightly decreasing of dressing percentage was according to Ouhayoun (2003) caused by lower carcass weight in restricted rabbits, by increase of weight of the full digestive tract and by the reduced growth rate, which enhanced the relative growth of early-maturing organs as the digestive tract. Similar results reported also Gidenne et al. (2009). Presumably in the restriction and realimentation periods, priority is given to the development of internal organs, which grow faster than other parts of the body (Tůmová et al., 2006). Generally, a negative effect of feed restriction on dressing percentage might be caused by a rate of compensatory growth and therefore final live weight. If restricted rabbits do not fully compensate their growth then lower live weight has a negative effect on dressing percentage.

There has been detected the effect of feed restriction on carcass composition. Ferreira and Carregal (1996) observed increasing share of thigh in restricted rabbits compared to the ADL fed ones. Tůmová et al. (2006) did not find out differences in share of hind legs in *ad libitum* fed and restricted rabbits with various duration of limited feed intake. However, Gidenne et al. (2009) stated that rabbits with restriction on 70% of ADL between days 34–55 had significantly reduced percentage of hind leg from carcass, but rabbits with restriction on 80 or 60% of ADL in the same period did not differ from the *ad libitum* fed group. The effect of time restriction on share of thigh studied Matics et al. (2008). They found significantly higher proportion of hind legs to the body weight in *ad libitum* fed rabbits than in the restricted group. Contradictory findings in results of carcass composition could be caused by different intensity and time of feed restriction. Not only thigh share but also loin percentage is affected by feed restriction. Ferreira, Carregal (1996) stated decreasing of the loin proportion of the carcass in rabbits restricted on 50% of ADL between days

70–120 of age. Tůmová et al. (2006) detected the effect of beginning and length restriction on the loin proportion. They registered a significantly ($P \leq 0.05$) lower proportion of loin in restricted rabbits than in the ADL fed rabbits. The lowest share of the loin was detected in group with restriction for 3 weeks and in the group with late restriction after weaning (56–63 days of age). According to the published results the influence of restriction on the share loin is not clear, but it seems that if the restriction is very intensive or applied later, than rabbits have lower share of loin. This situation might be caused by growth allometry of thigh and loin. Thighs had an earlier growth than the loin (Pascual et al., 2008). Feed restriction also influences meat to bone ratio. Perrier, Ouhayoun (1996) recorded the significantly lowest muscle to bone ratio in rabbits restricted on 90% of ADL between days 35–56 of age and then on 70% between days 56–77 of age. On the other hand, group with different restriction intensity did not vary in muscle to bone ratio and it corresponds with Gidenne et al. (2009). These results are in contrast with Perrier (1998) who registered differences in meat to bone ratio according to the intensity of feed restriction. Lower meat to bone ratio was also detected by Larzul et al. (2004) in rabbits with longer feed limitation.

One of the most important effects of restriction is the influence on fat content in carcass. In restricted rabbits, Perrier (1998) reported lower fat content compared to those fed *ad libitum*. Similar results are described by Gondret et al. (2000) or Tůmová et al. (2003, 2007) and Larzul et al. (2004). Also Tůmová et al. (2006) showed lower renal fat content in the restricted group at the end of experiment. They detected renal fat in restricted rabbits at the age of 63 days, whereas in the *ad libitum* fed ones already at 56 days of age. Significantly higher fat content was detected by Tůmová et al. (2003) in rabbits restricted one week between days 42–49 of age than in the *ad libitum* fed group. However, time restriction did not affect share of renal fat (Tůmová et al., 2003; Matics et al., 2008). It has been shown that an improvement in growth rate during the *ad libitum* feeding period increases the development of late-stage tissue and especially adipose tissue (Ouhayoun, 2003). *Ad libitum* fed rabbits take more energy from feed and it is stored in the form of fat deposits. Part of the fat is stored directly into the muscles and causes marbling of meat, which is the source of taste and juiciness of the meat. The precise mechanism by which accumulation of intramuscular lipids is impaired by feed restriction is not understood. Marbling may be due to *de novo* lipogenesis in the intramuscular adipose tissue and occurs as a result of an uptake of fatty acids via lipoprotein lipase activity. Complete feed deprivation depresses the rate of *de novo* lipogenesis in extramuscular adipose tissue of various species, however, data are lacking on the variations of lipogenic enzyme activities in skeletal muscles of animals adapted to feed intake below *ad libitum* (Gondret et al., 2000).

Feed restriction and meat chemical composition

Meat chemical composition is an important trait of meat quality. Chemical composition of meat can be affected by several factors and feed restriction is one of the most important. Moisture, defined as sum of free and linked water (Ouhayoun, Dalle Zotte, 1996), is a main component of muscles and can be influenced by feed restriction. Xicatto (1999) calculated that water content in rabbit meat increased with growing level of feed restriction. They showed 62.3% water content in meat of *ad libitum* fed rabbits and 66.2% water content in meat of rabbits with limited feed intake on 80% of ADL. Likewise Larzul et al. (2004) observed significantly higher water content in rabbits with quantitative restriction than in the *ad libitum* fed ones. Metzger et al. (2009) detected significantly higher moisture content in rabbits with energy restriction (80% DE of ADL between weeks 4–12 of age; 76.9 vs. 75.8% in ADL). The water content is negatively correlated with lipid content in meat (Bernardini et al., 1994). It seems that if the restricted rabbits receive feed with lower quantity of energy, only a few amounts of fat deposit in meat and it leads in increasing of water content. It corresponds with Xiccato (1999), who demonstrated lower fat content (9.4%) in restricted rabbits (80% of ADL) than in the *ad libitum* fed group (13.8%). He indicated that more intensive restriction decreased fat in higher range. Also Gondret et al. (2000) revealed that restricted fed rabbits had significantly lower total lipid content in *Biceps femoris*, *Longissimus lumborum*, and *Semimembranosus proprius* muscles than the *ad libitum* fed group. Likewise Larzul et al. (2004) determined lower percentage of lipid content in the meat in rabbits with limited feed intake. However, Metzger et al. (2009) stated that rabbits with energy restriction did not differ from the *ad libitum* fed in total lipid content in hind leg. Lipids and fatty acid composition defines the nutritive value and the organoleptic value of meat (Ouhayoun, Dalle Zotte, 1996). The lower lipid content in restricted rabbits might be probably due to a decrease in activities of the enzymes implicated in fatty acid biosynthesis (malic enzyme and glucose-6-phosphate dehydrogenase; Gondret et al., 1997).

Rabbit meat fat includes saturated fatty acids (SFA) with concentration around 36.9% of total fatty acids (Hernández, 2008), unsaturated fatty acids representing 57–59% of the total fatty acids (Dalle Zotte, 2000), and polyunsaturated fatty acids (PUFA) with concentration of 34.6% of total fatty acids in hind leg (Hernández, 2008). The PUFA and other fatty acid contents can be influenced by dietary manipulation, but highly increased PUFA content could have a negative effect on oxidative stability of meat (Hernández, 2008). Metzger et al. (2009) found significant differences in fatty acid composition among energy restricted and *ad libitum* fed rabbits, which received feed rich in polyunsaturated fatty acids. They showed higher content of linoleic acid and its derivates, as well as increasing of PUFA *n*-6 in restricted rabbits. It is well known that rabbits are able to incorporate dietary fatty acids into adipose and muscle tissue lipids (Hernández, Gondret, 2006). However, the effect of quantitative feed restriction on fatty acid content and composition in rabbits has not been observed by any authors.

Proteins of rabbit meat have a high nutritional value, because it contains all essential amino acids. Concentration protein in meat is affected mainly by dietary protein concentration. Lebas, Ouhayoun (1987) found the significant decrease in the intensively growing muscles in rabbits with low protein ratio in feed. But when rabbits were again fed *ad libitum*, then the protein content in meat increased. In quantitatively restricted rabbits, Xiccato (1999) showed slightly higher protein level in rabbits with restriction than in those fed *ad libitum*. It indicates that if the diet has an excess of protein in relation to energy, retention of nitrogen may be slightly improved by addition dietary energy until energy to protein ratio approaches a certain value beyond which additional energy content of the diet will result in reduces of nitrogen as a component of the body (Fraga et al., 1983).

Feed restriction and muscle fibres

Morphological, physiological, and biochemical characteristics of muscles and meat quality can be modified by feed restriction (Gondret et al., 2000; Metzger et al., 2009). The two muscles considered the most representative of rabbit meat quality are the *musculus Longissimus* and *Biceps femoris* (Blasco, Ouhayoun, 1996). Muscle fibre characteristics (composition, fibre areas, and capillary density) correspond with colour stability, tenderness, and water-holding capacity. The most commonly observed muscle fibre characteristics are number of muscle fibres, fibre cross-sectional area, diameter, perimeter, fibre type distribution, and compactness index (perimeter^2/area). The number of muscle fibres per 1 mm^2 is closely related to fibre cross-sectional area. These parameters can be affected by intensity of feed restriction. Gondret et al. (2000) did not find any difference for cross-sectional area of fibres in *musculus Longissimus lumborum* and *Biceps femoris* between restricted (70% ADL between 11–18 weeks of age) and control rabbits slaughtered at the same weight. Likewise Dalle Zotte et al. (2005b) stated that maternal feed restriction did not affect fibre cross-sectional area in *musculus Longissimus lumborum* at weaned rabbits. However, larger fibre cross-sectional area in rabbits with limited feed intake was revealed in all types of muscle fibres of *Biceps femoris* (Dalle Zotte et al., 2004, 2005a). They found out that when the feed restriction was more intensive and longer, it increased cross-sectional area of muscle fibres in a higher range. The effect of energy restriction on muscle fibre characteristics examined Dalle Zotte, Ouhayoun (1998). They observed reduction of cross-sectional areas of all types of muscle fibres in restricted rabbits. Gondret et al. (2000) reported that enlargement of muscle fibres is positively correlated with body weight rather than age. This is contrary to Dalle Zotte et al. (2005a), who stated that the mean cross-section of βR and αW fibres doubled from weaning (5 weeks of age) to 11 weeks of age, while αR fibres stopped enlargement at 8 weeks of age. Feed restriction causes a reduction growth, which is probably related to the decreasing fibre-cross area of muscle fibres.

Also diameter is an important characteristics of the muscle fibres. Hegarty, Kim (1981) restricted rabbits by 45% of ADL for 15 days and they found a large decrease of the diameter of fibres of *Biceps brachii,* but the number of muscle fibres did not change. Similar results were reported in broiler chickens (Rehfeldt et al., 2004).

It seems that the feed restriction modifies a percentage of muscle fibres type. Restricted feed intake during growth increases the percentage of oxidative fibres indicating the enhancement of the metabolism pathway in beef cattle, pig, and lamb (Seideman, Crouse, 1986; Solomon, Lynch, 1988; Solomon et al., 1988). Fibre type distribution can be influenced by intensity of feed restriction in rabbits as well. Gondret et al. (2000) did not find any significant difference in fibre type composition of *Biceps femoris, Longissimus lumborum* and *Semimembranosus proprius* muscles between quantitatively restricted rabbits and the *ad libitum* fed group. However, these authors stated that *Longissimus lumborum* had lower proportion of oxidative fibres in restricted group (11.8 vs. 16.9% in restricted rabbits and *ad libitum* fed), but proportion of oxidative fibres in *Biceps femoris* and *Semimembranosus proprius* were not affected by feed restriction. On the other hand, the proportion of oxidative fibres varied between muscles, irrespective of the feeding status. *Musculus Semimembranosus proprius* consisted only from oxidative muscle fibres, lower concentration of oxidative fibres was in *Biceps femoris* and the lowest in *musculus Longissimus lumborum*. In contrast to these authors, Dalle Zotte et al. (2005a) found the significantly lowest share of βR and the highest share of αW muscle fibres in *Biceps femoris* muscle of rabbits restricted on 70% from 5 to 8 weeks of age and then on 90% to 11 weeks of age. These authors did not find differences between rabbits with variable restriction intensity. *Ad libitum* fed rabbits had the significantly lowest share of αW fibres (60%) than restricted groups. Dalle Zotte et al. (2005b) examined the effect of feed restriction in does, on the development of muscle fibres of *Longissimus lumborum* in the offspring. They found significantly different fibre type distribution only in rabbits at weaning. Rabbits from restricted females had the significantly lowest share of αR muscle fibres than from the *ad libitum* fed group. Differences were not recorded in offspring at the age of 81 days. The percentage of αW fibres increased after weaning – from 71.8% at weaning to 86.3% at 81 days of age, while the percentage of βR fibres decreased – from 10.2 to 1.7%. The effect of energy restriction (9.67 MJ DE kg in restricted and 11.99 MJ DE kg in *ad libitum* fed rabbits) studied Dalle Zotte, Ouhayoun (1998). They contemplated that restricted rabbits Hyplus did not have significantly various percentages of different types of fibres. The lack of differences in contractile fibre-type composition between two groups is consistent with the fact that the muscle contractile differentation is mostly completed at 2 months of age in rabbits (Gondret et al., 1996, 2000). Compensatory growth may involve a fast enhancement of glycolytic energy metabolism and correlated with fast lowering of oxidative energy metabolism in muscles. The enlargement of βR and αW fibres continued constantly until 11 weeks, the αR fibres stopped at 8 weeks of age (Dalle Zotte et al., 2005a). It may be the reason why the feed restriction affects mainly βR and αW muscle fibres. Selective increasing of the proportion of βR fibres during a period of reduced energy availability would be physiologically relevant as a way to spare energy.

Fibre shape abnormalities are expressed in compactness index (perimeter^2/area) and large variability of this parameter is associated with pathology of fibres. Dalle Zotte et al. (2004, 2005a) found significantly higher compactness index in αR fibres rabbits restricted on 70% of *ad libitum* fed group (2.05). Likewise, αW fibres of rabbits restricted between 5–8 weeks of age had the significantly highest compactness index (2.12 and 2.15, respectively) than *ad libitum* fed group (2.02). In the following research Dalle Zotte et al. (2005b) presented that feed restriction of does did not have a significant effect on compactness index of *musculus Longissimus lumborum* of offspring.

Feed restriction and meat colour

Meat colour is an important meat quality trait that is partly related to muscle energy metabolism, ultimate pH, and processing or storage conditions of meat (Ouhayoun, Dalle Zotte, 1996). Colour of meat is dependent on pigment content (myoglobin and haemoglobin), which is reliant on breed, age (Pla, 2008), as well as on *ante* and *post mortem* conditions. Nutrition is one of the parameters which can affect meat colour parameters – L* (lightness), a* (redness), and b* (yellowness). These parameters also depend on the type of muscles where the colour is measured in rabbits. *Biceps femoris* is more oxidative than *Longissimus lumborum* and has higher values for redness and chroma (C*) parameters (Pla et al., 1995). Hernández et al. (1997) recommend to measure meat colour on muscle surface, because rabbit carcasses are usually sold whole, but most authors performed colour measurements on meat cuts. Only few authors investigated the effect of intensity of limited feed intake on rabbit meat colour parameters. Colour of *Biceps femoris* muscle examined Dalle Zotte et al. (2005a) and Gidenne et al. (2009). They did not determine differences in lightness, yellowness, and redness parameters between rabbits with various intensity of feed restriction and the *ad libitum* fed group. Gidenne et al. (2009) declared average of L*, a*, and b* parameters in the hind leg on 55.5, 2.83, and 3.1, respectively. Also length of restriction (5–8 vs. 5–11 weeks) did not affect lightness, yellowness, and redness of the *Biceps femoris* muscle (Dalle Zotte et al., 2005a). Likewise Tůmová et al. (2006) did not register differences in colour of the loin in rabbits with various duration of feed restriction (1 vs. 3 weeks). Some authors studied effect of energy restriction on rabbit meat colour. Dalle Zotte, Ouhayoun (1998) did not observe differences in colour parameters between rabbits with low energy intake and *ad libitum* fed group. However, Metzger et al. (2009), who applied energy restriction, stated significantly lower values of a* and b* parameters in loin in energy restricted rabbits than in the control group (2.21 and 0.23 vs. 3.35 and 0.91). However, L* parameter was not influenced by feeding technique. Carrilho et al. (2009) found significantly lower lightness of *musculus Longissimus dorsi* in rabbits with low fibre content in diet (14.28%) than in medium (18.04%) or high (20.48%) fibre content in diet taken for three weeks after weaning. According to published results, quantitative restriction of feed only moderately affects meat colour in rabbits. The influence of qualitative restriction on colour of meat is not quite clear, because this issue was studied only by few authors.

Feed restriction and pH value

The pH value affects the sensory qualities of meat – water holding capacity, colour, and tenderness. Immediately after slaughtering the pH value is near neutral, and within few hours it drops to a stable value, so-called ultimate pH (pHu). The ultimate pH value of meat is influenced by the glycogen stores in muscle at the moment of slaughtering and in rabbits usually lies between 5.3 and 6 (Hulot, Ouhayoun, 1999). The reason for the pH decreasing is an accumulation of lactic acid in muscles, which comes from degradation of glycogen.

The pH of meat is mainly influenced by the composition of muscle (glycolytic and oxidative fibres).

Musculus Biceps femoris has higher oxidative metabolism and lower glycolytical potential, i.e. it has higher pH value than *musculus Longissimus dorsi* (Dalle Zotte et al., 1996; Pla et al., 1998; Hulot, Ouhayoun, 1999). Hernández et al. (1998, 2000) investigated the correlation between parameters of meat quality. They observed high positive correlation between pH of *musculus Longissimus dorsi* and that of *Biceps femoris*. It has been shown that feed restriction promotes oxidative metabolism of muscle fibres (Metzger et al., 2009).

As mentioned above, feed restriction influences muscle fibre characteristics. Together with the change of the ratio of different types muscle fibres the pH value can also be altered. Many authors have examined the effect of feed restriction on the pH value. According to Dalle Zotte, Ouhayoun (1995) restricted rabbits had significantly higher muscle pH value compared to the *ad libitum* fed rabbits. Perrier, Ouhayoun (1996) found differences between various rationing plans on average pH ultimate value. They observed significantly lowest ultimate pH of the thigh muscles (5.73) in rabbits with restriction on 70–90%, groups restricted on 80% and on 90–70% of ADL did not mutually differ and the authors assume that improvement of the muscular glycolytic metabolic pathway as the reason. However, Dalle Zotte et al. (2005a) did not find the effect of feed restriction intensity on the pH value but presented that pH value depends on length of restriction. Authors indicated significantly lower pHu in rabbits with longer period of restriction (between 5–11 weeks of age) than in rabbits with restriction between 5–8 weeks of age (5.70 vs. 5.89, respectively). Likewise Tůmová et al. (2006) determined the pH 3 h *post mortem* and values of pH were higher in rabbits with limited feed intake for 3 weeks and in group restricted between 56–63 days of age than in rabbits restricted earlier or *ad libitum* fed. But pH value measured 24 h *post mortem* did not show any differences between groups. The ultimate pH of meat is mainly influenced by the glycogen stores in muscle at the moment of slaughtering. This is related to fibre composition of muscle and *ante mortem* factors that can lead to a depletion of glycogen stores in muscles. Restricted feeding could favour the oxidative metabolism pathway, as evidenced by the higher percentage of oxidative fibres in muscles of feed restricted compared to *ad libitum* fed animals (Metzger et al., 2009). Decrease in the ultimate pH of meat, published by some authors, may be due to stimulation of glycolytic pathway of muscle energy metabolism (Ouhayoun, 2003).

Some authors examined effect of energy or qualitative restriction on pH value. Ouhayoun, Dalle Zotte (1996) found decrease of pH value in rabbits with less energy component in feed and the *Biceps femoris* muscle of rabbits had a slightly higher pH (5.70) than the *musculus Longissimus lumborum* (5.51). This result is in contrast with Dalle Zotte, Ouhayoun (1998), who did not observe differences between rabbits with energy restriction and *ad libitum* fed rabbits in *Biceps femoris*. Metzger et al. (2009) applied energy restriction between weeks 4–12 of age and detected that restricted rabbits had got higher pHu value of the *Longissimus lumborum* than the *ad libitum* fed rabbits (5.87 vs. 5.73). Higher pH value in *Biceps femoris* than in *Longissimus lumborum* corresponds to a more oxidizable muscle in thigh. Lower pH value could be probably because of a balance in the metabolism of energy favouring the glycolytic pathway (Perrier, Ouhayoun, 1996).

CONCLUSION

Feed restriction has a positive effect on the health status of rabbits after weaning, but it can also affect the rabbit meat quality. The impact of feed restriction depends on the duration, intensity, and time of its application. If the limited feed intake is more intensive or longer, then it is harder for rabbits to reach full growth compensation. Strict limiting of feed negatively affects dressing percentage, proportion of thighs and loin from carcass, and meat to bone ratio. On the other hand, positive influence was observed in the amount of fat. There were published higher water and lower lipid contents in restricted rabbits, but fatty acids and protein contents have not been observed by any authors. Quantitatively feed restriction decreases cross-sectional area of muscle fibres and affects mainly βR and αW muscle fibres. Feed restriction also affects muscle fibre characteristics, it can change the percentage of oxidative fibres and it leads to higher pH value. On the other hand, quantitatively feed restriction only moderately influences meat colour.

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