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Effect of weaning age upon the slaughter and physicochemical traits of rabbit meat

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ABSTRACT

The effect of the weaning age of rabbits on slaughter traits and physicochemical properties of meat was investigated. Sixteen New Zealand White rabbits (*Oryctolagus cuniculus*) were used, divided in two groups: group A (n = 8) - weaned at the age of 21 days (early weaned) and group B (n = 8) - weaned at the age of 35 days (normally weaned). The animals were fed with two categories of pelleted feed: for weaned rabbits up to 50 days of age and for growing rabbits older than 50 days of age. It was established that the early weaning of rabbits resulted in a statistically significantly lower body mass, dressed carcass weight and dressing percentage as compared to normally weaned animals. Also, the pH of meat by the 24th hour after slaughtering and the dry matter of m. longissimus lumborum (LL) were significantly lower in group A. Simultaneously, a statistically significantly higher water-holding capacity, water content and lightness were established in the meat of early weaned compared to normally weaned rabbits. The protein and fat contents of LL and m. semimembranosus (SM) in rabbits from group A correlated negatively and significantly with water content, and positively with the dry matter. In group B, water content also correlated significantly and negatively with protein content. Fat and ash in SM meat was in a positive statistically significant relationship for both experimental groups. The results from the present study showed that the weaning age influenced both the slaughter traits and physicochemical properties of rabbit meat.

Key words: early weaned rabbits, body mass, dressing percentage, physicochemical properties, meat

Introduction

The increased extent of rabbit breeding for meat over the last 20 years, including in Bulgaria, necessitates additional, up to date information and critical appraisal of current

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recommendations for nutrition, rearing and health care from the point of view of higher productivity. A considerable amount of human resources are being spent on extensive investigations into the influence of various factors (genetic, physiological, related to diet etc.) on the growth, development, productivity and meat quality in rabbits (MENDEZ et al., 1986; XICCATO, 1999; ZITA et al., 2007; MAERTENS et al., 2008; OUYED and BRUM, 2008).

The annual production of rabbit meat in Europe is estimated at about 500 thousand tones, which represents 30% of the world production (PETRACCI et al., 2009). Rabbit meat production in Bulgaria is 47.4 tons per year (DIMITROVA et al., 2008).

The transition from nursing to pelleted feed is related to considerable changes in the digestive tract physiology in early weaned rabbits (PADILHA et al., 1995; PIATTONI et al., 1995; KOVĂCS et al., 2008). These changes are influenced to a greater extent by the different feed type rather than by weaning itself (PIATTONI et al., 1997). Some authors believe that the digestive enzymes of rabbits weaned between the 30th and 35th day of age are not fully developed (GIDENNE and FORTUN-LAMOTHE, 2002) and some nutrients pass undigested through the intestine into the caecum, which the microflora has recently colonized after the age of 14 days. With age, the number of bacteria gradually increases and reaches a steady level at weaning (BENNEGADI et al., 2003).

The information about the efficacy of early weaning of rabbits is rather contradictory. It has been established that the body mass of early weaned rabbits is lower during fattening as compared to rabbits weaned at the age of 32 days (TROCINO et al., 2001). Others have demonstrated that early weaning resulted in an increased mortality rate of offspring of up to 53% (MENDEZ et al., 1986) and reduction of growth rate from 4% to 26% (MAERTENS et al., 1988; BARRETO and DE BLAS, 1993). The negative impact of early weaning on the live body mass of rabbits has also been reported by other investigators (FERGUSON et al., 1997; GALLOIS et al., 2004).

In contrast to these facts are data that early weaning has no effect on rabbit meat production (RAO et al., 1978), on body mass during fattening (PETERSEN et al., 1992; GIDENNE et al., 2004) and on meat quality (ZITA et al., 2007).

The purpose of the present experiment was to investigate the slaughter traits and physicochemical properties of rabbit meat with relation to the weaning age.

Materials and methods

The experimental procedure was approved by the Commission of Ethics at the Faculty of Veterinary Medicine of Trakia University. The experiment was carried out in the vivarium of the Animal Physiology Unit at Trakia University.

For this purpose, sixteen New Zealand White rabbits (provided by the Agricultural Institute, Stara Zagora) were divided into two groups: group A (n = 8) - weaned at the age

of 21 days (early weaned) and group B (n = 8) - weaned at the age of 35 days (normally weaned).

The animals were kept in a special facility equipped with metal cages sized 80/60/40 cm. At the beginning of the experiment, the rabbits were kept in groups of four per cage, with the advance of age in groups of three and after the age of 60 days -one pair per cage. A heating device and natural and artificial light sources were provided. The feeding was done with two categories of pelleted feed: for weaned rabbits up to 50 days of age and for growing rabbits older than 50 days of age, produced by Norex-Agro, Bulgaria (Table 1). Feed and water were provided ad libitum. The facility was cleaned on a daily basis by collection of faeces and washing with water.

Table 1. Ingredients and chemical composition of the diet of rabbits

Ingredients, %	For weaned rabbits	For growing rabbits
Barley	5.00	5.00
Calcium carbonate	0.20	0.50
Sodium chloride	0.40	0.40
Alfalfa hay	34.00	28.00
Oats	30.87	31.88
Wheat bran	20.00	20.00
Dicalcium phosphate	0.30	0.30
DL-methionine-99%	0.10	-
VMP ROCHE rabbits	0.40	0.30
Sunflower meal	5.00	13.00
Soybean meal	3.00	-
Mycofix +	0.10	-
Wafolin S	0.50	0.50
L-lysine 78%	0.08	0.10
Cycostat 66G	0.05	-
Thyme	-	0.03
Chemical composition, %*		
Dry matter	88.87	88.98
Crude protein	16.18	16.63
Fat	3.46	3.40
Crude fibre	15.16	15.40
Ash	6.91	5.20

* Calculated

At the age of 90 days the rabbits were weighed and slaughtered as per the recommendations of the Committee for Animal Experimentation at the Faculty of Veterinary Medicine. After slaughtering and removal of viscera, the carcasses with the heads were individually weighed.

During carcass processing, samples from m. longissimus lumborum (LL) and m. semimembranosus (SM) were collected from each animal. Muscle samples were cooled and stored at 2 °C for 24 h for evaluation of the qualitative traits of meat.

Then meat pH was determined by means of a Consort C532 pH meter with a combined penetration electrode for analysis of meat. Prior to work, the pH meter was calibrated with standard solutions at pH 4.0 and pH 7.0. The pH values of m. longissimus lumborum were determined at the level of the 7th thoracic vertebrae and those of m. semimembranosus in its middle third.

The water-holding capacity of muscles was determined by the technique of GRAU and HAMM (1953).

The determination of total protein, fat, water (moisture) and mineral content (ash) was done by the classical methods for general chemical analysis (VASHIN et al., 1999) in cooled samples.

The colour of the meat was evaluated on transverse cross sections of both muscles at the 24th hour post mortem by a colorimeter (Lovibond Introduction SP60, USA) by means of coordinates L* (lightness, white colour), a* (redness) and b* (yellowness), previously calibrated by standard images for black and white.

The statistical processing of the data was performed by ANOVA (Statistica v. 6.1, StatSoft Inc., USA, 2002). All data were presented as mean values ± standard error of the mean (mean ± SEM) and tested for normality by the Smirnov test. The statistical significance of differences between groups was determined by the LSD-test of the Post Hoc comparison of ANOVA. Three levels of significance were considered: $P<0.05$; $P<0.01$ and $P<0.001$. The Pearson test was used for the determination of correlation coefficients between parameters.

Results

The slaughter traits of rabbits from both groups are presented on Fig. 1. By the end of the study period (age of 90 days) body mass averaged 2450 ± 38 g in group A and 2979 ± 100 g in group B ($P<0.001$). Dressed carcasses with heads weighed 1248 ± 26 g in group A and 1594 ± 59 g in group B ($P<0.001$). The average dressing percentage in early weaned rabbits was estimated at 50.9 ± 0.67 %, whereas for normally weaned animals it was 53.48 ± 0.33% ($P<0.01$).

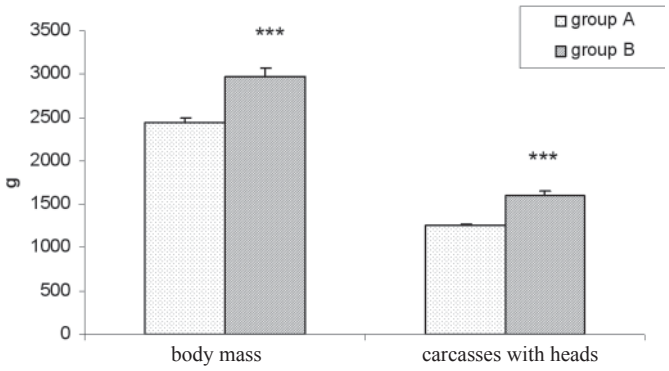

Fig. 1. Live body mass and weight of dressed carcasses with heads in early weaned (group A) and normally weaned (group B) rabbits

Table 2. Physico-chemical parameters of m. longissimus lumborum (LL) and m. semimembranosus (SM) in early weaned rabbits (group A) and in normally weaned rabbits (group B)

	LL			SM		
Parameters	A	B	P value	A	B	P value
Water, %	73.48 ± 0.55	70.79 ± 0.76	<0.05	75.35 ± 0.74	73.66 ± 0.74	NS
Protein, %	22.15 ± 0.36	24.40 ± 0.66	NS	21.46 ± 0.63	22.48 ± 0.58	NS
Fat, %	3.38 ± 0.30	3.61 ± 0.37	NS	2.20 ± 0.16	2.68 ± 0.25	NS
Dry matter, %	26.60 ± 0.55	29.21 ± 0.76	<0.05	24.74 ± 0.75	26.36 ± 0.75	NS
Ash, %	1.09 ± 0.09	1.21 ± 0.04	NS	1.08 ± 0.06	1.26 ± 0.07	NS
pH/24h	5.49 ± 0.08	5.77 ± 0.05	<0.05	5.65 ± 0.10	5.83 ± 0.09	NS
WHC, %	33.04 ± 0.77	16.89 ± 1.02	<0.001	29.92 ± 1.13	33.17 ± 1.19	<0.05
Lightness (L*)	61.75 ± 0.62	57.24 ± 0.48	<0.001	56.34 ± 0.46	51.92 ± 0.61	<0.001
Redness (a*)	-2.00 ± 0.31	-1.03 ± 0.26	NS	0.31 ± 0.26	0.90 ± 0.24	NS
Yellowness (b*)	9.03 ± 0.31	8.63 ± 0.21	NS	5.89 ± 0.39	6.75 ± 0.35	NS

Means ± SEM; NS: Not significant.

The physicochemical parameters of meat from early and normally weaned rabbits are shown in Table 2. More significant changes occurred in LL values as compared to SM values. The analysis of data showed that weaning age had a pronounced effect on water content, dry matter and water-holding capacity (WHC) of meat.

Table 3. Correlation coefficients between physico-chemical parameters in m. longissimus lumborum in early weaned rabbits (group A) and in normally weaned rabbits (group B)

	Early weaned (group A) LL		Normally weaned (group B) LL	
	water %	dry matter%	water %	dry matter%
Protein	r = - 0.78	r = 0.77	r = - 0.85	r = 0.85
	P<0.05	P<0.05	P<0.01	P<0.01
Crude fat	r = - 0.74	r = 0.76	r = - 0.51	r = 0.51
	P<0.05	P<0.05	NS	NS

NS: Not significant.

Table 4. Correlation coefficients between physico-chemical parameters in m. semimembranosus in early weaned rabbits (group A) and in normally weaned rabbits (group B).

	Early weaned (group A) SM			Normally weaned (group B) SM		
	water %	dry matter %	ash	water %	dry matter %	ash
Protein	r = - 0.97	r = 0.97		r = - 0.92	r = 0.92	
	P<0.001	P<0.001		P<0.001	P<0.001	
Crude fat	r = - 0.75	r = 0.75	r = 0.76	r = - 0.70	r = 0.69	r = 0.72
	P<0.05	P<0.05	P<0.05	NS	NS	P<0.05

NS: Not significant.

Water content of rabbit meat from group A was 73.48 ± 0.55 % and in group B it decreased to 70.79 ± 0.76% (P<0.05). A similar trend at a higher level of statistical significance (P<0.001) was observed in WHC values. At the same time, the opposite tendency was observed for meat dry matter, that averaged 26.60 ± 0.55% (group A) and increased to 29.21 ± 0.76% in group B (P<0.05).

It should be however noted that SM meat exhibited statistically significant differences only with regard to WHC (P<0.05) whereas the water content and dry matter of this muscle did not differ considerably between the groups.

The other parameters studied (protein, fat and ash) did not show statistically significant differences between two muscles. Regardless of that, higher values of all three parameters were determined in animals from group B.

The meat pH_{24} values were also influenced by the weaning age of the rabbits. The pH_{24} of LL meat was lower in early weaned rabbits: 5.49 ± 0.08 as compared to 5.77 ± 0.05 in those normally weaned (P<0.05). Statistically insignificantly lower pH_{24} values were measured in SM. For both groups, meat pH_{24} was within the reference range for this type of muscles.

Surface light reflectance values (L*) are important in the evaluation of meat colour. The lightness of LL meat in group A was 61.75 ± 0.62, and 57.24 ± 0.48 in group B ($P<0.001$). A similar pattern of change was observed for SM too ($P<0.001$). The intensity of the red and yellow colours of both muscles in the two experimental groups did not show any statistically significant differences.

Comparing data within groups, it was observed that in both groups, WHC and fat were statistically significantly higher (Table 2). There were no considerable variances between water, dry matter and protein contents of LL and SM in group A. However, in group B, protein ($P<0.05$) and dry matter ($P<0.01$) were statistically significantly higher in LL, and water content in SM ($P<0.01$). There were no important differences in pH and ash between the two groups of rabbits.

The regression analysis of data revealed the following relationships: in rabbits from group A, water content correlated negatively and significantly with protein and fat contents both in LL (Table 3) ($r = -0.78$, $P<0.05$ and $r = -0.75$, $P<0.05$ respectively), and SM (Table 4) ($r = -0.97$, $P<0.001$ and $r = -0.75$, $P<0.05$ respectively). Dry matter correlated positively and significantly with meat protein and fat with coefficients of correlations $r = 0.77$, $P<0.05$ and $r = 0.76$, $P<0.05$ respectively for LL and $r = 0.97$, $P<0.001$ and $r = 0.75$, $P<0.05$ respectively for SM.

In rabbits from group B there was also a negative significant relationship between water and protein contents ($r = -0.85$, $P<0.01$ for LL, and $r = -0.92$, $P<0.001$ for SM), whereas dry matter was positively correlated to protein content ($r = 0.85$, $P<0.01$ for LL and $r = 0.92$, $P<0.001$ for SM).

Another interesting finding was the statistically significant positive correlation between fat and ash content for only SM but not for LL in both groups A ($r = 0.76$, $P<0.05$) and B ($r = 0.72$, $P<0.05$).

Discussion

The combined effect of the different external and internal factors upon the development of rabbits after weaning is expressed by the differences between the body weights in the two groups of animals. At the age of 90 days, the average body mass of rabbits from group A was 2450 ± 38 g. In a similar experimental design with rabbits weaned at the age of either 35 or 90 days (VACHKOVA, 2008), the body mass gain in early weaned rabbits was positively and closely related to blood plasma total protein and triiodothyronine. In rabbits weaned at 90 days of age, this parameter correlated statistically significantly and positively with blood creatinine and total protein. By the end of the study period, the body mass of normally weaned rabbits attained 2979 ± 100 g. According to these data, the increase in body mass in normally weaned rabbits as compared to early weaned ones

is related to enhance buildup of muscle mass, and this way, hence the higher determined dressing percentage. In other studies of ours (VACHKOVA et al., 2010) we have shown that the body mass of rabbits weaned at 35 days of age and slaughtered at 95 days of age was statistically significantly higher than body weights of rabbits weaned at 21 days of age. In a study of the effect of weaning rabbits at the ages of 25, 28, 31 and 35 days, the highest dressing percentages (53.11% and 53.07%) were observed in rabbits weaned at 25 and 35 days of age respectively. Considerably lower values of this trait (50.89% and 52.67%) were observed in rabbits weaned at the ages of 28 and 31 days respectively (ZITA et al., 2007).

Our results confirm that early weaning resulted in reduced growth rate of rabbits and show the negative impact of early weaning upon the live body mass of animals at the end of the experimental period, as shown also by others (FERGUSON et al., 1997; GALLOIS et al., 2004; VACHKOVA et al., 2010). Although the growth rate of early weaned rabbits was relatively more intensive, they showed a delay with regard to the buildup of muscle mass as compared to normally weaned rabbits (VACHKOVA, 2008). Furthermore, due to the higher mucous surface, corresponding to a higher absorption potential and higher digestive capacity (GALLOIS et al., 2005), the animals from group B exhibited a higher degree of maturity and higher total body mass at the end of the trial.

The rate of meat pH_{24} reduction during the first hours after slaughtering the animals is essential for the organoleptic and technological properties of meat and for its durability. The pH_{24} values of m. longissimus lumborum in early weaned animals were statistically significantly lower compared to normally weaned ones. The decrease in pH_{24} correlates to the production of lactic acid. The rate of pH_{24} decrease is the highest in rabbits compared to other animals slaughtered for meat. This is attributed to the higher content of ATP/P in the muscles of these animals just prior to slaughtering. Compared to the muscles of other animal species, rabbit muscles contain less creatine phosphate (CP) which is extremely important for the resynthesis of ATP throughout the first stage of rigor mortis (HERNANDEZ, 2008). According to LAWRIE (1991) rabbit muscles contain more glucose (0.5 mg/g) than equine muscles (0.04 mg/g), due to the different activity of amylase, which is actively involved in the conversion of muscle glycogen into glucose and the post mortem conversion of glycogen into lactic acid. Numerous factors influence the rate of post mortem pH reduction: animal species, age, production and feeding technologies, pre-slaughter preparation, slaughtering, cold storage. Under the action of muscle glycolytic enzymes, muscle glycogen is metabolized to lactic acid and as a result, the pH_{24} of meat decreases. The pH_{24} values of the two muscles studied in both experimental groups in this study were within the reference range for this animal species. Similar data are reported for rabbit musculature and meat (HERNANDEZ and GONDRET, 2006). The insignificant differences in meat pH_{24} values in our study and in the study of TUMOVA et al. (2006) are

probably due to the age of weaning. It should be mentioned that the meat of the early weaned rabbits had a higher water content that, in our view, is also responsible for the lower meat pH_{24} in this group. A similar negative relationship between meat pH_{24} and the water-holding capacity of muscle proteins in various meat types is also reported by LAWRIE (1991).

The water-holding capacity of meat is an important quality trait determining the retention of tissue water, thus decreasing meat pH_{24}. This fact is confirmed by our results with the two experimental groups, where WHC and pH_{24} values correlated negatively. Evidently, this relationship was more significant in early weaned rabbits. On the other hand, in normally weaned rabbits there was a closer negative correlation between dry matter and water content. The higher dry matter and lower water content of meat in normally weaned rabbits could be attributed to the higher body mass and the higher weight of the dressed carcass with head. In our study, a negative relationship was established between the water and fat contents in normally weaned animals.

The weaning age of rabbits had a pronounced effect upon the contents of water, protein, fat and dry matter in both muscles studied. The positive effect of later weaning upon traits determining the nutritive value of rabbit meat should be emphasized. In normally weaned animals, the muscles contained insignificantly more protein, fat and ash. Comparing the fat contents in both muscles, the relatively higher content of intramuscular fat in LL compared to SM should be noted, probably due to the type of biochemical processes occurring in muscles at different topographic sites. The intramuscular fat content is extremely important for the quality of meat (HERNANDEZ, 2008), as it is responsible for organoleptic properties as juiciness and flavour, especially valuable for consumers. According to DALLE ZOTTE (2002) rabbit meat has fewer calories compared to other meat types because of the lower fat content. Our data about the LL fat content are within the wide range specified by HERNANDEZ and GONDER (2006): from 0.6 to 14.4%. GONDRET et al. (1998) investigated the effect of slaughter age of rabbits upon the chemical composition and sensory traits of LL, and found that intramuscular fat content increased from 1.3% at the age of 11 weeks to 2.2% at the age of 18 weeks.

It is acknowledged that the colour of meat is determined by the amount of myoglobin in muscle cells and is dependent on the gender, age, breed etc (VARNAM and SUTHERLAND, 1995). The L* values (lightness) showed that early weaned rabbits had statistically significantly ($P<0.001$) lighter meat as compared to normally weaned. A similar very significant difference between groups was also observed for m. semimembranosus. We believe that these differences are due to the higher water content of the meat from group A. The values of the other colorimetric coordinates: a* (redness) and b* (yellowness), did not show such relationships. The analysis showed that rabbit meat was whiter (L*) and less red (a*) than pork and beef meats (OLIVER et al., 1994).

The coefficients of correlation between LL and SM traits exhibited specific relationships. In rabbits from groups A and B, fat content was found to correlate statistically significantly with ash content, but only in SM. In both groups, the water content of LL and SM was linked closely and negatively with meat protein and dry matter, and significantly and positively with protein. It was also found that in early weaned rabbits, water content was also in reverse significant correlation with fat, whereas dry matter related proportionally to protein. Similar relationships were not found in group B and allowed us to assume that they could be attributed to the earlier weaning of rabbits and 14 days deprivation of doe's milk (from the 21st to the 35th day) as compared to normally weaned animals.

PLA et al. (2004) established positive correlations between the protein, fat and water contents of rabbit meat with the highest coefficient of correlations (about 1) between water and fat contents. By means of canonical correlation analysis, COMBES et al. (2008) investigated the relationships between the sensory and physiochemical traits of meat from rabbits from three different production systems and found strong correlations between physicochemical and sensory variables (R^2 = 0.73 and 0.68 between the two pairs of canonical variables).

In conclusion, the weaning age had an influence on the slaughter and physicochemical traits of rabbit meat. Our studies demonstrated that early weaning of rabbits resulted in statistically significantly lower body mass, dressed carcass weight, dressing percentage, pH of meat by the 24th h after slaughtering and meat dry matter as compared to normally weaned rabbits. At the same time, the meat of early weaned rabbits had statistically significantly higher water-holding capacity, water content and lightness. In rabbits weaned earlier, the protein and fat contents of both muscles studied correlated negatively to water content and positively to dry matter percentage. Normally weaned rabbits exhibited an inverse relationship between meat water and protein contents, whereas dry matter correlated positively to protein. In both groups, the fat and ash contents of m. semimembranosus were also positively correlated .

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SAŽETAK

Istražen je učinak dobi odbijanja od sise kunića na klaonička i fizikalnokemijska svojstva njihova mesa. Šesnaest novozelandskih bijelih kunića (*Oryctolagus cuniculus*) bilo je podijeljeno na dvije skupine: skupinu A (n = 8) - odbijenu u dobi od 21 dan (rano odbijanje) i skupinu B (n = 8) - odbijenu u dobi od 35 dana (normalno odbijanje). Kunići su bili hranjeni dvjema kategorijama peletirane hrane: za odbijene kuniće do dobi od 50 dana te za tovljene kuniće starije od 50 dana. Ustanovljeno je da rano odbijanje dovodi do statistički značajno manje tjelesne mase, manje mase obrađenog mesa i manjeg postotka obrađivanja u usporedbi s normalno odbijenim kunićima. Vrijednosti pH mesa 24 sata nakon klanja i suhe tvari najdužeg leđnog mišića bile su značajno manje u skupini A. Istodobno je statistički značajno veći kapacitet zadržavanja vode i veći sadržaj vode bio ustanovljen u mesu rano odbijenih kunića u odnosu na normalno odbijene. Sadržaj bjelančevina i masti u m. longissimus dorsi i m. semimembranosus (SM) u kunića skupine A bio je u negativnoj i značajno većoj korelaciji sa sadržajem vode i pozitivnoj sa suhom tvari. Sadržaj vode u skupini B također je bio u značajno većoj i negativnoj korelaciji sa sadržajem bjelančevina. Sadržaj masti i pepela u mesu semimembranoznog mišića bio je u pozitivnom statistički značajnom odnosu u obje pokusne skupine. Rezultati istraživanja pokazuju da dob odbijanja od sise utječe na klaoničku obradu i fizikalnokemijska svojstva kunićjeg mesa.

Ključne riječi: rano odbijeni kunići, tjelesna masa, postotak obradbe, fizikalnokemijska svojstva mesa