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EFFECT OF FLOOR TYPE ON CARCASS AND MEAT QUALITY OF PEN RAISED GROWING RABBITS

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Abstract: The aim of the experiment was to compare the carcass and meat quality traits of growing rabbits housed on different floor types. At the age of 35 d, rabbits (n=126) were randomly sorted into 3 groups and housed in pens with different floor types: plastic-mesh, deep-litter straw or wire-mesh. Slaughter weight, carcass and its parts' weight, meat (*Longissimus thoracis et lumborum* [LL] muscle and hind leg) pH and colour, oxidative status and fatty acid profile were measured and correlations calculated. The deep-litter straw rabbits showed the lowest pHu and b* values of LL muscle and oxidation of the both muscles. The fatty acid profile of LL muscle of deep-litter straw rabbits showed a higher percentage of monounsaturated fatty acids and long chain n-3 polyunsaturated (PUFA) fatty acids, whereas the content of C18:2*n*-6 and total PUFA was lower. We concluded that housing the growing rabbits on wire- or plastic-mesh floors showed no substantial differences, while housing rabbits on deep-litter negatively affected certain qualitative traits.

Key Words: floor type, growing rabbit, carcass traits, meat quality.

INTRODUCTION

In recent years, much attention has been paid to more rabbit welfare-friendly types of farming. Consequently, many scientific papers have been produced in order to assess the impact of new farming techniques on the welfare and productivity of breeding and fattening rabbits. Complete reviews on this topic have been published (Trocino and Xiccato, 2006; Szendrő and Dalle Zotte, 2011; Szendrő and McNitt, 2012). The authors concluded that there is an increasing demand for products originating from rabbits reared in nature-like environments, but the results have often conflicted because of the numerous variables involved (stocking density, group size, genotype, floor type, etc.).

There are recommendations suggesting group-housing of rabbit does and rearing growing rabbits in large groups, as well as certain regulations making these systems compulsory. In the rabbit industry wire-mesh floors are the most commonly used, but from an animal welfare standpoint, the floor is one of the most important technological elements, as the animals spend most of their time in close contact with it. In the first part of this trial (Gerencsér *et al.*, 2014) we investigated the effect of floor type (plastic-mesh, wire-mesh and deep-litter) on productive traits and behaviour of growing rabbits, observing no significant differences in mortality, feed intake and feed conversion ratio. Significant differences were instead recorded between the plastic-mesh and deep-litter groups for the average daily gain. Concerning behaviour, the least preferred floor was the deep-litter, regardless of the room temperature and the age of the rabbits. We concluded that housing rabbits on wire- or plastic-mesh floors showed no substantial differences, while housing rabbits on deep-litter negatively affected certain traits, but the alterations were smaller compared to the results in the relevant literature (Szendrő and Dalle Zotte, 2011). Considering that the floor strongly influences the

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behaviour of rabbits (Jekkel and Milisits, 2009) and consequently their locomotor activity, we considered it important to evaluate its effect on meat quality, with particular attention to the oxidative status and fatty acid profile. Indeed, to our knowledge, only few studies have demonstrated that rabbit muscles turn to a more oxidative metabolic pattern in response to motor activity, but no research was carried out in order to establish the correlation between floor type and meat oxidative status in rabbit. Gondret *et al.* (2009) showed that rabbit muscles have a clear oxidative adaptation to jump exercise, but no modifications were observed on lipid traits in fast-twitch muscles, or only minor modifications in slow-twitch muscles. Volek *et al.* (2014) observed that different stocking densities, and consequently different motor activity, modified fibre type distribution and histomorphological characteristics of the *biceps femoris* muscle of rabbits, with influence on lauric, myristic acid and docosahexaenoic acids. Thus, in this paper, which represents the second part of the aforementioned experiment (Gerencsér *et al.*, 2014), the meat quality traits, with particular attention to the oxidative status of growing rabbits, were examined depending on the different floor types (plastic-mesh, wire-mesh and deep-litter).

MATERIAL AND METHODS

Animals, housing and diets

The experiment was performed at Kaposvár University (Hungary) using the maternal line of the Pannon breeding programme (Matics *et al.*, 2014a). At the age of 35 d, 126 rabbits (sex ratio 1/1) were randomly sorted to 3 groups and housed in 9 pens with a basic area of 1.27 m^2. The floor type of pens was wire-mesh (WM), plastic-mesh (PM) or straw deep-litter (DL). Deep-litter was replaced weekly and fresh straw was provided daily. Daily lighting period was 16 h and the temperature ranged between 15-18°C. The rabbits were fed a commercial pellet *ad libitum* (5-9 wk of age: digestible energy [DE]=10.3 MJ/kg; crude protein [CP]=16.1%; ether extract [EE]=2.8%; crude fibre [CF]=16.9% and medication [1 ppm Clinacox {diclazuril}, 500 ppm OTC, 50 ppm Tiamulin]; 9-12 wk of age: DE=11.0 MJ/kg; CP=16.1%; EE=4.4%; CF=16.0%) with no medication. Water was available *ad libitum* from nipple drinkers.

Sampling and analyses

The rabbits were slaughtered at 84 d of age. The slaughter dissection procedures were performed according to the WRSA recommendation (Blasco and Ouhayoun, 1996). Rabbits were slaughtered by cutting the carotid arteries and jugular veins after electro-stunning. Rabbits were then bled and the skin, genitals, urinary bladder, gastrointestinal tract and the distal leg parts were removed. Warm carcasses (with head, set of organs consisting of thymus, trachea, oesophagus, lungs and heart, liver, kidneys, perirenal and scapular fat) were weighed, then chilled at +4°C for 24 h. After 24 h, the chilled carcasses (CC) were weighed. The head, set of organs, liver and kidneys were removed from each carcass to obtain the reference carcass (RC), which includes the meat, bones and fat depots. After that, the carcasses were cut between the 7^{th} and 8^{th} thoracic vertebra and between the 6^{th} and 7^{th} lumbar vertebra to obtain the fore, mid, and hind parts, which were weighed separately. *Longissimus thoracis et lumborum* (LL) muscle and meat on hind legs (HL) were dissected, and HL meat to bone ratio was calculated. The dressing out percentage (CC weight divided by live weight×100) and the ratio of the organs and carcass parts to either the CC or to the RC weight were calculated.

The pHu of the LL (measured between 6^{th} and 7^{th} lumbar vertebrae) and HL muscles (measured in *Biceps femoris*) was measured by Testo 205 pH meter.

The colour (calibration=D65; L*=lightness, a*=redness, b*=yellowness) of the right LL was measured on the fresh intersection surface of cross-section of LL (between the 6^{th} and 7^{th} lumbar vertebrae) using MINOLTA CR-300 chroma meter. The LL muscle of both sides and HL meat of randomly selected 15 rabbits per experimental group were individually packed in polyethylene bags. The deep-frozen meat samples were transported to the Department of Agricultural, Food and Environmental Sciences of University of Perugia (Italy) for meat related analysis.

The raw LL and HL meat was defrosted and ground; samples were analysed according to the AOAC (1995) methods to determine moisture (934.01) and ash (942.05), whereas protein content was determined according to the AOAC (1995) method, procedure 992.15.

Total lipid content of the meat was analysed using the chloroform/methanol (2:1) fat extraction method (Folch *et al.*, 1957).

The fatty acid composition was determined on lipids extracted from muscle samples. Total lipids were extracted in duplicate from 5 g of each homogenised sample and calculated gravimetrically (Folch *et al.*, 1957). Fatty acids were quantified as methyl esters (FAME) with a Mega 2 Carlo Erba gas chromatograph (model HRGC, Milano, Italy), using a D-B wax capillary column (0.25 mm Ø, 30 m long).

The FAME peaks were identified by comparing the retention time with the commercially available FAME standards. Individual fatty acid methyl esters were quantified using nonadecanoic acid (C19:0) methyl ester, added before extraction, as internal standard. The relative proportion of individual fatty acids was expressed as a percentage. The average amount of each fatty acid was used to calculate the sum of the total saturated (SFA), total monounsaturated (MUFA), and total polyunsaturated (PUFA) fatty acids.

Peroxidability index (PI) was calculated according to the equation proposed by Arakawa and Sagai (1986): PI=(% monoenoic×0.025)+(% dienoic×1)+(% trienoic×2)+(% tetraenoic×4)+(% pentaenoic×6)+(% hexaenoic×8).

The amount of each fatty acid was used to calculate the indexes of Atherogenicity (AI) and Thrombogenicity (TI), as proposed by Ulbricht and Southgate (1991) and the hypocholesterolaemic/hypercholesterolaemic ratio (HH), as suggested by Santos-Silva *et al.*, (2002):

AI=(C12:0+4×C14:0+C16:0)/[(MUFA+(n-6)+(n-3)];

TI=(C14:0+C16:0+C18:0)/[(0.5×MUFA+0.5×(n-6)+3×(n-3)+(n-3)/(n-6)];

HH=[(C18:1n-9+C18:2n-6+C20:4n-6+C18:3n-3+C20:5n-3+C22:5n-3+C22:6n-3)/(C14:0+C16:0)].

The α-Tocopherol level of meat was assessed according to Hewavitharana *et al.* (2004) with HPLC method (pump model Perkin Elmer series 200, equipped with an autosampler system, model AS 950-10, Tokyo, Japan) on an Ultrasphere ODS column (250×4,6 mm internal diameter, 5 µm particle size; CPS analitica, Milan, Italy). Tocopherols were identified using a FD detector (model Jasco, FP-1520) set at excitation and emission wavelength of 295 nm and 328 nm, respectively, and were quantified using external calibration curves prepared with increasing amounts of pure tocopherols in ethanol. Retinol was identified using a UV–VIS spectrophotometer detector (Jasco UV2075 Plus) set at λ 325 nm and quantified by comparing the sample with pure commercial standard in ethanol (Sigma-Aldrich, Steinheim, Germany; Extrasynthese, Genay, France).

The extent of muscle lipid oxidation was evaluated by a spectrophotometer set at 532 nm (Shimadzu Corporation UV-2550, Kyoto, Japan), according to the modified method of Ke, Ackman, Linke, and Nash (1977), which measured the absorbance of thiobarbituric acid-reactive substances (TBARS). Oxidation products were quantified as malondialdehyde equivalents (mg MDA/kg muscle) through a 1,1,3,3-tetraethoxypropane calibration curve.

Statistical analyses

Data were analysed using SAS 9.1 statistical analysis software for Windows (SAS, 2008). A one-way Anova tested the floor as fixed effect and pen as random effect on carcass and meat characteristics (ProcMixed). Predicted means were obtained and pairwise comparisons were performed using the Bonferroni test; the significance of differences ($P<0.05$) was evaluated by multiple t-tests.

RESULTS AND DISCUSSION

No significant differences were found for slaughter weight, warm carcass, reference carcass and carcass parts weight (Table 1).

Table 1: Effect of floor type on rabbit carcass traits.

	Floor type			SE
	Plastic-mesh	Deep litter	Wire-mesh	
No. rabbits	42	42	42	
Slaughter weight (SW), (g)	2731	2696	2765	19
Warm carcass, (g)	1674	1636	1684	13
Chilled carcass (CC), (g)	1629	1584	1633	13
Reference carcass (RC), (g)	1370	1330	1376	11
Chilled carcass yield, (%SW)	59.7[b]	58.7[a]	59.0[ab]	0.1
Head, (g)	139.0	135.7	140.9	0.9
Heart and lungs, (g)	23.7	24.0	23.8	0.3
Liver, (g)	75.6	78.6	75.3	1.0
Kidneys, (g)	16.3	16.3	17.4	0.2
Perirenal fat, (g)	19.6	19.2	19.5	0.8
Scapular fat, (g)	7.42	6.30	7.36	0.36
Fore part, (g)	427.8	407.7	427.8	4.0
Mid part, (g)	413.9	397.4	409.6	3.7
Hind part, (g)	503.2	499.2	512.0	3.7
M. Longissimus thoracis et *lumborum*, (g)	145.3	147.7	149.8	1.5
Right hind leg, (g)	237.2	232.0	238.2	1.7
Right hind leg meat, (g)	189.3	185.4	191.1	1.5
Hindleg meat/bone ratio	3.98	3.99	4.06	0.02
% CC				
Head	8.57	8.59	8.66	0.05
Heart and lungs	1.46	1.52	1.46	0.02
Liver	4.63[a]	4.97[b]	4.61[a]	0.05
Kidneys	1.01	1.03	1.07	0.01
Fore part	26.2[b]	25.7[a]	26.2[ab]	0.1
Mid part	25.4	25.1	25.1	0.1
Hind part	30.9[a]	31.5[b]	31.4[ab]	0.1
% RC				
Dissectible fat [1]	1.82	1.89	1.86	0.07
Fore part	31.2	30.7	31.1	0.1
Mid part	30.2	29.9	29.8	0.1
Hind part	36.8[a]	37.6[b]	37.3[ab]	0.1

[1] Sum of perirenal and interscapular fat.

SE: standard error.

[a b] means in the same row with the same superscript do not differ significantly ($P<0.05$).

Concerning chilled carcass yield, rabbits reared on plastic-mesh (PM) showed the highest values and those reared on deep-litter (DL) the lowest. The carcass dissection did not evidence particular differences between experimental groups, with the exception of the liver percentage, which was higher in the DL rabbits; concerning the percentage of the hind part, the highest value was observed in DL rabbits, the lowest in the PM and the intermediate in the WM ones.

Some comparisons were done between wire-mesh and steel-slat floors by Trocino *et al.* (2004), wire-mesh, steel-slat and plastic-slat floors by Trocino *et al.* (2008), wire-mesh and plastic-mesh floors by Dalle Zotte *et al.* (2009). In most cases no differences were found in carcass traits. Significant differences were only found in dressing out percentage and dissectible fat with higher values on wire-mesh, and in percentage of head and fore part with higher values on plastic-mesh by Trocino *et al.* (2008). In contrast to the above mentioned results, in the present experiment no differences were found between wire-mesh and plastic-mesh floors, which agrees with the results published by Trocino *et al.* (2004) and Dalle Zotte *et al.* (2009).

Significant differences were found in carcass traits when wire-mesh floor was compared with deep-litter floor (Szendrő and Dalle Zotte, 2011), however in these experiments not only the floor type but the size of cages or pens were different. Dal Bosco *et al.* (2002) compared the 2 floors (wire-mesh and deep-litter) when the size of pens was similar. In the latter experiment, the dressing out percentage, ratio of fore part and perirenal fat to reference carcass and meat-to-bone ratio were lower, and the carcass hind part was larger on deep-litter. In the present experiment, similar results in dressing out percentage and ratio of hind part were found. The reason of the slightly (not significant) lower slaughter weight observed in animals reared in DL pens could be connected with consumption of straw litter (Szendrő and Dalle Zotte, 2011). Jekkel *et al.* (2008) observed high straw consumption after placing straw litter into pens. The consumption of straw may reduce pellet intake, which results in lower weight gain and lower carcass traits (Dal Bosco *et al.*, 2002). In the present experiment, the effect of straw litter on productive traits was lower than in the previous trials (Szendrő and Dalle Zotte, 2011); this is why the differences in carcass traits between deep-litter and wire-mesh or plastic-mesh floors were low or non-significant.

Proximate composition of the 2 analysed muscles was little affected by treatment (Table 2). Only a significantly ($P<0.05$) lower lipid content was observed in LL and BF muscles of DL rabbits. Lipid content in both anatomical parts was in agreement with previous analyses on rabbits of the same genetic origin (Dalle Zotte *et al.*, 2014; Matics *et al.*, 2014b) and confirms the very lean meat in this rabbit line, probably due to CT-based genetic selection to improve meat production (Matics *et al.*, 2014a).

As for the physical characteristics of both muscles (Table 3), the DL rabbits showed the tendentially lowest pHu of both muscles and the lower b* value of LL muscle.

In our previous research (Dal Bosco *et al.*, 2002), the pHu value of rabbit reared on straw litter was significantly lower compared to that of rabbits reared on wire-net; the differences with the present study are probably related to the different genotype used.

DL rabbits showed lower TBARS value in both muscles. The retinol content in LL muscle was higher in PM and DP rabbits, whereas in HL it was higher in PM rabbits. For the tocopherol contents, the higher values were always observed in DL animals.

The fatty acid profile of LL muscle (Table 4) showed some differences between the groups: in DL and PM rabbits the percentage of MUFA was higher when compared with the WM group; in DL samples the content of long chain n-3 PUFA was higher, whereas that of C18:2n-6 and total PUFA was lower compared with PM and WM rabbits.

In BF muscle however, DL rabbits showed lower PUFA content. According to Enser (1999), when the lipid content of the muscle falls, the proportion of phospholipids in the total lipid rises and consequently the level was higher.

Concerning the fatty acid indexes, DL rabbits showed the higher peroxidability index (similar to that of WM rabbits in BF muscle); In LL muscle, DL rabbits showed higher peroxidability index with no differences among groups for AI

Table 2: Effect of the floor type on proximate composition (%) of rabbit meat.

	Floor type			
	Plastic mesh	Deep litter	Wire mesh	SE
M. Longissimus thoracis et *lumborum*				
Moisture	74.8	75.0	74.7	1.6
Protein	23.0	23.2	23.3	1.1
Lipids	0.74[b]	0.54[a]	0.73[b]	0.22
Ash	1.36	1.23	1.26	0.34
Hindleg meat				
Moisture	74.2	74.3	74.1	1.1
Protein	22.2	22.4	22.2	1.0
Lipids	2.31[b]	2.03[a]	2.44[b]	0.43
Ash	1.27	1.30	1.29	0.27

n: 15/treatment/muscle.

SE: standard error.

[a b] Means in the same row with the same superscript do not differ significantly ($P<0.05$).

Table 4: Effect of the floor type on major fatty acids (%) and nutritional indexes of rabbit meat.

	Floor type			
	Plastic mesh	Deep litter	Wire mesh	SE
M. Longissimus thoracis et *lumborum*				
SFA	34.2	34.5	35.3	1.8
MUFA	31.4[b]	31.6[b]	30.1[a]	0.6
C18:2n-6	24.9[b]	23.7[a]	25.3[b]	1.1
C20:4n-6	2.68[a]	3.02[b]	2.53[a]	0.32
C18:3n-3	3.60[b]	2.94[a]	3.50[b]	0.29
C20:3n-3	1.85	1.94	1.87	0.19
C20:5n-3	0.32[a]	0.66[b]	0.43[a]	0.08
C21:5n-3	0.11[a]	0.36[b]	0.19[a]	0.16
C22:5n-3	0.66[b]	0.68[b]	0.48[a]	0.14
C22:6n-3	0.24[a]	0.59[b]	0.35[ab]	0.08
PUFA	34.3[b]	33.8[a]	34.6[b]	5.4
Peroxidability index	55.8[a]	61.2[b]	56.3[a]	2.3
Atherogenicity index	0.52	0.54	0.52	0.09
Thrombogenicity index	0.68	0.72	0.71	0.14
HH ratio	2.30	2.14	2.17	0.29
M. Biceps femoris				
SFA	35.4[b]	33.6[ab]	33.0[a]	1.6
MUFA	28.9[a]	31.8[b]	31.7[ab]	1.1
C18:2n-6	26.5[b]	25.2[a]	25.5[a]	1.0
C20:4n-6	2.78	2.50	2.58	0.21
C18:3n-3	3.43	3.27	3.81	0.63
C20:3n-3	1.38[a]	1.66[b]	1.65[b]	0.18
C20:5n-3	0.42[ab]	0.56[b]	0.37[a]	0.09
C21:5n-3	0.08[a]	0.27[b]	0.18[ab]	0.11
C22:5n-3	0.87	0.75	0.77	0.17
C22:6n-3	0.19[a]	0.51[b]	0.48[b]	0.11
PUFA	35.7[b]	33.6[a]	36.4[b]	1.7
Peroxidability index	57.7[a]	59.4[b]	59.3[ab]	1.0
Atherogenicity index	0.51[b]	0.43[a]	0.47[ab]	0.09
Thrombogenicity index	0.73[b]	0.65[a]	0.63[a]	0.12
HH ratio	2.28	2.41	2.54	0.32

n: 15/treatment/muscle.

SE: standard error. SFA: total saturated fatty acids. MUFA: monounsaturated fatty acids. PUFA: polyunsaturated fatty acids. HH: hypocholesterolaemic/hypercholesterolaemic.

[a b] Means in the same row with the same superscript do not differ significantly ($P<0.05$).

CONCLUSIONS

Based on our findings, it could be concluded that housing the growing rabbits on wire- or plastic-mesh floors made no substantial differences to the rabbits' slaughter performance and meat quality. Housing the rabbits on deep-litter negatively affected certain traits, but the alterations were smaller compared to the available relevant results.

This study once again confirms the great variability of the results when rabbits are reared under alternative systems for the influence of many factors, such as the density and genotype but also floor and presence of straw litter.

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