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CARCASS TRAITS AND MEAT QUALITY OF GROWING RABBITS IN PENS WITH AND WITHOUT DIFFERENT MULTILEVEL PLATFORMS

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Abstract: The aim of this trial was to determine the effect of the presence of wire or plastic mesh elevated platforms on carcass traits and meat quality characteristics, with particular attention to the oxidative status of growing rabbits. A total of 174 five-week old rabbits were randomly divided into 3 groups with 2 replications (6 pens; 29 rabbits/pen): pens without platforms (NoP) with a stocking density of 16 rabbits/m^2 and pens with wire-mesh platforms (WP) or plastic-mesh platforms (PP) that were placed on 2 levels, with a stocking density of 16 rabbits/m^2 on the floor or 9.14 rabbits/m^2 when the platform were included. At 84 d rabbits were slaughtered. The slaughter traits and *Longissimus lumborum* (LL) physical and chemical compositition were not affected by treatments. Rabbits from the PP group showed the highest retinol and γ-tocotrienol content on LL muscle, whereas the NoP ones showed a higher α-tocotrienol and α-tocopherol level. The absence of platforms led to decreased (P<0.001) thiobarbituric acid-reactive substances values and induced an improvement in n-3 polyunsaturated fatty acids. Levels of linoleic, linolenic and docosahexaenoic acids were equal to those of the WP group (23.45, 3.75, 0.64% in NoP and 22.6, 4.14, 0.53% in WP, respectively) but higher than in PP rabbits (20.86, 3.05, 0.45%, respectively). It can be concluded that the pens with elevated platforms provide greater possibilities for movement, which is beneficial from the viewpoint of animal welfare. However, this greater activity influences the oxidative status of the meat, decreasing the antioxidant content and worsening the lipid oxidation of rabbit meat.

Key Words: platform, growing rabbit, carcass traits, meat quality.

INTRODUCTION

Improving welfare of growing rabbits involves improving housing conditions. In previous years, in some European countries (e.g. in Italy and Hungary) the common practice was to house growing rabbits in pairs in bicellular cages (Trocino and Xiccato, 2006). In most experiments, housing 2 rabbits per cage gave better growth performance than housing in larger groups (Trocino and Xiccato, 2006; Princz *et al.,* 2009; Szendrő and Dalle Zotte, 2011; Xiccato *et al.,* 2013), and a good health status was promoted (Verga *et al.,* 2007). On the other hand, according to the recommendations of the European Food and Safety Authority (EFSA, 2005) the benefits of group housing (3 or more rabbits per cage) have been emphasised because it allows expression of species-specific behaviour patterns (social contact, hopping, uprising position, stretching, etc.) and stereotypic behaviours (e.g. cage biting) may be prevented.

The effect of group size (cage *vs.* pen) on carcass traits and meat quality was investigated by Dal Bosco *et al.* (2002), Dalle Zotte *et al.* (2009), Lazzaroni *et al.* (2009) and Combes *et al.* (2010). It was clear that greater locomotor activity resulted in lower dressing out percentage (DoP), lower fat deposition and a decrease in the meat-to-bone ratio. There was no definite change in the intermediate part of the carcass while the fore part decreased a little and the hind part of animals housed in larger groups increased. Meat pHu values tended to decrease and the meat colour (L*) was

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lighter with increasing group size, although the effects of group size on redness (a*) and yellowness (b*) values were unclear. The meat of rabbits kept in large groups was leaner and contained more water, but neither protein content nor ash content was affected by the group size. The total amounts of polyunsaturated fatty acids (PUFA), n-6, n-3 and n-6/n-3 ratio increased in pen-housed rabbits (31.2 *vs.* 29.2, 28.1 *vs.* 26.0, 3.1 *vs.* 2.9% for PUFA, n-6 and n-3 respectively), where the stoking density was 10.2 rabbits/m^2, while monounsaturated fatty acids (MUFA) decreased compared to rabbits in cages (about 27 *vs.* 29%, 16.6 rabbits/m^2) (Dal Bosco *et al.,* 2002).

When the group size increases, the results are confounded by the simultaneous change in cage size. One way to increase group size with the same floor area and maintaining low stocking density is the use of elevated platforms. The usage of elevated platforms was also recommended as an environmental enrichment (de Jong *et al.,* 2008). Furthermore, the platforms promote locomotion (e.g. jumping) and give rabbits the chance to choose the more comfortable part of cage (on, under or in front of the platform) or to withdraw from their aggressive cage-mates. Nevertheless, elevated platforms are still a new element under investigations and results in reports should be more specific about their technical characteristics (size, material, height from the floor, number of levels). Until now, only a few papers have been published comparing the effect of different platform materials on productive performance and behaviour of growing rabbits (Lang and Hoy, 2011; Szendrő and McNitt *et al.,* 2012; Matics *et al.,* 2014b). The main conclusion of these studies was that wire-mesh floor promotes better hygienic conditions, whereas plastic-mesh floor was more comfortable. It is also necessary to consider that a platform could influence the locomotor activity and thus the oxidative status and fatty acid profile of meat (Dal Bosco *et al.,* 2015). To our knowledge, only a few studies have demonstrated that rabbit muscles turn to a more oxidative metabolic pattern in response to motor activity, but no research has been carried out to establish the correlation between the presence of a platform and oxidative status. Gondret *et al.* (2009) showed that rabbit muscles have an oxidative adaptation to jump exercise, but no modifications were observed in lipid traits in fast-twitch muscles and only minor modifications in slow-twitch muscles.

Thus, the aim of this trial was to verify the effect of the presence of wire- or plastic-mesh elevated platforms on the carcass traits and meat quality, with particular attention to the oxidative status of growing rabbits.

MATERIAL AND METHODS

The study was approved by the Institutional Animal Welfare Committee of Kaposvár University. All animals were handled according to the principles stated in the EC Directive 86/609/EEC on the protection of animals used for experimental and other scientific purposes.

Housing and experimental design

The experiment was conducted at the rabbit farm of Kaposvár University using the maternal line (Pannon Ka) growing rabbits from the Pannon Breeding Programme (Matics *et al.,* 2014a). The rabbits were housed in a room with temperature ranging between 15 and 18°C, humidity between 65-70%, and the lighting period was 16L:8D. The rabbits were fed *ad libitum* with commercial pelleted diets between 5 and 9 wk of age: 9.6 MJ digestible energy (DE)/kg, 16.1% crude protein (CP), 2.7% ether extract (EE), 18.5% crude fibre (CF), and medicated with 1 ppm of diclazuril, 500 ppm oxytetracycline and 50 ppm tiamulin. Between 9 and 11 wk the rabbits were given: 9.7 MJ DE/kg, 17.0% CP, 3.0% EE, 18.0% CF, without medication. Water was available throughout the trial from 5 nipple drinkers per pen.

A total of 174 rabbits of both sexes (1:1) were weaned at 5 wk of age. They were randomly divided into 3 groups (58 rabbits/group) and distributed into 6 pens (1000×1830 mm) with wire-mesh floors (29 rabbits/pen, 2 pens/treatment). The hole size and thickness of wire-mesh floor were 10.7×49.6 mm openings and 2.5 mm diameter wire. There were 2 pens per treatment with 29 rabbits per pen. The pens differed only in the presence or absence of platforms and the materials used to construct the platforms.

Pen without platform (NoP). The stocking density was 16 rabbits/m^2.

Pens with wire-mesh platforms (WP) (wire: 2.05 mm thick, hole size: 10.9×23.5 mm). The pens were equipped with seven elevated platforms that were placed along the perimeter on 2 levels (Figure 1 and 2a): 3 platforms on the first level (1 of 0.35 m^2 and 2 of 0.165 m^2 surface) inserted 25 cm above the floor, and 4 platforms on the

second level (each 0.165 m^2) placed 50 cm above the floor. The total area of the platforms was 1.34 m^2 (under the platforms 1.15 m^2 and the rest 0.68 m^2). Stocking density was 16 rabbits/m^2 and 9.14 rabbits/m^2 (when the platform areas were included).

Pens with plastic-mesh platforms (PP; Figure 2b) were equipped with the same plastic-mesh platforms with rhombic shape (4.5 mm thick, diagonal openings measuring 14.5×23 mm). The same stocking density as WP was used.

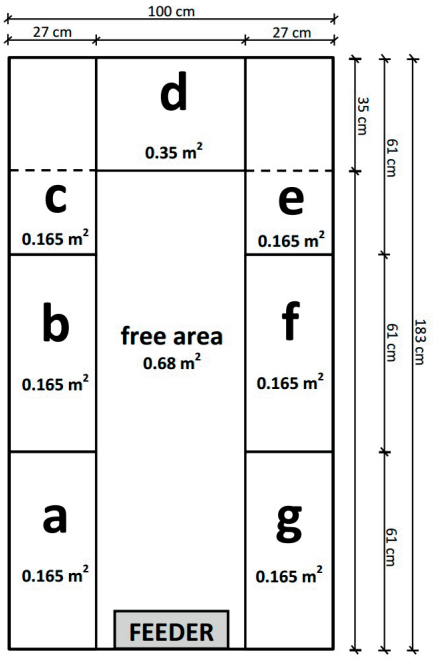

Figure 1: Layout of pens with elevated platforms (first level: b, d, f; second level: a, c, e, g).

Sampling and analysis

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 bled and the skin, genitals, urinary bladder, gastrointestinal tract and the distal part of legs 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 included the meat, bones and fat depots. The carcasses were then cut. between the 7th and 8th thoracic vertebra and between the 6th and 7th lumbar vertebra to obtain the fore, mid and hind parts, which were weighed separately. *Longissimus thoracis et lumborum* (LL) muscles and the meat on hind legs (HL) were dissected, and the 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 6th and 7th lumbar vertebrae) was measured by a Testo 205 pH meter (Testo Ltd, Newman Lane, Alton, Hampshire).

a b

Figure 2: Pen with wire-mesh platforms (a) and plastic-mesh platforms (b).

The colour (calibration=D65; L*=lightness, a*=redness, b*=yellowness) of the right LL was measured on the on the fresh cut surface of the cross-section of LL between the 6th and 7th lumbar vertebrae using MINOLTA CR-300 chroma meter. The LL muscle of both sides were randomly selected from 15 rabbits per experimental group and were individually packed in polyethylene bags. All meat samples were frozen at –80°C for 2 wk, then transported to the Department of Agricultural, Food and Environmental Sciences of University of Perugia (Italy), where the deep-frozen samples (–80°C) were analysed in the 5 subsequent days.

The raw LL meat was defrosted, ground, and samples were analysed according to the AOAC (1995) methods to determine moisture, ash and protein content.

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

The fatty acid composition was determined on lipids extracted from muscle samples. 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 the internal standard. The relative proportion of individual fatty acids was expressed as a percentage. Tocopherol (α-, γ(β)-, δ-tocopherol) and tocotrienol (α-, γ(β)-tocotrienol) levels of meat were 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 a Sinergy Hydro-RP column (4 µm, 4.6×100 mm; Phenomenex, Bologna, Italy). Tocopherols and tocotrienols were identified using a FD detector (model Jasco, FP- 1520) set at excitation and emission wavelengths of 295 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 *et al.* (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.

Preference test

24-h video recordings in the pens equipped with platforms (PP and WP) took place once a week, using infrared cameras (KPC-S50 NV, B/W CCD) and specialised software (GeoVision GV-800 System, Multicam Surveillance System 6.1.). The number of rabbits was counted every 30 min in the various locations in the pens: in front of the platforms, under the platforms and on the platforms (on the first and on the second levels). As the area of the different parts of the pen were different, the number of rabbits in each location could be dependent on the platform size. This is why the comparison of preference of rabbits was based on the animal density (rabbits/m^2). The 24-h observations were divided into four 6-h periods.

Statistical analyses

Data were analysed using SAS 9.1 statistical analysis software for Windows (SAS, 2008). ANOVA was used to test the platform preference as a fixed effect and pen as a 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.

Location preference among the parts of the pens (in front of the platforms, under the platforms, on the first or second level of the platform, and on the floor or on the platforms) was analysed with a chi-square test (procedure CAT-MOD/ STATA).

Table 1: Presence of rabbit (% of rabbit) in the different parts of cages.

		On the platform		
	On the floor	First level	Second level	χ^2
No platform	100[b]			
Wire-Mesh platforms	70.0[ay]	7.8 [ax]	22.2[x]	8.9
Plastic-Mesh platforms	60.1[ay]	15.5[bx]	24.4[x]	7.2
χ^2	15.2	6.2	3.0	

Means in the same column with unlike superscripts (a,b) differ (P<0.05).
Means in the same row with unlike superscripts (x,y) differ (P<0.05).

RESULTS

During the experimental period, and irrespective of the material of platforms, rabbits were observed more frequently on the floor than on the platforms (Table 1, P<0.05), however, the platforms were used roughly 30-40% of the time, respectively, in PP and WP.

No significant differences were found for slaughter weights or percentages, warm carcass, reference carcass and carcass parts weight (Tables 2 and 3).

Nor were the physical and chemical compositions of LL muscle affected by treatment (Tables 4 and 5).

The oxidative status and fatty acid profiles differed among the three experimental groups (Tables 6 and 7). Rabbits of PP group showed the highest retinol content (P<0.0001) in LL, as well as γ-tocotrienol (P<0.05), whereas the NoP ones showed a higher α-tocotrienol and α-tocopherol content (P<0.0001).

The extent of lipid oxidation was higher when the plastic platform was present (P<0.001) (TBARS 0.06 *vs.* 0.11 and 0.10 mg MDA/kg of meat, in NoP, PP and WP, respectively).

The fatty acid profile of LL muscle showed some differences between the groups; in particular, the absence of platform affected the fatty acids profile (P<0.05). C21:5 and C22:5n-3 and total n-3 polyunsaturated fatty acids,

Table 2: Effect of housing system of growing rabbits on carcass traits.

Traits	NoP	PP	WP	SE	*P*-value
n	46	53	47		
Body weight at slaughter (g)	2396	2427	2412	17	0.766
Warm carcass (g)	1447	1441	1438	11	0.946
Chilled carcass (g)	1411	1402	1402	10	0.930
Reference carcass (g)	1158	1153	1152	9	0.959
Head (g)	135	134	134	1	0.958
Set of organs (g)	19.8	20.7	20.2	0.3	0.417
Liver (g)	78.0	75.4	77.8	1.2	0.610
Kidneys (g)	15.3	14.6	15.0	0.2	0.337
Perirenal fat (g)	14.3	13.2	13.3	0.5	0.619
Scapular fat (g)	4.98	4.90	4.80	0.17	0.912
Fore part (g)	321	317	319	2	0.763
Mid part (g)	379	383	381	4	0.920
Hind part (g)	439	435	436	3	0.852
Hind legs (g)	422	414	416	3	0.471
HL (g)	305	304	303	2	0.943
MLL (g)	131	134	131	2	0.665

NoP: Pen without platform, PP: Pen with plastic-mesh platforms, WP: Pen with wire-mesh platforms. SE: standard error.
Set of organs: thymus, trachea, oesophagus, lungs and heart. HL: meat on hind leg, MLL: m. *longissimus lumborum.*

Table 3: Effect of housing system of growing rabbits on dressing out percentage and ratios of carcass parts to reference carcass.

Traits	NoP	PP	WP	SE	*P*-value
n	46	53	47		
Dressing out percentage					
Warm carcass	60.3	59.4	59.7	0.2	0.193
Chilled carcass	58.8	57.9	58.2	0.2	0.143
Reference carcass	48.3	47.6	47.8	0.2	0.283
% of reference carcass					
Fore part	27.8	27.5	27.7	0.1	0.576
Mid part	32.7	33.1	33.0	0.1	0.263
Hind part	38.0	37.8	37.9	0.1	0.712
Perirenal fat	1.17	1.12	1.06	0.04	0.561
Scapular fat	0.39	0.41	0.38	0.01	0.718
Meat-to-bone ratio	2.62	2.75	2.70	0.03	0.231

NoP: Pen without platform, PP: Pen with plastic-mesh platforms, WP: Pen with wire-mesh platforms, SE: standard error.

improving their proportion. Levels of C18:2n-6, C18:3n-3 and C22:6n-3 were equal to those of the WP group, but higher compared to PP.

DISCUSSION

As already mentioned, the results could be interpreted by the behaviour patterns of rabbits. A clear preference was observed for plastic-mesh platform (1.98 times higher density than that on WP) and for the the second level of platforms compared to the first one. Accordingly, the platforms increased the possibilities for growing rabbits to move even if they preferred staying on the floor. The preference of the rabbits for the plastic platforms rather than wire ones (de Jong *et al.,* 2008; Szendrő and Dalle Zotte, 2011; Rommers and de Jong 2011) may enhance locomotory activity (Dal Bosco *et al.,* 2015).

As shown in our previous experiments, rabbits like staying at a place covered by a solid platform (Dalle Zotte *et al.,* 2009; Matics *et al.,* 2014b), which is similar to the warren or vegetation (e.g. scrubs) for European wild rabbits (Lombardini *et al.,* 2003, 2007; Palomeras, 2003; Beja *et al.,* 2007). At the same time, rabbits stayed on the plastic-mesh platforms more frequently than on the wire-mesh ones, probably because the plastic-mesh floors are more comfortable for the growing rabbits (Princz *et al.,* 2009; Szendrő and McNitt *et al.,* 2012; Gerencsér *et al.,* 2014, Dal Bosco *et al.,* 2015).

In the present study, 3 factors could affect the productive traits: stocking density, which was lower in pens with platforms, the difference in kinetic activity between pens with and without platforms and the materials of the platforms (wire-mesh or plastic-mesh).

Table 4: Effect of housing system of growing rabbits on Longissimus lumborum physical characteristics.

Traits	NoP	PP	WP	SE	*P*-value
n	46	53	47		
pH	5.89	5.91	5.90	0.02	0.916
Colour					
L* value	77.9	80.4	79.0	0.8	0.418
a* value	–0.34	–2.07	–1.49	0.33	0.094
b* value	–12.6	–11.9	–11.9	0.15	0.166

NoP: Pen without platform, PP: Pen with plastic-mesh platforms, WP: Pen with wire-mesh platforms. SE: standard error.

Table 5: Effect of housing system of growing rabbits on Longissimus lumborum chemical composition (%) of growing rabbits.

Traits	NoP	PP	WP	SE	*P*-value
n	10	10	10		
Moisture	75.3	75.1	74.9	2.3	0.6354
Protein	22.9	23.0	23.2	1.8	0.5748
Lipids	0.68	0.58	0.65	0.18	0.3015
Ash	1.12	1.32	1.25	0.23	0.0856

NoP: Pen without platform, PP: Pen with plastic-mesh platforms, WP: Pen with wire-mesh platforms. SE: standard error.

In agreement with other authors (Trocino *et al.,* 2004, 2005; Jekkel *et al.,* 2006), the "actual" stocking density –due to the large use of platforms– did not modify the main carcass traits (dressing out percentage [DoP], ratio of carcass parts, fat deposits and meat-to-bone ratio).

When caged rabbits were compared to pen-raised rabbits, in most cases poorer DoP, lower fat deposition, a decrease in the meat-to-bone ratio and higher hind part were observed in larger groups (Dal Bosco *et al.,* 2002; Dalle Zotte *et al.,* 2009; Combes *et al.,* 2010), partly caused by the higher locomotor activity. In the present experiment the group sizes were the same, so only the elevated platforms could affect the locomotor activity of the rabbits. When Matics *et al.* (2014b) compared similar sized pens with and without platforms, they found no differences in carcass traits and meat quality (pH, colour, chemical composition). The possibilities for movement between pens with and without elevated platforms were more similar than between cages and pens, as previously mentioned. Thus, in the present experiment, differences in carcass traits, physical characteristics and chemical composition of meat were not observed, in agreement with Postollec *et al.* (2008).

The presence of platforms strongly affected the behaviour of rabbits and, in consequence, conditioned their physical activity. The main effects of platforms were on the oxidative status and the fatty acid profiles of meat. The higher kinetic activity increases free radical production (Fang *et al.,* 2002), which, in turn, alters the oxidative metabolism by increasing the pro-oxidant thrust and consequently the TBARS values (index of lipid peroxidation) (Dal Bosco *et al.,* 2015). NoP rabbits probably had a lower motor activity and this would have reduced the lipid oxidation and increased some bioactive compounds (α-tocotrienol, α-tocopherol and long chain n-3 fatty acids). Indeed, the higher PUFA level of this group could be due to the better oxidative status than in groups with platforms, as unsaturated fatty acids are easily oxidisable (Palmquist, 2009).

It appears that housing the growing rabbits in pens with platforms had no substantial effects on the slaughter performance, but worsened the fatty acid profile and oxidative status (α-tocopherol, TBARS) of meat.

Table 6: Effect of housing system of growing rabbits on *Longissimus lumborum* oxidative status.

Traits	NoP	PP	WP	SE	*P*-value
n	10	10	10		
Retinol (ng/g)	57.2^{A}	202.7^{B}	83.1^{A}	8.5	<0.0001
α-tocotrienol (ng/g)	44.7^{b}	22.3^{a}	35.4^{ab}	3.9	0.0267
γ-tocotrienol (ng/g)	11.9^{a}	24.7^{b}	13.4^{a}	1.4	0.0125
α-tocopherol (ng/g)	2734^{B}	1762^{A}	2137^{AB}	61	<0.0001
γ-tocopherol (ng/g)	15.6	13.5	15.5	2.7	0.4944
δ-tocopherol (ng/g)	8.23	9.06	7.14	0.75	0.7375
TBARS (mg MDA/kg)	0.06^{A}	0.11^{B}	0.10^{AB}	0.04	0.0001

NoP: Pen without platform, PP: Pen with plastic-mesh platforms, WP: Pen with wire-mesh platforms, SE: standard error, TBARS: thiobarbituric acid-reactive substances, MDA: malondialdehyde.
Means in the same row with unlike superscripts (a,b) differ ($P<0.05$).
Means in the same row with unlike superscripts (x, y) differ ($P<0.01$).
Means in the same row with unlike superscripts (A,B) differ ($P<0.0001$).

Table 7: Effect of housing system of growing rabbits on Longissimus lumborum fatty acids (%) profile.

Main fatty acids	NoP	PP	WP	SE	*P*-value
n	10	10	10		
C14:0	2.21	2.37	2.20	0.45	0.4881
C16:0	27.1^{x}	38.5^{y}	26.8^{x}	1.6	0.0055
C18:0	7.57	8.48	7.54	1.08	0.0550
C14:1Δ^{7c}	0.23	0.22	0.20	0.01	0.7118
C16:1Δ^{9c}	3.54	4.13	3.63	0.83	0.0972
C18:1Δ^{9c}	25.9	26.8	27.0	1.7	0.1640
C18:2$\Delta^{9c.12c}$ [n-6]	23.45^{B}	20.86^{A}	22.66^{AB}	1.88	0.0001
C18:3$\Delta^{9c.12c.15c}$ [n-3]	3.75^{y}	3.05^{x}	4.14^{y}	1.02	0.0069
C20:3$\Delta^{8c.11c.14c}$ [n-6]	0.25	0.13	0.16	0.02	0.0627
C20:4$\Delta^{5c.8c.11c.14c}$ [n-6]	3.59	3.79	3.78	0.42	0.3693
C20:5$\Delta^{8c.11c.14c.17c}$ [n-3]	0.62	0.53	0.51	0.15	0.1289
C21:5$\Delta^{6c.9c.12c.15c.18c}$ [n-3]	0.34^{y}	0.22^{x}	0.21^{x}	0.13	0.0052
C22:5$\Delta^{7c.10c.13c.16c.19c}$ [n-3]	0.30^{y}	0.15^{x}	0.17^{x}	0.12	0.0010
C22:6$\Delta^{4c.7c.10c.13c.16c.19c}$ [n-3]	0.64^{b}	0.45^{a}	0.53^{ab}	0.19	0.0185

NoP: Pen without platform, PP: Pen with plastic-mesh platforms, WP: Pen with wire-mesh platforms. SE: standard error.
Means in the same row with unlike superscripts (a,b) differ ($P<0.05$).
Means in the same row with unlike superscripts (x,y) differ ($P<0.01$).
Means in the same row with unlike superscripts (A,B) differ ($P<0.0001$).

However, some antioxidant compounds in meat, such as retinol and γ-tocotrienol, were higher in the PP group than in WP. The baseline levels of antioxidant molecules in this group were probably higher (Matics *et al.,* 2003; Princz *et al.,* 2009; Szendrő and McNitt *et al.,* 2012; Gerencsér *et al.,* 2014), but the greater movement due to jumps to the various floors (Gondret *et al.,* 2009) likely caused higher antioxidant molecule consumption, involved in radical chain reactions (Niki, 2010).

CONCLUSIONS

It can be concluded that rabbit pens enriched with platforms provide greater possibilities for movement, which is beneficial for animal welfare, without influencing the carcass traits, physical characteristics or chemical composition of meat. The greater motor activity of platform groups influences the oxidative status of the meat, slightly decreasing the antioxidant content and worsening lipid oxidation.

The absence of multilevel platforms leads to decreased lipid peroxidation and, as a result, improves the meat's lipid profile, as it preserves n-3 polyunsaturated fatty acids by oxidation and in turn promotes their storage in rabbit meat.

Further studies should be carried out to clarify the influence of genotype on movement and consequently on oxidative status, considering that each strain has a different metabolic adaptive response.

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REFERENCES

AOAC. 1995. Official Methods of Analysis. 15th ed. *Association of Official Analytical Chemists. Washington, DC. USA.*

Beja P., Pais M., Palma L. 2007. Rabbit *Oryctolagus cuniculus* habitats in Mediterranean scrubland: the role of scrub structure and composition. *Wildlife Biol., 13: 28-37. doi:10.2981/0909-6396(2007)13[28:ROCHIM]2.0.CO;2*

Blasco A., Ouhayoun J. 1996. Harmonization of criteria and terminology in rabbit meat research. Revised proposal. *World Rabbit Sci., 4: 93-99.*

CIE. Commission Internationale de l'Eclairage. 1976. *Official Recommendations on Uniform Colour Spaces, Colour Differences Equations and Metric Colour Terms. Supplement n. 2, CIE Publication n. 15. Colorimetry. Paris, France.*

Combes S., Postollec G., Cauquil L., Gidenne T. 2010. Influence of cage or pen housing on carcass traits and meat quality of rabbit. *Animal, 4: 295-302. doi:10.1017/S1751731109991030*

Dal Bosco A., Castellini C., Mugnai C. 2002. Rearing rabbits on a wire net floor or straw litter: behaviour, growth and meat qualitative traits. *Livest. Prod. Sci., 75: 149-156. doi:10.1016/S0301-6226(01)00307-4*

Dal Bosco A., Szendrő Zs., Matics Zs., Castellini C., Ruggeri S., Szendrő K., Gerencsér Zs. 2015. Effect of floor type on carcass and meat quality of pen raised growing rabbits. *World Rabbit Sci., 23: 19-26. doi:10.4995/wrs.2015.3270*

Dalle Zotte A., Princz Z., Metzger Sz., Szabó A., Radnai I., Biró-Németh E., Orova Z., Szendrő Zs. 2009. Response of fattening rabbits reared under different housing conditions. 2. Carcass and meat quality. *Livest. Sci., 122: 39-47. doi:10.1016/j.livsci.2008.07.021*

de Jong I., Reimert H., Rommers J. 2008. Effect of floor type on footpad injuries in does: a pilot study. *In Proc.: 9th World Rabbit Congress, June 10-13, 2008, Verona, Italy, 1171-1175.*

EFSA (European Food and Safety Authority). 2005. Scientific Report. The Impact of the Current Housing and Husbandry Systems on the Health and Welfare of Farmed Domestic Rabbit. *EFSA-Q-2004-023, pp. 1-137 (Annex to EFSA J. 267, 1-31).*

Fang Y.Z., Yang S., Wu G. 2002. Free radicals, antioxidants, and nutrition. *Nutrition, 18: 872-879. doi:10.1016/S0899-9007(02)00916-4*

Folch J., Lees M., Sloane-Stanley H. 1957. A simple method for the isolation and purification of total lipids from animal tissue. *J. Biol. Chem., 226: 497-509.*

Gerencsér Zs., Szendrő K., Szendrő Zs., Odermatt M., Radnai I., Nagy I., Dal Bosco A., Matics Zs. 2014. Effect of floor type on behaviour and productive performance of growing rabbits. *Livest. Sci., 165: 114-119. doi:10.1016/j.livsci.2014.04.022*

Gondret F., Hernandez P., Rémignon H., Combes S. 2009. Skeletal muscle adaptations and biomechanical properties of tendons in response to jump exercise in rabbits. *J. Anim. Sci., 87: 544-553. doi:10.2527/jas.2008-1286*

Hewavitharana A.K., Lanari M.C., Becu C. 2004. Simultaneous determination of vitamin E homologs in chicken meat by liquid chromatography with fluorescence detection. *J. Chromat., 1025: 313-317. doi:10.1016/j.chroma.2003.10.052*

Jekkel G., Milisits G., Bíróné Németh E., Radnai I., Matics Zs., Princz Z., Orova Z., Gerencsér Zs., Szendrő Zs. 2006. Effect of floor type and stocking density on the slaughter value of growing rabbits. *In Proc.: 18th Hungarian Conference on Rabbit Production, Kaposvár, Hungary, pp. 189-194.*

Ke P.J., Ackman R.G., Linke B.H., Nash D.M. 1977. Differential lipid oxidation products in various parts of frozen mackerel. *J. Food Technol., 12: 37-47. doi:10.1111/j.1365-2621.1977.tb00083.x*

Lang C., Hoy S. 2011. Investigations on the use of an elevated platform in group cages by growing rabbits. *World Rabbit Sci., 19: 95-101. doi:10.4995/wrs.2011.800*

Lazzaroni C., Biagini D., Lussiana C. 2009. Fatty acid composition of meat and perirenal fat in rabbits from two different rearing systems. *Meat Sci., 83: 135-139. doi:10.1016/j.meatsci.2009.04.011*

Lombardini L., Fernández N., Moreno S. 2007. Habitat use and spatial behaviour in the European rabbit in three Mediterranean environments. *Basic Appl. Ecol., 8: 453-463. doi:10.1016/j.baae.2006.09.004*

Lombardini L., Fernández N., Moreno S., Villafuerte R. 2003. Habitat-related differences in rabbit (*Oryctolagus cuniculus*) abundance, distribution and activity. *J. Mammal., 84: 26-36. doi:10.1644/1545-1542(2003)084%3C0026:HRDIRO%3E2.0.CO;2*

Matics Zs., Nagy I., Gerencsér Zs ., Radnai I., Gyovai P., Donkó T., Dalle Zotte A., Curik I., Szendrő Zs. 2014a. Pannon Breeding Program in rabbit at Kaposvár University. *World Rabbit Sci., 22: 287-300. doi:10.4995/wrs.2014.1511*

Matics Zs., Szendrő Zs., Odermatt M., Gerencsér Zs., Nagy I., Radnai I., Dalle Zotte A. 2014b. Effect of housing conditions on production, carcass and meat quality traits of growing rabbits. *Meat Sci., 96: 41-46. doi:10.1016/j.meatsci.2013.07.001*

Matics Zs., Szendrő Zs., Radnai I., Biró-Németh E., Gyovai M. 2003. Examination of free choice of rabbits among different cage-floors. *Agric. Consp. Scient., 68: 265-269.*

Niki E. 2010. Assessment of antioxidant capacity *in vitro* and *in vivo. Free Radical Bio. Med., 49: 503-515. doi:10.1016/j.freeradbiomed.2010.04.016*

Palmquist D.L. 2009. Omega-3 fatty acids in metabolism, health, and nutrition and for modified animal product foods. *Prof. Anim. Sci., 25: 207-249. doi:10.15232/S1080-7446(15)30713-0*

Palomeras F. 2003. Warren building by European rabbits (*Oryctolagus cuniculus*) in relation to cover availability in a sandy area. *J. Zool., 259: 63-67. doi:10.1017/S0952836902002960*

Postollec G., Boilletot E., Maurice R., Michel V. 2008. The effect of pen size and an enrichment structure (elevated platform) on the performances and the behaviour of fattening rabbits. *Anim. Welfare, 17: 53-59.*

Princz Z., Dalle Zotte A., Metzger Sz., Radnai I., Biró-Németh E., Orova Z., Szendrő Zs. 2009. Response of fattening rabbits reared under different housing conditions. Live performance and health status. *Livest. Sci., 121: 86-91. doi:10.1016/j.livsci.2008.05.018*

Rommers, J., de Jong, I. 2011. Technical Note: Plastic mats prevent footpad injuries in rabbit does. *World Rabbit Sci., 19: 233-237. doi:10.4995/wrs.2011.868*

SAS/STAT. 2008. *User's Guide, Version 6, Cary NC.*

Szendrő Zs., Dalle Zotte A. 2011. Effect of housing conditions on production and behaviour of growing meat rabbits: A review. *Livest. Sci., 137: 296-303. doi:10.1016/j.livsci.2010.11.012*

Szendrő Zs., McNitt J.I. 2012. Housing of rabbit does: group and individual systems: A review. *Livest. Sci., 150: 1-10. doi:10.1016/j.livsci.2012.09.017*

Trocino A., Xiccato G., Queaque P.I., Sartori A. 2004. Group housing of growing rabbits: Effect of stocking density and cage floor on performance, welfare, and meat quality. *In Proc.: 8th World Rabbit Congress, September 7-10, 2004, Puebla City, Mexico, 1277-1281.*

Trocino A., Carraro L., Fragkiadakis M., Xiccato G. 2005. Como la densidad y el tipo de suelo influyen en los rendimientos productions y el bienestar de conejos de engorde en jaulas colectivas. *In Proc.: 31rd Symposium de Cunicultura ASESCU, Lorca, Spain, pp. 45-55.*

Trocino A., Xiccato G. 2006. Animal welfare in reared rabbits: A review with emphasis on housing systems. *World Rabbit Sci., 14: 77-93. doi:10.4995/wrs.2006.553*

Verga M., Luzi F., Carenzi C. 2007. Effects of husbandry and management systems on physiology and behaviour of farmed and laboratory rabbits. *Horm. Behav., 52: 122-129. doi:10.1016/j.yhbeh.2007.03.024*

Xiccato G., Trocino A., Majolini D., Tazzoli M., Zuffellato A. 2013. Housing of growing rabbits in individual, bicellular and collective cages: growth performance, carcass traits and meat quality. *Animal, 7: 627-632. doi:10.1017/S175173111200198X*