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Growth performance, carcass characteristics and meat quality of growing rabbits housed in cages or open-air park

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Abstract

The study was carried out to investigate the effects of two housing systems on the growth performance, carcass traits, and meat quality of growing rabbits during the terminal fattening period. The rabbits were lodged in conventional cages between 35 and 59 days of age (growing period). At this age, they were moved into two different housing systems until they were 87 days of age (fattening period). During the fattening period, 48 rabbits were housed in 12 wire cages (0.5×0.6×0.35 m) and 48 rabbits were housed in one open-air pasture pen (20×9 m). At 87 days, 12 rabbits per treatment were slaughtered and the carcass characteristics and meat quality were evaluated. During the fattening period, the rabbits reared in cages had significantly higher live weights (3 062 vs. 2 705 g), weight gains (45.9 vs. 34.2 $g \cdot d^{-1}$) and feed intakes (163.4 vs. 110.2 $g \cdot d^{-1}$) than those reared in pens. The rabbits in the open-air group had a lower percentage of dissectible fat (1.35 vs. 4.19 %), a higher proportion of hind part (34.9 vs. 33.1 %), and less hind leg muscle (79.3 vs. 81.9 %) than caged rabbits. The *m. biceps femoris* of the rabbits in the open-air group had a higher cooking loss (3.64 vs. 3.02 %), Warner-Bratzler Shear Force (4.26 vs. 3.29 $kg \cdot cm^{-2}$), and myoglobin concentration (0.41 vs. 0.32 $mg \cdot g^{-1}$) than caged rabbits. The housing system had no effect on the dressing out percentage, viscera proportion, and ultimate pH. Open-air housing system reduces the growth of rabbits and the fat content of carcasses and increases the redness colour of meat.

Keywords: rabbit, growth, carcass, meat, housing system

Zusammenfassung

Mastleistung, Schlachtkörperqualität und Fleischqualität von wachsenden Kaninchen untergebracht in Drahtkäfigen oder Freilandkäfigen

Die Studie wurde durchgeführt um die Auswirkungen der Haltungssysteme in der Endmastperiode auf die Leistung, Schlachtleistung und Fleischqualität von wachsenden Kaninchen zu untersuchen. Die Kaninchen wurden in konventionellen Käfigen zwischen dem 35 bis 59 Lebenstag (Wachstumperiode) untergebracht, und ab diesem Alter bis zum 87 Lebenstag (Mastperiode) auf zwei verschiedene Haltungssysteme gehalten. In diesem Zeitraum wurden 48 Kaninchen in 12 Drahtkäfigen (0.5×0.6×0.35 m; 4 Kaninchen pro Käfig) und 48 Kaninchen in einem Freilandkäfig (20×9 m) untergebracht. Am Tag 87 wurden 12 Kaninchen pro Behandlung geschlachtet und die Schlachtkörperqualität und Fleischqualität gemessen. Während der Mastperiode zeigten Kaninchen in Drahtkäfigen ein höheres (P<0,05) Lebendgewicht (3 062 vs 2 705 g) und eine höhere Gewichtszunahme (45,9 vs 34,2 g·t^{-1}) als die in Freilandkäfige aufgezogene Tiere. Die in Freilandkäfige gehaltene Kaninchen hatten einen geringeren Prozentsatz des sezierten Fettes (1,35 vs 4,19 %), einen höherer Anteil des Hinterleib (34,9 vs 33,1 %) und die Hinterläufe hatten weniger Muskel (79,3 vs 81,9 %). Der *M. biceps femoris* an der Freilandkäfige gehaltene Kaninchen hatten einen höhere Kochverlust (3,64 vs 3,02 %), eine höhere Warner-Bratzler Scherkraft (4,26 vs 3,29 kg·cm^{-2}) und eine höhere Myoglobin Konzentration (0,41 vs 0,32 mg·g^{-1}). Das Haltungssystem hatte keinen Einfluss auf Ausbeute Prozentsatz, Eingeweideanteil und pHu. Freiland Käfighaltung reduziert das Wachstum von Kaninchen und Fettgehalt der Schlachtkörper und erhöht die Rötung des Fleisches.

Schlüsselwörter: Kaninchen, Wachstum, Schlachtkörper, Fleisch, Haltungssystem

Introduction

In recent years, consumer interest in specialty products derived from free-range or organic production systems has steadily increased in Europe and in other parts of the world. Customers who prefer rabbit specialty products have expectations of higher quality meats derived from these systems and higher standards of animal welfare. To meet these consumer expectations, several studies have examined alternative housing systems for fattening rabbits (Maertens & Van Oeckel 2001, Pla 2008, Jekkel *et al.* 2010). Cages with different sizes, different stocking densities and group sizes, pens with litter, open-air pens, and movable cages have been proposed, although in most cases there is little scientific evidence to support these options. Generally, extensive housing systems provide animals with more space and freedom of movement, which permits a broad range of behaviour patterns and better satisfies the natural and social needs of rabbits (Morisse *et al.* 1999). Consumers, scientists, and the food industry need concrete information on the effects of extensive housing systems on animal welfare as well as on meat quality and animal health. Verga (2000), Marai & Rashwan (2004) and Pinheiro & Mourão (2007) have reviewed the main results of the studies in this field.

Rabbit pasture pen housing systems provide more space and a more 'natural' environment than conventional cages. However, when rabbits are kept in pastures, they may come into contact with faeces, which can increase health problems, such as enteric diseases and coccidiosis, and reduce growth performance. In order to determine the feasibility of extensive housing systems, some alternative organic production systems for growing rabbits that involved movable cages were tested in small farms in Italy (Cavani *et al.* 2000) and France (Lebas 2001). In these studies, the rabbits were placed in movable cages that were provided with water and feed, and the cages were moved in the pastures.

Several studies have reported that housing systems can affect body weight, carcass traits and sometimes meat quality (Mertens & van Oeckel 2001, Pla 2008) and reproductive behaviour (Marai & Rashwan 2003). Housing systems with floor pens or colony cages seem to reduce stress and aggressive behaviour in animals (Mertens & van Oeckel 2000, Lebas 2001) but these systems increase mortality and decrease growth rates, feed intake, feed efficiency, and sometimes meat quality (Dal Bosco *et al.* 2000, Lambertini *et al.* 2001, Combes *et al.* 2003, McNitt *et al.* 2003). However, the studies on extensive housing systems have often been inconclusive due to the numerous variables involved (stocking density, group size, type of pen, and others).

The aim of this study was to examine the effects of housing systems (cages or open-air pens) on the growth performance of rabbits at the end of fattening period when the animals were between 59 and 87 days old. Moreover, the carcass characteristics and meat quality were compared.

Material and methods

Animals, housing treatments and diets

The study was carried out at the Experimental Rabbit Facilities of the Animal Production Department at the University of Trás-os-Montes e Alto Douro (UTAD) in Vila Real, Portugal. Hybrid rabbits of both sexes (New Zealand White×Californian) were housed under controlled conditions from 35 to 87 days of age (d).

The rabbits were divided into two groups and subjected to two housing treatments: a) cage treatment, where rabbits were housed in cages during the growing and fattening periods, and b) open-air treatment where rabbits were housed in cages during the growing period and in a pasture pen during the fattening period. All of the rabbits were fed *ad libitum* with commercial pellet feed (containing 92.2 % organic matter, 15.9 % crude protein, 25.2 % starch, 3.5 % crude fat, and 16.8 % acid detergent fibre [ADF]) and had free access to water. The animals in the open-air treatment group also had access to the natural pasture available in the pen during the growing period.

The study was divided into two periods: the growing period (35 to 59 d) and the fattening period (59 to 87 d). At 35 d the rabbits were sexed and tattooed for individual identification. In both periods, there were equal proportions of both sexes (half males and half females) housed in the cages or pens. During the growing period, 144 rabbits were lodged in 24 wire cages (cage dimensions: 0.5×0.6×0.35 m) with 6 animals/cage. The animals were lodged in a temperature-controlled building and were exposed to 12 h of light daily (8:00 to 20:00). During the fattening period, only 96 rabbits were used because the cages with high morbidity and mortality during the growing period were excluded. Forty-eight rabbits were reared under conditions similar to the growing period, but the number of animals per cage was reduced to 4 (12 cages). The second group of 48 rabbits was kept in one pasture pen (20×9 m) in a natural environment. The dominant species within the pasture hays in the Northeast region of Portugal are red fescue (*Festuca rubra L.*), creeping velvetgrass (*Holcus mollis L.*), common velvetgrass (*Holcus lanatus L.*), bristle bent (*Agrostis setacea Curtis*), perennial ryegrass (*Lolium perenne L.*), and smooth brome (*Bromus inermis Leyss*). Legumes are present at a low proportion (w/w) representing approximately 120 g/kg of species. The chemical composition of these hays is, on average (g per kg of hay), 8 crude protein, 70 neutral detergent fibre and 6 ash (Rodrigues et al. 2007).

Measurements

The individual body weights and feed intakes of the rabbits were recorded at 35 and 59 d, and then measured weekly to determine the daily weight gain and daily feed intake. The

pasture feed intake during the fattening period was not controlled. In this period, the deaths of rabbits were controlled for, and the mortality rate was determined.
At the end of the fattening period (87 d), 12 rabbits per treatment were slaughtered, and the carcasses were obtained and dissected in accordance with the norms of the World Rabbit Science Association (WRSA) (Blasco & Ouhayoun 1996). Carcasses with the head, liver, kidneys, and thoracic viscera (lungs, thymus, oesophagus, and heart) were suspended from the tendon calcaneus for 60 min in a ventilated area and then cooled at 3 °C for 24 h. The carcasses were then weighed to obtain the chilled carcass weight. The dressing out percentage (chilled carcass weight/live weight) was calculated. The drip loss percentage (DLP) was determined as the difference between the hot carcass weight and chilled carcass weight, relative to the hot carcass weight. The head, liver, kidneys, and thoracic viscera were removed and weighed to obtain the reference carcass weight. The perirenal and scapular fat (dissectible fat) of the carcass were removed and weighed. Next, the hind part was obtained by the technological division (Blasco & Ouhayoun 1996) and the bone and meat of the right hind legs were dissected, and the weights were recorded. The femur length and diameter were recorded, and the length of the femur was expressed as a function of the live weight. The head, liver, and reference carcass weights were expressed as a percentage of the chilled carcass weight. The hind part and dissectible fat weights were expressed as a percentage of the reference carcass weight. The meat to bone ratio of the hind leg was calculated as the ratio between the weights of the dissected meat and the bone.

The carcass and meat colours were measured at 24 h *post-mortem* in accordance Ouhayoun & Dalle Zotte (1996) using a Minolta CR-300 Chroma Meter (Minolta Camera, Osaka, Japan) in the CIELAB colour space: lightness (L*), redness (a*) and yellowness (b*). The carcass colour was determined on the surface of the left *m. biceps femoris*. The meat colour was measured on the transversal section of this muscle. The ultimate pH (pHu) was measured at slaughter and again 24 h *post-mortem* (pHu_{24h}) in the right *m. biceps femoris* by penetrating the muscle with a 5-mm glass pH electrode (pH 91, WTW, Weilheim, Germany).

The cooking loss (CL, %) was determined in the left *m. biceps femoris*. The meat samples were individually placed inside polyethylene bags in a water bath at 75 °C. The samples were heated to 70 °C (monitored with thermocouples placed in the core) and cooled for 30 min under running tap water. The samples were then dried with filter paper and weighed. The CL was expressed as the percentage of weight loss relative to the initial weight, according to the methods published by Silva *et al.* 1999. After measuring the CL, the samples were stored overnight in a refrigerator (4 °C). The tenderness of the samples was determined by measuring the Warner-Bratzler Shear Force (WBSF, $kg \cdot cm^{-2}$) after reaching room temperature. The WBSF was measured in sub-samples that were 1 cm^2 in cross section and 2.5 cm in length. The fibres were placed perpendicularly to the direction of the blade, driving at 100 $mm \cdot min^{-1}$, which was attached to a Stevens QTS 25 Texture Analyser (Stevens Advanced Weighing Systems Ltd., Great Dunmow, England). The myoglobin pigment concentration of the *m. biceps femoris* was measured according to the method proposed by Trout 1991, which is particularly suitable for meat with low pigment concentrations.

Statistical analysis

Data were analysed using analysis of valiance (ANOVA) procedures for continuous variables with the housing treatments as the factor. The means were compared using Tukey's test. Statistical significance was accepted at $P<0.05$, and the analyses were performed using JMP 5.0.1 (SAS Institute Inc., Cary, NC, USA).

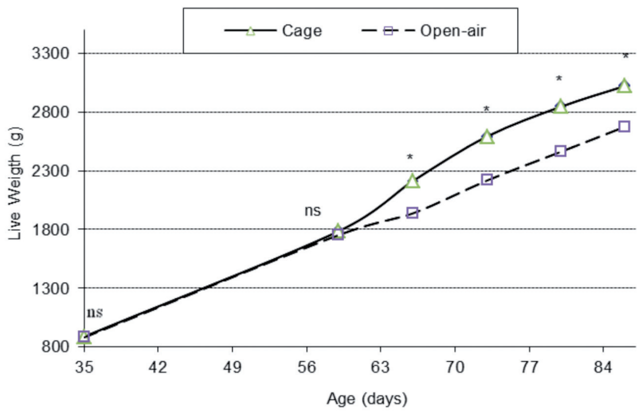
Results and discussion

Some limitations of the research unity reduced the capability to have large open air parks with available forages, allowing a higher number of rabbits. This fact determined an initial number of rabbits per treatment lower than what is commonly used in other assays, and might have influenced the significance of results obtained. Although, the results showed a general trend of housing system effects on growth performances, carcass characteristics and meat quality.

Growth performances

The sex of the rabbits did not influence the growth performance parameters, carcass characteristics and meat quality, confirming the observations of Oliveira & Lui (2006), who studied rabbits of a similar age. In the growing period, the mortality was not controlled. During the fattening period, two rabbits died that were housed in cages, and one died in the open-air pens. However, mortality was not statistically analysed due to the low number of deaths in the study.

The results of the growth trial are summarized in Table 1 and Figure 1. In the growing period, the two groups of rabbits were lodged in the same type of housing system and exposed to the same conditions, so there were no differences in live weight, feed intake, and daily weight gain between the two groups. The growth performance values were in agreement with those observed in previous trials conducted under similar conditions (Pinheiro *et al.* 2009).



ns: not significant, *$P<0.0001$

Figure 1
Effects of housing systems on the live weights of rabbits during the fattening period

Table 1
Effects of housing systems on rabbit growth performance

	Housing system		SEM
	Open-air[1]	Cages[1]	
Live weight, g			
at 35 d[2]	888	880	8.3
at 59 d	1 752	1 785	14.5
at 87 d	2 705[b]	3 062[a]	48.7
Weight gain, g·d^{-1}			
35-59 d[2]	36.0	37.7	1.2
59-66 d	26.4[b]	61.2[a]	1.9
66-73 d	39.9[b]	54.2[a]	1.1
73-80 d	35.0	36.2	1.2
80-87 d	35.3	29.6	1.5
59-87 d	34.2[b]	45.9[a]	0.8
Pellet feed intake, g·d^{-1}			
35-59 d[2]	121	124	3.7
59-87 d[3]	110	163	4

[1]n=48 per treatment for live weight and weight gain, n=12 per treatment for feed intake for 35-59 d, and n=1 per treatment for feed intake in open-air park [2]During days 35-59, all the rabbits were lodged in cages. [3]Statistical analysis was not done due to sample size in the open-air (n=1). [ab]Values with different letter in same line are significantly different (P<0.05).

In the fattening period (59 to 87 d), the rabbits reared in cages had a significantly higher final live weight (357 g or 13 % greater) than the open-air rabbits. In this period, the weight gain was also significantly higher in rabbits reared in cages, which is in accordance with the results observed by Lambertini *et al.* (2001) McNitt *et al.* (2003). The weight gain and feed intake of the caged rabbits were 34 % and 48 % higher than the rabbits in the open-air system, respectively. Probably, the intake of pasture in the open-air group, not determined in this essay, did not fully compensate for the reduction of pellet feed intake. Consequently, the nutrient intake and the weight gain were reduced (McNitt *et al.* 2003). Also Jekkel *et al.* (2010) found a decrease in the growth of rabbits housed in conventional systems, when compared with housing in different types of parks, but do not have observed effects in feed intake and conversion ratio. The reduction in feed intake in the outdoor rearing systems has been reported to play a role in lowering weight gains (Mertens & van Oeckel 2000). However, other factors associated with open-air pens also contribute to the negative effects observed on growth performance. In fact, open-air pens increase the energy maintenance requirements of rabbits, since they provide more space for animal movement, which increase locomotors activity (Mertens & van Oeckel 2000) and thermoregulation expenditures (Verga 2000). The available space had a negative effect on growth performance in a study where the size of a park was even lower than that of the pen used in the present study, as observed by Princz *et al.* (2008). The increased energy requirements combined with the decrease in feed intake might result in lower growth.

The treatments had no effects on the weight gains and live weights of the rabbits during the growing period when the housing systems were similar (Figure 1). However, when the open-air group was moved to the pasture pen, these rabbits experienced a significant decrease in weight gain (26.4 vs. 61.2; P<0.05). As time passed, the negative effects of the open-air treatment on growth were less evident, and after 73 days the weight gain was similar to that observed in the caged rabbits (Table 1). This change in weight gain could indicate that the animals experience adaptation problems in the new housing system, which contributes to the decreased growth performance.

Carcass characteristics

The effects of housing treatments on the carcass characteristics at 87 d are presented in Table 2. The caged rabbits had higher slaughter weights, reflecting their greater weight gain, as discussed previously, and higher hot and chilled carcass weights in comparison to the open-air group. The dressing out percentage in the caged rabbits was similar to that of the open-air rabbits, which confirms the findings of Mertens & van Oeckel (2001) and Dalle Zotte *et al.* (2008). However, Dal Bosco *et al.* (2000) and Metzger *et al.* (2003) observed that there were negative effects of the pens on the dressing out percentage. The lack of statistical significance in present study findings is probably due to the low number of rabbits studied.

Table 2
Effects of housing systems on rabbit carcass characteristics

	Housing system		SEM
	Open-air[1]	Cages[1]	
Slaughter live weight, g	2 717[b]	3 091[a]	47.5
Hot carcass, g	1 647[b]	1 901[a]	33.6
Chilled carcass, g	1 627[b]	1 879[a]	33.4
Dressing out percentage (DP)	59.9	60.7	0.32
Drip Loss Percentage (DLP)	1.20	1.15	0.09
Reference carcass			
weight, g	1 333[b]	1 490[a]	23
percentage of chilled carcass	81.96[a]	79.33[b]	0.33
Head, % chilled carcass	7.31	6.63	0.11
Liver, % chilled carcass	6.26	6.74	0.16
Kidneys, % chilled carcass	1.12	1.11	0.03
Heart and lungs, % chilled carcass	1.87	1.94	0.05
Dissectible fat, % reference carcass	1.66[b]	5.29[a]	0.41
Hind part, % reference carcass	34.94[a]	33.10[b]	0.24

[1]n=12 per treatment, [ab]Values with different letter in same line are significantly different (P<0.05).

In the present trial, the open-air rabbits had a higher reference carcass percentage, which is probably due to the decreased viscera weight, although this difference was not significant. The observed viscera weight in this study was greater than the weight previously reported by Pascual & Pla (2007), which is likely because these researchers studied younger and lighter rabbits, and age is known to affect the development of specific tissues and organs (Ouhayoun 1998).

The dissectible fat content in the carcasses of the rabbits in the open-air treatment was significantly lower (only 1/3) than that observed in the caged rabbits. Additionally, Dal Bosco *et al.* (2000) observed a lower lipid content in the carcasses of rabbits reared in open-air or indoor pens than in caged rabbits. Reductions in the energy available for growth and fat deposition likely contributed to this effect.

The open-air group had a higher proportion of the hind part (34.9 vs. 33.1; Table 2), less meat on the hind leg, a higher bone proportion, lower meat/bone ratio, and the femur had a larger diameter (Table 3). These effects are related to the increased exercise permitted in the open-air system, which has a larger available space. The results of this study are in accordance with those of Dal Bosco *et al.* (2000). In contrast, Metzger *et al.* (2003) did not observe any effects on muscles or the meat: bone ratios in the hind part when rabbits were lodged in a similar density in pens or cages.

Table 3
Effects of housing systems on rabbit hind leg characteristics

	Housing system		SEM
	Open-air[1]	Cages[1]	
Hind Leg			
meat, % hind leg	79.34[b]	81.94[a]	0.54
bone, % hind leg	19.07[a]	16.64[b]	0.45
meat/bone	4.20[b]	5.01[a]	0.14
Femur			
weight, g	14.48	14.52	0.26
length, mm	86.11	86.58	0.88
diameter, mm	7.23[a]	7.02[b]	0.05

[1]n=12 per treatment, [ab]Values with different letter in same line are significantly different ($P<0.05$).

Meat quality

The effects of the housing systems on the meat quality measured in the *m. biceps femoris* are shown in Table 4. The treatments had no effect on the meat pHu at slaughter or the pHu_{24h} in accordance with other authors (Pla *et al.* 1996, Pascual & Pla 2007 and Dalle Zotte *et al.* 2008). However, the results of this work differ from those of Metzger *et al.* (2003) since these researchers observed an increase in the meat pHu of rabbits reared in pens. This difference may be due to the differences in the sizes of the parks and the larger difference between the slaughter weights of the caged and open-air rabbits in the present study.

The carcasses of the open-air rabbits had a significantly lower lightness colour (L*) and the meat had a higher ($P<0.05$) redness colour (a*; 31 vs. –1.65), CL (3.64 vs. 3.02 %), WBSF (4.26 vs. 3.29 $kg{\cdot}cm^{-2}$), and amount of myoglobin pigment (0.41 vs. 0.32) than those kept in cages. The increase in the redness of the open-air rabbit meat can be explained by the fact that exercise increases the oxidative capacity of the muscle, which increases the proportion of oxidative myofibres (transition of type IIB to type IA fibres) and the myoglobin content (Monin & Ouali 1991). Dalle Zotte *et al.* (2003) and Pla (2008) also observed increases in meat redness, although their conditions differed from this study as previously mentioned.

The CL values observed were lower than those reported in other works (Pascual & Pla 2007), which is probably a result of the methodology used, namely the lower cooking time and temperature used. The CL was higher in the open-air rabbits (about 20 % more) than in the caged rabbits, which is probably due to the lower fat content and different maturity degree of the meat because of the lower growth rate (Lukefahr *et al.* 1983). The open-air treatment increased the WBSF. This results was in accordance with Pla (2008) but not with of Combes *et al.* (2003) and Metzger *et al.* (2003) who observed no effects of organic production on the WBSF of rabbit meat. In this study, the higher WBSF of open-air rabbit meat may be related with the higher cooking loss.

Table 4
Effects of housing systems on carcass meat quality (*m. biceps femoris*)

	Housing system		SEM
	Open-air[1]	Cages[1]	
pHu			
slaughter	6.96	7.04	0.05
24 h *post-mortem*	5.96	6.01	0.04
Δ	1.08	0.95	0.07
Carcass colour			
lightness, L*	50.72[b]	53.12[a]	0.50
redness, a*	3.73	3.66	0.42
yellowness, b*	5.22	4.98	0.46
Colour of *m. biceps femoris*			
lightness, L*	53.99	56.50	0.70
redness, a*	−0.31[a]	−1.65[b]	0.22
yellowness, b*	3.28	2.67	0.26
Cooking loss, %	3.64[a]	3.02[b]	1.52
WBSF, $kg \cdot cm^{-2}$	4.26[a]	3.29[b]	0.22
Myoglobin pigment, $mg \cdot g^{-1}$	0.41[a]	0.32[b]	0.02

[1]n=12 per treatment, [ab]Values with different letter in same line are significantly different ($P<0.05$).

Open-air rabbits had a meat with higher content of myoglobin and redness a* than those kept in cages. The relationship between the meat redness and the myoglobin concentration of the rabbit biceps femuris muscle is presented in Figure 2. The correlation was acceptable (r=0.64) and showed that increases in the myoglobin content were correlated with increases in the CIELAB a* values (increased meat redness). To date, there have been no studies on whether consumer decisions to eat rabbit meat are influenced by rabbit meat colour.

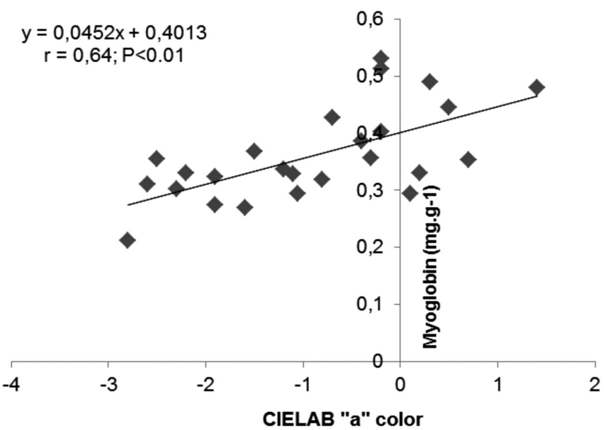


Figure 2
Relationship between meat colour (CIELAB redness, a*) and myoglobin concentration in biceps meat of rabbits housed in cages or the open-air system (n=24).

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