JOURNAL OF ANIMAL SCIENCE
The Premier Journal and Leading Source of New Knowledge and Perspective in Animal Science

Effect of genotype and rearing system on chicken behavior and muscle fiber characteristics

R. Branciari, C. Mugnai, R. Mammoli, D. Miraglia, D. Ranucci, A. Dal Bosco and C. Castellini

J Anim Sci 2009.87:4109-4117.
doi: 10.2527/jas.2009-2090 originally published online Aug 14, 2009;

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://jas.fass.org/cgi/content/full/87/12/4109

American Society of Animal Science
www.asas.org

Downloaded from jas.fass.org at Agraria Perugia on November 23, 2009.

Effect of genotype and rearing system on chicken behavior and muscle fiber characteristics[1]

R. Branciari,* C. Mugnai,† R. Mammoli,* D. Miraglia,* D. Ranucci,* A. Dal Bosco,†[2] and C. Castellini†

*Department of Biopathological Science and Hygiene of Animal and Food Production, University of Perugia, Via S. Costanzo, 4, 06126 Perugia, Italy; and †Department of Applied Biology, University of Perugia, Borgo 20 Giugno, 74, 06100 Perugia, Italy

ABSTRACT: The effect of the organic production system and genotype on chicken behavior and muscle fiber characteristics was assessed. Three hundred day-old male chicks from slow-growing (Leghorn), medium-growing (Kabir), and fast-growing (Ross 208) genotypes were assigned to 2 different production systems: conventional, housing in an indoor pen (0.12 m^2/bird); and organic, housing in an indoor pen (0.12 m^2/bird) with access to a grass paddock (4 m^2/bird). Behavioral observations were recorded from 73 to 80 d of age in the morning and afternoon. At 81 d of age, blood samples were collected to measure lactate dehydrogenase and creatine kinase, and 20 birds per strain and rearing system were slaughtered. Samples of pectoralis major, ileotibialis lateralis, and semimembranosus muscles were obtained for histological evaluations. Behavioral observations showed that genetic selection of animals for a better growth rate modified their behavior, reducing kinetic activity. Indeed, Leghorn birds were characterized by moving activities, whereas Kabir and Ross strains were discriminated on the basis of their lying, standing, and eating activities, and these activities were strongly associated with energy conservation, growth, and muscle fiber characteristics. Fiber characteristics and muscle enzyme functions were affected by rearing system only in animals adapted to the organic system. Interesting results relative to Leghorn chickens are the presence of α-Red fiber in breast muscle and the increased cross-sectional area of the ileotibialis lateralis muscle, which together with behavioral data could affirm that this genotype is the most adapted to the organic rearing system.

Key words: behavior, chicken genotype, muscle fiber, organic rearing system

©2009 American Society of Animal Science. All rights reserved.

J. Anim. Sci. 2009. 87:4109–4117
doi:10.2527/jas.2009-2090

INTRODUCTION

In recent years, animal welfare issues have influenced consumer acceptability of meat so that increasing numbers of people are willing to pay a higher price for a product if animals were reared extensively or, even better, organically (Sundrum, 2001). Animal welfare is complex to evaluate, but it can be partly characterized by the absence of abnormal behavior or behavioral problems (Dawkins, 2003; Ladewick, 2005; Macrae et al., 2006; Spinka, 2006; Watanabe, 2007). Moreover, the selection pressures that have resulted in altered behaviors are continuing and may result in further health problems to the detriment of welfare as leg disorders (Reiter and Bessei, 1998; Butterworth et al., 2002) and increased mortality (Havenstein et al., 1994).

As far as poultry is concerned, there are several strains with different behavioral patterns as well as different adaptability to varying rearing conditions (Schütz and Jensen, 2001; Castellini et al., 2002, 2008). For example, meat-type chickens are known to be less active than lighter-BW hybrids, especially as age increases (Weeks et al., 1994; Nielsen et al., 2003).

Organic rearing of poultry in accordance with the guidelines of European Economic Community Regulation 1804/1999 (European Economic Community, 1999) is perceived as being more respectful of animal welfare compared with intensive rearing because these regulations provide specifications for housing conditions, nutrition, breeding and animal care, disease prevention, and veterinary treatment. Nevertheless, not all breeds are well-adapted to organic rearing conditions; for example, modern meat-type birds, strongly selected for precocity and fast growing rates, do not benefit from extensive space. It is therefore important to determine

[1]The authors thank Giovanni Migni (Department of Applied Biology, University of Perugia, Perugia, Italy) and Stefania Diarena (Department of Applied Biology, University of Perugia) for technical assistance. Research supported by Regione Marche, Project No. 6.

[2]Corresponding author: dalbosco@unipg.it

Received April 30, 2009.
Accepted August 6, 2009.

Downloaded from jas.fass.org at Agraria Perugia on November 23, 2009.

which strains are best suited for each type of rearing system.

Although various authors (Castellini et al., 2002a,b; Fanatico et al., 2005, 2007) have considered the effect of the organic system on meat quality, little attention has been given to its effect on fiber composition of different types of skeletal muscles. The aim of the present study was to evaluate the effect of rearing system on behavior and consequently on muscle fiber characteristics of 3 different chicken genotypes characterized by different growing rates.

MATERIALS AND METHODS

All animals were reared according to Italian directives (Gazzetta Ufficiale, 1992) on animal welfare for experimental and other scientific purposes and the organic ones according to Council Regulation (EC) No. 834/2007.

Birds and Diets

Three hundred day-old male chicks from fast-growing (Ross 208), medium-growing (Kabir), and slow-growing (Leghorn) genotypes were reared separately (2 replications per genotype) under a brooder lamp for the first 3 wk of life at the experimental farm of the Department of Applied Biology (University of Perugia). The Leghorn strain originated from a conservative flock unselected for many generations and contained at the Department of Applied Biology since the 1960s.

Incandescent light (30 lx) placed at bird level was used for illumination. Chicks were vaccinated against Marek and Newcastle disease and coccidiosis (Paracox, Schering-Plough SpA, Milano, Italy). After 21 d, the birds of each strain were randomly assigned to 1 of 2 housing conditions: control group, housed in an indoor pen (0.12 m^2/bird) where the temperature was 17.5 ± 2.7°C, the relative humidity 65 to 75% and the daily photoperiod 12 h light and 12 h dark; organic group, housed in 4 covered shelters (0.12 m^2/bird) with straw litter and access to a grass paddock (4 m^2/bird); feeders and drinkers were available outdoors and indoors with a natural photoperiod.

The trial was carried out from April to June 2008. Chickens were fed ad libitum the same starter (1 to 21 d) and a grower-finisher (22 d to slaughter) diet, containing 100% organic ingredients certified by a national agency (Istituto per la Certificazione Etica e Ambientale, Bologna, Italy).

Bird mortality was recorded daily, whereas individual BW were recorded weekly, as well as the collective feed intake of each subgroup. The average feed consumption of the group was used to calculate the individual G:F.

Behavioral Observations

Behavioral observations were recorded during the last week of age (from 73 until 80 d) in the morning and afternoon, during 2 periods of 3 h each using the focal animal sampling method (Martin and Bateson, 1986). Before each observation, 5 min were allowed for the animals to adapt to the presence of the observer. Twenty birds per strain were chosen at random and marked with different colors on the tip of the tail. The behavioral observations included walking, standing, lying, eating (food and water), and others (preening, pecking, and scratching the litter or the ground). The behavior was recorded on a purpose-designed table, and their respective frequencies were calculated as a percentage of the total observed behaviors. Because no differences were found between weeks and hours, all data were pooled to obtain a mean value. The initial interest (percentage of birds that approached to investigate the observer on entering the pen) was performed according to Lewis et al. (1997).

Blood Sample Collection, Slaughtering, and Muscle Sampling

At 81 d of age, 5-mL blood samples from the brachial vein were collected in vacutainers, transported to the laboratory, and immediately centrifuged at 1,500 × *g* for 10 min at 4°C to measure lactate dehydrogenase (**LDH**) and creatine kinase (**CK**).

The same day, a sample of 20 birds per strain and rearing system, each weighing between ±10% of the population mean, were slaughtered in the department processing plant, 12 h after feed withdrawal. Chickens were not transported and were electrically stunned (110 V; 350 Hz) before killing.

After killing, carcasses were immerged into hot water (56.5°C for 2 min) and then plucked, eviscerated (nonedible viscera: intestines, proventriculus, gall bladder, spleen, esophagus, and full crop) and stored for 24 h at 4°C. Head, neck, legs, edible viscera (heart, liver, gizzard), and fat (perivisceral, perineal, and abdominal) were removed to obtain the ready-to-cook carcass (ASPA et al., 1996).

Muscle samples parallel to fiber direction were taken immediately after bleeding from the left half of the carcasses, rolled in talcum powder, wrapped in aluminum foil, labeled, frozen, and stored in liquid nitrogen until analyses were performed. Three muscles known, from the literature and from previous studies (Mammoli et al., 2004; Miraglia et al., 2006), to have a different fiber distribution were considered: 1) pectoralis major (**PM**), 2) ileotibialis lateralis (**ITL**), and 3) M. semimembranosus (**SM**). Serial cross-sections (8 μm thick) were made in a cryostat at −20°C and stained with hematoxylin-eosin for histological evaluations.

Blood and Muscle Processing

Serum CK and LDH activities were measured by spectrophotometry using commercially available kits [EnzyChrom Creatine Kinase Assay Kit (BioAssay Systems, Hayward, CA); QuantiChrom Lactate Dehydrogenase

Downloaded from jas.fass.org at Agraria Perugia on November 23, 2009.

Table 1. Effect of genotype and rearing system on performance of chickens[1]

Item	Ross		Kabir		Leghorn		
	Conventional	Organic	Conventional	Organic	Conventional	Organic	Pooled SE
BW, g	4,202[a]	3,434[b]	2,826[c]	2,314[c]	1,754[d]	1,498[d]	120
Feed intake, g/d	145.9[a]	129.5[b]	99.1[c]	92.3[c]	78.0[d]	73.9[d]	11.8
Daily BW gain, g/d	51.9[a]	42.3[ab]	34.7[b]	28.3[bc]	21.3[c]	18.1[c]	5.8
G:F	0.36[a]	0.32[a]	0.34[a]	0.30[ab]	0.27[b]	0.24[b]	0.05
Mortality, %	6[b]	16[a]	8[b]	4[b]	6[b]	2[b]	5*

[a–d]Means within rows bearing different superscripts differ significantly at $P < 0.05$.
[1]n = 100 per genotype.
*χ^2.

Kit (BioAssay Systems)]. Muscle samples were processed for myofibrillar ATPase activity after acid and alkaline preincubation (Padykula and Herman, 1955; Guth and Samara, 1969), for succinate dehydrogenase (**SDH**) activity (Nachlas et al., 1957) or for the combination of the 2 (Solomon and Dunn, 1988), depending on the muscle considered. Myofibers were classified, according to the terminology introduced by Ashmore and Doerr (1971), as types β-Red (**βR**), α-Red (**αR**), and α-White (**αW**). Beta-R fibers are stable after acid preincubation, labile after alkaline preincubation, and SDH positive; αR and αW fibers are labile after acid preincubation and stable after alkaline preincubation, whereas αR fibers are SDH positive and αW fibers are SDH negative.

Images were acquired and analyzed to determine percentages and cross-sectional areas (**CSA**), using an image analysis system (analySIS, Soft Imaging System, Münster, Germany) carried out on a workstation equipped with a graphic card linked to a video camera mounted on the microscope (Olympus BX51, Olympus Optical Co., Tokyo, Japan). Measurements were determined on about 200 fibers, from a random field in each muscle sample section stained with hematoxylin-eosin.

Statistical Analyses

Data were analyzed with a linear model (StataCorp, College Station, TX; ANOVA procedure), evaluating the interactive effect of rearing system and genotype for replication differences; the significance of differences was evaluated by the *t*-test ($P \leq 0.05$). Multivariate analyses were also performed to analyze the relationship between behavior pattern and muscle characteristics (BIPLOT procedure).

RESULTS AND DISCUSSION

In this trial, the minimum age to slaughter organically reared chickens (EU regulation 1804/99) was 81 d. However, for the Ross birds this is considerably older with respect to intensive rearing, where they are slaughtered at 49 d (www.rossbreeders.com; last accessed Sep. 29, 2008).

As expected, the growth rate of the Ross strain was much greater than that of Kabir and Leghorn (Table 1). At slaughter, the conventional Ross broilers reached the greatest BW with a satisfactory G:F and mortality rate. These fast-growing birds, in comparison with the slow-growing ones, worsened their performance significantly when reared under organic conditions (Castellini et al., 2002a).

The BW of Leghorn chickens was less than 2 kg in conventional and organic systems, and these BW were less than the minimum marketable BW for organic products (Sauveur, 1997); Leghorn chickens also had a smaller G:F than the Ross. Performance of Kabir chickens was in between that of the other 2 strains.

The main behaviors of the birds are presented in Table 2. Ross birds tended to stay indoors rather than forage in the pasture, whereas Leghorn birds spent more time outdoors ($P < 0.05$); Kabir birds showed an intermediate value.

It seems likely that the drive to forage may have been considerably reduced in meat-type birds that have a greater feed efficiency than layer strains (Masic et al., 1974). Under natural conditions, the energy spent in obtaining information from more unpredictable food sources is likely to be outweighed by a long-term more efficient feed intake. The behavior shown by the Leghorn birds is therefore probably more adaptive to a free-range situation.

This result confirms data obtained in previous research (Weeks et al., 1994; Castellini et al., 2002a,b) where the Ross genotype was compared with lighter strains. Ross birds showed conventionally and organically reared the greatest percentages of lying and standing behavior. In general, this genotype did not show significant behavioral ($P > 0.05$) changes in relation to rearing system, except for ground pecking behavior that increased significantly in organically reared birds.

It has been found that resting (lying and standing behavior) accounts for 80 to 90% of the time budget (Bessei, 1992) and that 6- to 10-wk-old broilers, respectively, spend 79 to 89% of their time lying down including those birds given access to pasture because these chickens lack motivation to use space (Weeks et al., 1994). There was a significant reduction in the time of lying, standing, and eating for the Kabir genotype,

Downloaded from jas.fass.org at Agraria Perugia on November 23, 2009.

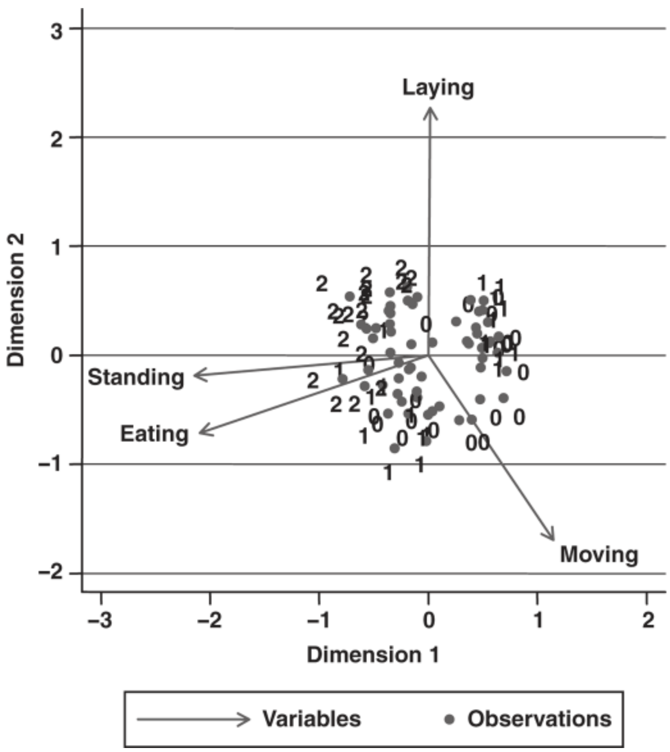

Figure 1. Multivariate analysis of principal behavioral patterns; 0, 1, and 2: Leghorn, Kabir, and Ross, respectively.

whereas moving, ground pecking, wing flapping, and others increased in organically reared birds. Leghorn birds were always the most active; indeed, they showed the greatest values of moving and the least of lying in conventional and organic rearing systems. However, the ground pecking, wing flapping, and other behavior increased in the organically reared birds, whereas lying and standing were reduced. These findings are in agreement with Schütz and Jensen (2001) who found that genetic selection of animals for a better growth rate has progressively modified their behavior, reducing kinetic activity, which represents a main energy cost to the animals. Weeks et al. (2000) found that the high levels of lying down are related to the BW and fast growth rates of meat-type chickens, whereas Siegel and Wisman (1966) showed that selection for increased BW is associated with an increase in appetite. Rest and sleep are strongly associated with energy conservation, tissue restoration, and growth (Blokhuis, 1983, 1984). Such findings contribute to explaining why meat type birds are more efficient feed converters than laying hens (Jackson and Diamond, 1996; Rauw et al., 1998).

The Kabir genotype showed behavioral differences (mainly lying and moving) depending on the rearing system. Even though they have been selected to allocate a greater proportion of resources into growth, they showed a good adaptation to a free-range environment.

An overview of relationships among the main behavior in the 3 experimental strains is shown in Figure 1. Leghorn birds were characterized by moving activities, whereas the Kabir and Ross broilers were discriminated on the basis of their lying, standing, and eating activities. The variables of standing and eating showed a positive association, whereas moving was negatively correlated with lying, standing, and eating.

Table 3 shows the results obtained for serum LDH and CK activities. Fast growing genotypes showed different values compared with Kabir and Leghorn, which in turn showed differences due to rearing systems. Increased serum LDH activity is a sensitive but nonspecific indicator of myocardial and skeletal muscle damage because LDH enzymes are found in many organs and tissues, whereas CK activity is a highly specific marker of myocardial infarction (heart attack), rhabdomyolysis (severe muscle breakdown), muscular dystrophy, and acute renal failure (Thoren-Tolling and Jonsson, 1983; Mitchell and Sandercock, 1995). The increase in serum CK and LDH may be indicative of stress-associated tissue dysfunction or may also reflect protein turnover, which is closely related to muscle growth rate or activity (Berri et al., 2007). These considerations can explain the greater enzyme concentrations found in the fast-growing genotype compared with the others; indeed, a relation between CSA and CK and LDH levels has been found by various authors (Gyenis et al., 2006; Berri et al., 2007). The increase in LDH and CK concentrations found in the organically reared Kabir and Leghorn may be explained by the greater physical activity recorded for these chickens as shown by the behavioral data. On

Table 2. Effect of genotype and rearing system on behavior of chickens[1]

	Ross		Kabir		Leghorn		
Item	Conventional	Organic	Conventional	Organic	Conventional	Organic	Pooled SE
Time spent outdoors, % total time	—	30.0[c]	—	50.0[b]	—	70.0[a]	19.9
Lying, % total time	36.8[a]	40.1[a]	44.2[a]	33.9[b]	30.7[b]	10.0[c]	16.9
Moving, % total time	0.1[c]	0.7[c]	2.6[b]	23.1[a]	27.8[a]	30.6[a]	12.5
Ground pecking, % total time	0.1[d]	2.5[c]	0.2[d]	5.4[b]	4.3[b]	13.9[a]	4.4
Standing, % total time	35.8[a]	29.5[a]	30.5[a]	6.6[b]	20.6[a]	11.3[b]	10.9
Eating, % total time	14.5[a]	14.5[a]	15.1[a]	5.8[b]	12.3[a]	11.3[a]	9.1
Wing flapping, % total time	0.2[b]	0.2[b]	0.0[b]	0.8[a]	0.3[b]	0.9[a]	2.2
Others, % total time	12.5[b]	12.5[b]	7.4[c]	24.4[a]	4.0[c]	22.0[a]	3.5

[a–d]Means within rows bearing different superscripts differ significantly at $P < 0.05$.

[1]n = 20 per rearing system and genotype.

Downloaded from jas.fass.org at Agraria Perugia on November 23, 2009.

Table 3. Effect of genotype and rearing system on in vivo enzyme activities of chickens[1]

	Ross		Kabir		Leghorn		
Item	Conventional	Organic	Conventional	Organic	Conventional	Organic	Pooled SE
Lactate dehydrogenase, IU	3,026[a]	3,237[a]	1,397[c]	2,028[b]	1,568[c]	2,350[b]	511
Creatine kinase, IU	4,542[a]	4,822[a]	1,954[c]	2,360[bc]	1,590[d]	2,774[b]	1,045

[a–d]Means within rows bearing different superscripts differ significantly at $P < 0.05$.
[1]n = 20 per rearing system and genotype.

the other hand, the Ross chickens had a similar behavior in both rearing systems, and therefore no differences in enzyme levels were found.

Fiber type distributions of the muscle fibers of PM, ITL, and SM muscles for the 3 genotypes considered are summarized in Table 4. In the PM muscle, all fibers belonged to the αW group in all genotypes except for the Leghorn, in which a small percentage of αR fibers were found in the conventional (0.5%) and organic (3.8%) rearing systems (Figure 2). In the ITL muscle, no genotype differences in the fiber distribution were found in the conventional rearing system, whereas in the organic system the Leghorn and the Kabir chickens had a greater percentage ($P < 0.05$) of αR fibers than the Ross (Figure 3). Furthermore, in the ITL muscle, the rearing system influenced the fiber type distribution within the genotype, with the Kabir and Leghorn genotypes having a greater ($P < 0.05$) αW fiber percentage in the conventional than in the organic rearing system. In the SM muscle, no significant difference ($P > 0.05$) in fiber type distribution was found in either rearing system, nor did the rearing system influence the fiber distribution of the strains.

In both rearing systems, in the PM (Figure 4) and the ITL muscles the fiber CSA decreased from the fastest to the slowest growing genotypes (Table 5). This was also true for the SM muscle in the conventional rearing system. On the contrary, in the organic system no differences were observed between the Kabir and Leghorn chickens; both had smaller CSA than the Ross. In the ITL muscle of Leghorns, the CSA of αW and αR fibers were larger in the organically reared birds.

In Figure 5 the first dimension describes the kinetic and not-kinetic behaviors, whereas the second dimension shows the relationship between the ITL muscle (percentage and area of fibers) and kinetic activity. Birds of different genotypes are plotted accordingly: fast-growing birds showed low kinetic activity and greater αW area in the ITL muscle and the opposite for slow-growing birds; medium-growing birds showed an intermediate situation. The presence of even a small percentage of αR fibers in the PM of Leghorn chickens is in itself interesting because this muscle usually is composed only of αW fibers and various authors (Ono et al., 1993; Sakakibara et al., 2000) have found a maximum of 0.03% of αR fibers in chickens at slaughter age. Only Chiang et al. (1995) found 3% of αR fibers in chicks a few days old, which, however, disappeared in adult animals.

The PM muscle is involved in flight movement (Nelson et al., 2004), so the presence of αR fibers that increase with exercise (Brackenbury and Holloway, 1991), could be due to the frequent flutter movements performed by this breed especially in an outdoor environment, as evidenced by the behavioral observations (data not shown, r = 0.33; $P < 0.01$). The ITL muscle showed the most significant differences for genetic and rearing system effects. The differences in muscle fiber distribution can be explained by an increase in the percentage of αR fibers in the organically reared Kabir and Leghorn chickens,

Table 4. Effect of genotype and rearing system on pectoralis major, ileotibialis lateralis, and semimembranosus muscle fiber percentage (%) of chickens[1]

	Ross		Kabir		Leghorn		
Item	Conventional	Organic	Conventional	Organic	Conventional	Organic	Pooled SE
Muscle							
Pectoralis major							
αW	100.0[a]	100.0[a]	100.0[a]	100.0[a]	99.5[b]	96.2[b]	0.6
αR	—	—	—	—	0.5[b]	3.8[a]	0.6
Ileotibialis lateralis							
αW	58.7[b]	63.1[a]	54.1[b]	42.1[c]	54.7[b]	44.1[c]	5.5
αR	41.3[b]	36.9[c]	45.9[b]	57.9[a]	45.3[b]	55.8[a]	4.2
Semimembranosus							
αW	37.1	32.1	32.4	32.3	36.3	32.5	3.3
βR	8.9	7.04	6.96	8.6	9.5	9.4	1.3
αR	54.0	60.9	60.7	59.1	54.2	58.1	2.8

[a–c]Means within rows bearing different superscripts differ significantly at $P < 0.05$.
[1]n = 20 per rearing system and genotype. R = red; W = white.

Downloaded from jas.fass.org at Agraria Perugia on November 23, 2009.

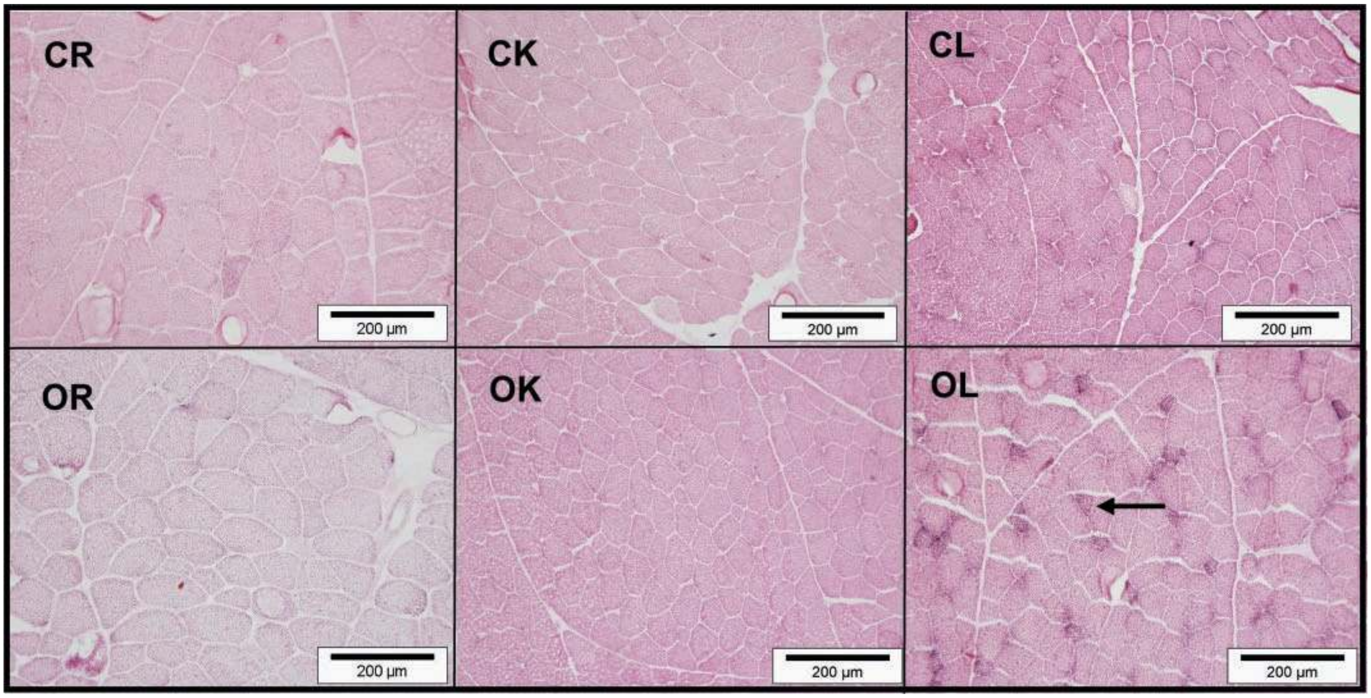

Figure 2. Comparison of pectoralis major muscle cross-sections taken from conventional (C) and organic (O) Ross (R), Kabir (K), and Leghorn (L) chickens stained for succinate dehydrogenase activity; arrow: α-Red fibers.

possibly due to a variation in their behavior according to the rearing system. In particular, the time spent lying decreases in the organic rearing system, whereas the time spent moving and ground pecking increases. Brackenbury and Holloway (1991) studied the effects of exercise on a treadmill on chicken ITL and showed an increase in αR fibers. Figure 5 easily visualizes the relationship between behavior variables and fiber type in the muscle. The positions of the different breeds on the plot show a different behaviors of fast-growing strain placed in the nonkinetic behaviors area, thus explaining their greater αW area (CSA and percentage), compared with slow-growing breeds. The marked effect of exercise on certain muscles can be explained by their

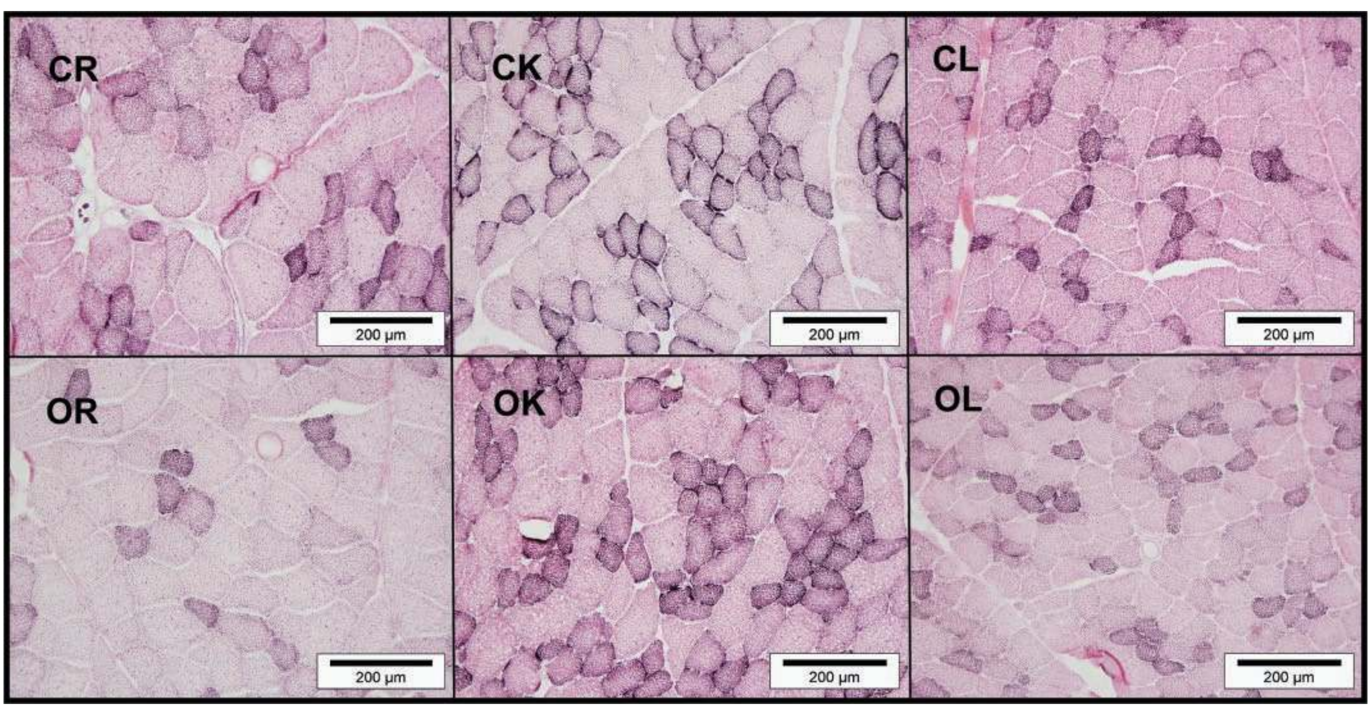

Figure 3. Comparison of ileotibialis lateralis muscle cross-sections taken from conventional (C) and organic (O) Ross (R), Kabir (K), and Leghorn (L) chickens stained for succinate dehydrogenase activity.

Downloaded from jas.fass.org at Agraria Perugia on November 23, 2009.

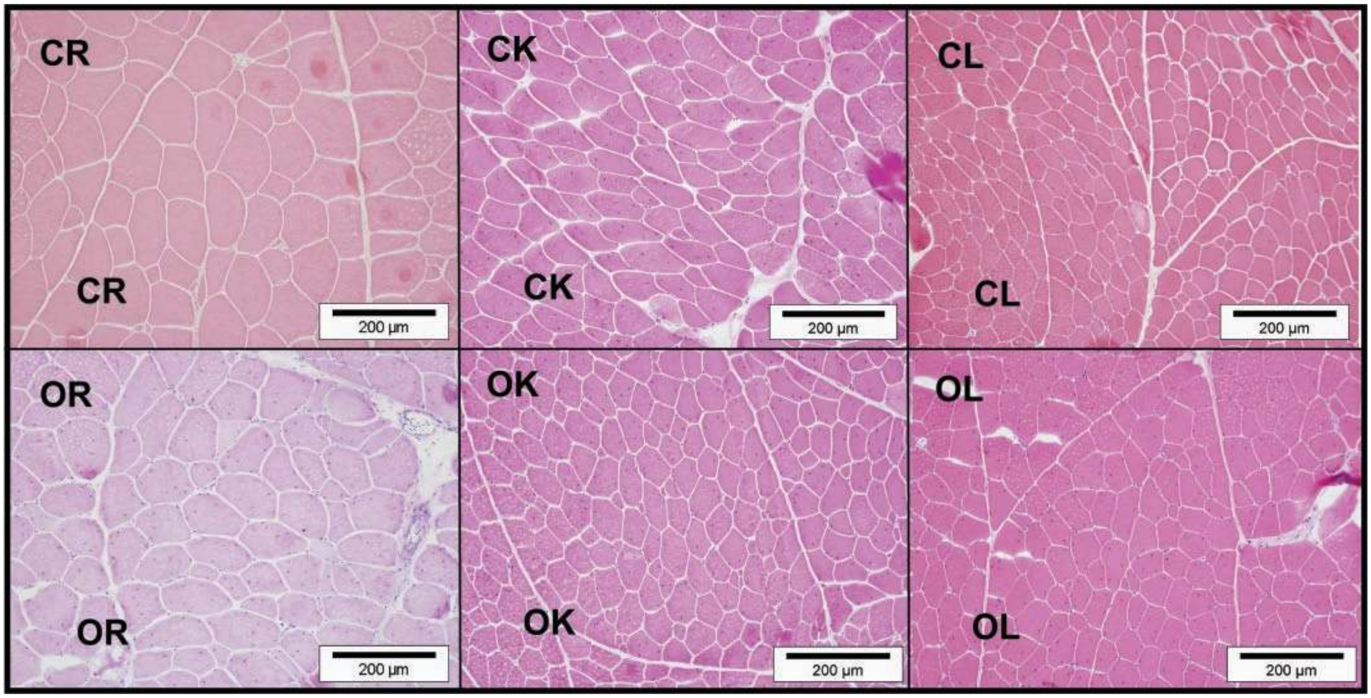

Figure 4. Comparison of pectoralis major muscle cross-sections taken from conventional (C) and organic (O) Ross (R), Kabir (K), and Leghorn (L) chickens stained for hematoxylin-eosin.

position and by the activities they are involved in; the ITL muscle in particular is involved in walking and running movements. On the other hand, the SM is a postural muscle stimulated not only by movement but also by the standing position, thus explaining the lack of significant differences between rearing systems found in this muscle.

As far as the CSA are concerned, various authors (Iwamoto et al., 1992; Burke and Henry, 1997; Scheuermann et al., 2004) have reported that fast-growing birds normally have fibers with a greater CSA than slow-growing breeds and this genetic effect is evident in both rearing systems. The greater CSA of the ITL muscle fibers of organically reared Leghorn chickens could be due to their greater adaptability to motor activity in agreement with Leisson et al. (2008) who observed that horses with a better endurance performance had greater percentages and relative areas of type I and IIA fibers and smaller percentages and relative areas of type IIX fibers in the gluteus medius muscle than did moderate performers. On the other hand, the smaller CSA of αR and αW fibers of the Ross chickens in the organic rearing system can be due to a poor suitability of fast-growing breeds to extensive rearing as confirmed by the behavioral data.

In conclusion, the results are generally consistent with the idea that selecting for high production causes a reallocation of resources with modified behavioral strategies as a consequence. Behavior that is high in energy cost, such as moving activity, was decreased in

Table 5. Effect of genotype and rearing system on pectoralis major, ileotibialis lateralis, and semimembranosus muscle fiber area (μm^2) of chickens[1]

	Ross		Kabir		Leghorn		
Item	Conventional	Organic	Conventional	Organic	Conventional	Organic	Pooled SE
Muscle							
Pectoralis major							
αW	5,713[a]	5,164[a]	2,546[b]	2,417[b]	1,610[c]	1,699[c]	293
αR	—	—	—	—	955[a]	908[b]	87
Ileotibialis lateralis							
αW	5,690[a]	5,074[a]	3,723[b]	3,939[b]	2,396[d]	3,006[c]	309
αR	3,623[a]	3,420[a]	2,260[b]	2,303[b]	1,272[d]	1,758[c]	175
Semimembranosus							
αW	7,268[a]	5,715[b]	3,297[c]	2,801[cd]	2,122[d]	2,390[d]	391
βR	3,166[a]	2,794[a]	2,144[b]	1,896[b]	1,342[c]	1,340[c]	205
αR	5,245[a]	4,222[b]	2,074[c]	1,952[c]	1,527[c]	1,791[c]	269

[a–d]Means within rows bearing different superscripts differ significantly at $P < 0.05$.
[1]n = 20 per rearing system and genotype. R = red; W = white.

Downloaded from jas.fass.org at Agraria Perugia on November 23, 2009.

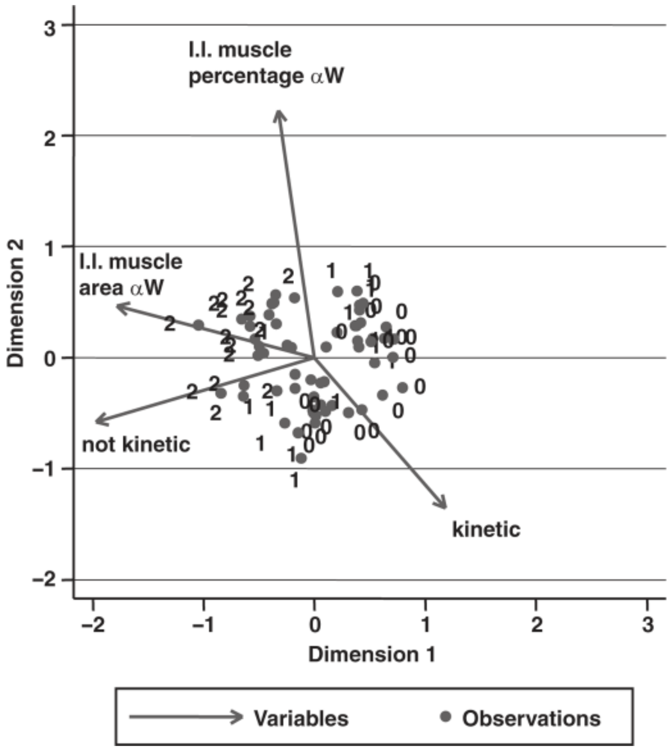

Figure 5. Multivariate analysis of the ileotibialis lateralis muscle (percentage and area of fibers) and kinetic and not-kinetic behaviors; 0, 1, and 2: Leghorn, Kabir, and Ross, respectively. αW = α-White.

the fast- and medium-growing birds compared with the slow-growing birds, allowing the Ross and Kabir chickens to conserve energy that can be reallocated to production traits.

Our results characterize meat-type birds as very inactive birds, quite distinct from Leghorn chickens. At an older age than meat-type chickens are selected, besides alterations in ethogram, they showed lameness, ascites, and other related problems. In these birds, mainly if organically reared, problems correlated to welfare (defined as normal morphological development and undisturbed physiological, behavioral, and mental status of the animals; Bessei, 2006) did not decrease, but on the contrary, became more prominent. Fiber characteristics and muscle enzyme functions are affected by rearing system only in animals adapted to the organic system. Some interesting results of this trial are the residues of αR fiber in the PM muscle and the greater CSA of ITL muscle in the organically reared Leghorn birds that show evidence at the histological level of their adaptability to this rearing system.

LITERATURE CITED

Ashmore, C. R., and L. Doerr. 1971. Comparative aspects of muscle fiber types in different species. Exp. Neurol. 31:408–418.

Romboli, I., L. Cavalchini, M. Gualtieri, A. Franchini, A. Nizza, and A. Quarantelli. 1996. Metodologie relative alla macellazione del pollame, alla valutazione e dissezione delle carcasse e delle carni avicole. Zootec. Nutr. Anim. 22:177–180.

Berri, C., E. Le Bihan-Duval, M. Debut, V. Santé-Lhoutellier, E. Baéza, V. Gigaud, Y. Jégo, and M. J. Duclos. 2007. Consequence of muscle hypertrophy on characteristics of Pectoralis major muscle and breast meat quality of broiler chickens. J. Anim. Sci. 85:2005–2011.

Bessei, W. 1992. Das Verhalten von Broilern unter intensiven Haltungsbedingungen. Arch. Geflugelkd. 56:1–7.

Bessei, W. 2006. Welfare of broilers: A review. Worlds Poult. Sci. J. 62:455–466.

Blokhuis, H. J. 1983. The relevance of sleep in poultry. Worlds Poult. Sci. J. 39:33–37.

Blokhuis, H. J. 1984. Rest in poultry. Appl. Anim. Behav. Sci. 12:289–303.

Brackenbury, J. H., and S. A. Holloway. 1991. Age and exercise effects on mitochondrial density and capillary fiber ratio in bird leg muscle. Br. Poult. Sci. 32:645–653.

Burke, W. H., and M. H. Henry. 1997. Characteristics of the *Pectoralis superficialis* and semimembranosus of broiler strain chickens, bantam chickens, and the reciprocal crosses. Poult. Sci. 76:767–773.

Butterworth, A., C. A. Weeks, P. R. Crea, and S. C. Kestin. 2002. Dehydration and lameness in a broiler flock. Anim. Welf. 11:89–94.

Castellini, C., C. Berri, E. Le Bihan-Duval, and G. Martino. 2008. Qualitative attributes and consumer perception of organic and free-range poultry meat. Worlds Poult. Sci. J. 65:120–135.

Castellini, C., A. Dal Bosco, C. Mugnai, and M. Bernardini. 2002. Performance and behaviour of chickens with different growing rate reared according to the organic system. Ital. J. Anim. Sci. 1:291–300.

Castellini, C., C. Mugnai, and A. Dal Bosco. 2002a. Effect of conventional versus organic method of production on the broiler carcass and meat quality. Meat Sci. 60:219–225.

Castellini, C., C. Mugnai, and A. Dal Bosco. 2002b. Meat quality of three chicken genotypes reared according to the organic system. Ital. J. Food Sci. 14:403–414.

Chiang, W., M. B. Solomon, and K. L. Kotula. 1995. Muscle fiber types of selected muscles from broiler chickens in relation to age and sex. J. Muscle Foods 6:197–210.

European Economic Community. 1999. Council Regulation (EC) n.1804/99 of July 1999 supplementing Regulation (ECC) n. 2092/91 on organic production of agricultural products. Off. J. L 222, 24/08/1999, 1–28.

Dawkins, M. S. 2003. Behaviour as a tool in the assessment of animal welfare. Zoology 106:383–387.

Fanatico, A. C., L. C. Cavitt, P. B. Pillai, J. L. Emmert, and C. M. Owens. 2005. Evaluation of slower-growing broiler genotypes grown with and without outdoor access: Meat quality. Poult. Sci. 84:1785–1790.

Fanatico, A. C., P. B. Pillai, J. L. Emmert, and C. M. Owens. 2007. Meat quality of slow- and fast-growing chicken genotypes fed low-nutrient or standard diets and raised indoors or without outdoor access. Poult. Sci. 86:2245–2255.

Gazzetta Ufficiale. 1992. Attuazione della Direttiva 86/609/CEE in materia di protezione degli animali utilizzati ai fini sperimentali o ad altri fini scientifici, D.L. January 27, 1992, No. 116. Pages 1–12 in Supplemento ordinario alla Gazzetta Ufficiale, No. 40, 18/2/1992.

Guth, L., and F. J. Samara. 1969. Qualitative differences between actomyosin ATPase of slow and fast mammalian muscle. Exp. Neurol. 25:139–152.

Gyenis, J., Z. Suto, R. Romvari, and P. Horn. 2006. Tracking the development of serum biochemical parameters in two laying hen strain—A comparative study. Arch. Tierz. Dumm. 49:593–606.

Havenstein, G. B., P. R. Ferket, S. E. Sheiderler, and B. T. Larson. 1994. Growth, livability and feed conversion of 1957 vs. 1991 broilers when fed typical 1975 and 1991 broiler diets. Poult. Sci. 73:1785–1794.

Downloaded from jas.fass.org at Agraria Perugia on November 23, 2009.

Iwamoto, H., Y. Hara, Y. Ono, and H. Takahara. 1992. Breed differences in the histochemical properties of the M. Ileotibialis lateralis myofiber of domestic cocks. Br. Poult. Sci. 33:321–328.

Jackson, S., and J. Diamond. 1996. Metabolic and digestive responses to artificial selection in chickens. Evolution 50:1638–1650.

Ladewick, J. 2005. Of mice and men: Improved welfare through clinical ethology. Appl. Anim. Behav. Sci. 92:183–192.

Leisson, U., A. Jaakma, and T. Seeneb. 2008. Adaptation of equine locomotor muscle fiber types to endurance and intensive high speed training. J. Equine Vet. Sci. 28:7–15.

Lewis, P. D., G. C. Perry, L. J. Farmer, and R. L. S. Patterson. 1997. Responses of two genotypes of chicken to the diets and stocking densities typical of UK and 'Label Rouge' production systems: I. Performance, behaviour and carcass composition. Meat Sci. 45:501–516.

Macrae, V. E., M. Mahon, S. Gilpin, D. A. Sandercock, and M. A. Mitchell. 2006. Skeletal muscle fiber growth associated myopathy in the domestic chicken (*Gallus domesticus*). Br. Poult. Sci. 47:264–272.

Mammoli, R., R. Branciari, D. Ranucci, D. Miraglia, A. Ciuffi, P. Avellini, and M. Severini. 2004. Giant fibers in broiler chickens. Proc. 50th ICoMST, Helsinki, 8–13 August 2004, 213–216.

Martin, P., and P. Bateson. 1986. Measuring Behaviour: An Introductory Guide. Cambridge Univ. Press, Cambridge, UK.

Masic, B., D. G. M. Wood Gush, I. J. H. Duncan, and C. Mc Corquodale. 1974. A comparison of feeding behaviour of young broiler and layer males. Br. Poult. Sci. 15:499–505.

Miraglia, D., R. Mammoli, R. Branciari, D. Ranucci, and B. T. Cenci Goga. 2006. Characterization of muscle fiber type and evaluation of the presence of giant fibers in two meat chicken hybrids. Vet. Res. Commun. 30(Suppl. 1):357–360.

Mitchell, M. A., and D. A. Sandercock. 1995. Creatine Kinase isoenzyme profiles in the plasma of the domestic fowl (*Gallus domesticus*): Effects of acute heat stress. Res. Vet. Sci. 59:30–34.

Nachlas, M., T. Kwang Chung, and E. J. DeSouza. 1957. Cytochemical demonstration of succinic dehydrogenase by the use of a new p-nitrophenyl substituted ditetrazole. J. Histochem. Cytochem. 5:565–572.

Nelson, F. E., A. M. Gabaldòn, and T. J. Roberts. 2004. Force-velocity properties of two avian hindlimb muscles. Comp. Biochem. Physiol. 137:711–721.

Nielsen, B. L., M. G. Thomsen, P. Sorensen, and J. F. Young. 2003. Feed and strain effects on the use of outdoor areas by broilers. Br. Poult. Sci. 44:161–169.

Ono, Y., H. Iwamoto, and H. Takahara. 1993. The relationship between muscle growth and the growth of different fiber types in the chicken. Poult. Sci. 72:568–576.

Padykula, H. A., and E. Herman. 1955. Factors affecting the activity of adenosine tryphosphatase and other phosphates as measured by histochemical techniques. J. Histochem. Cytochem. 29:89–90.

Rauw, W. M., E. Kanis, E. N. Noordhuizen-Stassen, and F. J. Grommers. 1998. Undesirable side effects of selection for high production efficiency in farm animals: A review. Livest. Prod. Sci. 56:15–33.

Reiter, K., and W. Bessei. 1998. Effect of locomotor activity on bone development and leg disorders in broilers. Arch. Gefluegelkd. 62:247–253.

Sakakibara, K., S. Tabata, N. Shiba, T. Gotoh, S. Nshimura, and H. Iwamoto. 2000. Myofiber composition and total collagen content in M. *Ileotibialis lateralis* and M. *Pectoralis* of Silkie and White Leghorn chickens. Br. Poult. Sci. 41:570–574.

Sauveur, B. 1997. Les critères et facteurs de la qualité des poulets Label Rouge. Prod. Anim. 10:219–226.

Scheuermann, G. N., S. F. Bilgili, S. Tuzun, and D. R. Mulvaney. 2004. Comparison of chicken genotypes: Myofiber number in Pectoralis muscle and myostatin ontogeny. Poult. Sci. 83:1404–1412.

Schütz, K. E., and P. Jensen. 2001. Effects of resource allocation on behavioural strategies: A comparison of red junglefowl (*Gallus gallus*) and two domesticated breeds. Poult. Ethol. 107:753–762.

Siegel, P. B., and E. L. Wisman. 1966. Selection for body weight at eight weeks of age. 6. Changes in appetite and feed utilization. Poult. Sci. 45:1391–1397.

Solomon, M. B., and M. C. Dunn. 1988. Simultaneous histochemical determination of three fiber types in single sections of ovine, bovine and porcine skeletal muscle. J. Anim. Sci. 66:255–264.

Spinka, M. 2006. How important is natural behaviour in animal farming systems? Appl. Anim. Behav. Sci. 100:117–128.

Sundrum, A. 2001. Organic livestock farming. A critical review. Livest. Prod. Sci. 67:207–215.

Thoren-Tolling, K., and L. Jonsson. 1983. Creatine kinase isoenzymes in serum of pigs having myocardial and skeletal muscle necrosis. Can. J. Comp. Med. 47:207–216.

Watanabe, S. 2007. How animal psychology contributes to animal welfare. Appl. Anim. Behav. Sci. 106:193–202.

Weeks, C. A., T. D. Danbury, H. C. Davies, P. Hunt, and S. C. Kestin. 2000. The behaviour of broiler chickens and its modification by lameness. Appl. Anim. Behav. Sci. 67:111–125.

Weeks, C. A., C. J. Nicol, C. M. Sherwin, and S. C. Kestin. 1994. Comparison of the behaviour of broiler chicken in indoor and free-range environments. Anim. Welf. 3:179–192.

Downloaded from jas.fass.org at Agraria Perugia on November 23, 2009.

References This article cites 49 articles, 7 of which you can access for free at:
http://jas.fass.org/cgi/content/full/87/12/4109#BIBL

Downloaded from jas.fass.org at Agraria Perugia on November 23, 2009.