Green and Blue Monochromatic Lights Promote Growth and Development of Broilers Via Stimulating Testosterone Secretion and Myofiber Growth

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Primary Audience: Researchers, Complex Managers, Producers

SUMMARY

Methods of light treatment such as light schedule, intensity or illuminance, and color are important factors that influence avian productivity. Therefore, artificial illumination has been widely used in modern poultry husbandry. Although progress had been made in understanding of the effects of light schedule and intensity on avian growth, effects of light color on avian growth are not clear. In this study, 276 male Arbor Acres broilers were reared under white, red, green, and blue lights from light-emitting diode lamps as light sources. Broilers' growth and productive performance were increased under green light during the early period (0 to 26 d of age) or blue light during the later period (27 to 49 d of age). Furthermore, both blue and green lights were more effective to stimulate testosterone secretion and myofiber growth that led to increased body growth. These results indicate that light-emitting diode lamps have value in the modern broiler husbandry.

Key words: monochromatic light, growth, productive performance, myofiber, testosterone, broiler

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DESCRIPTION OF PROBLEM

In modern poultry husbandry, artificial illumination has been widely used to promote avian productive performance. Previous studies found that the light schedule, intensity of illumination, and wavelength of light were 3 major factors that influenced growth and well-being of broilers [1, 2]. For example, body weight was increased in turkeys under treatment of intermittent light as compared with that of constant light [3]. Studies by Charles et al. [4] suggested that broiler carcasses had a lower percentage of body fat and higher percentage of body protein in high light intensity than those of low light intensity. However, Yahav et al. [5] found that low light intensity (10 lx) improved feed conversion of turkeys and resulted in an increase of body weight and a decrease of feed intake. In contrast, no effect of light intensity was reported in roaster chickens at 3, 6, or 9 wk of age [6].

It has been suggested that green light (**GL**) promotes cockerel growth at 14L:10D [7], whereas pink light decreased body weight of

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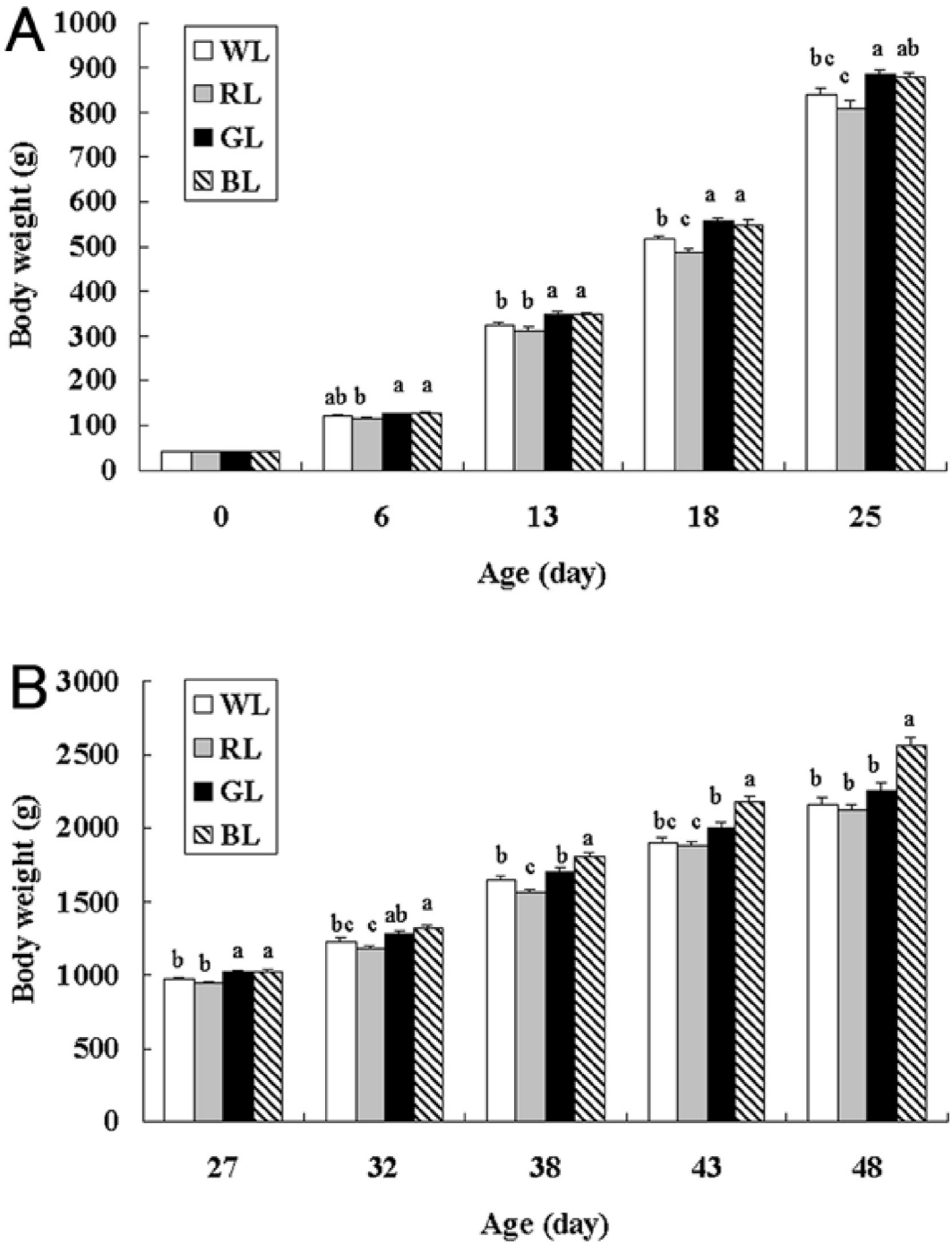

Figure 1. Body weight of broilers reared under white light (WL), red light (RL), green light (GL), and blue light (BL) from d 0 (n = 264) to d 26 (n = 232) and d 27 (n = 232) to d 49 (n = 216). A: d 0 to 26; B: d 27 to 49. [a–c]Different letters indicate significant differences among the 4 light treatments ($P < 0.05$).

Table 1. Productive performance of broilers reared under white light (WL), red light (RL), green light (GL), and blue light (BL) at d 49 (g, mean ± SEM, n = 216)

Tissue	WL	RL	GL	BL
Carcass	1,998.88 ± 36.87[b]	1,924.12 ± 37.11[b]	2,121.19 ± 59.45[ab]	2,340.81 ± 47.63[a]
Breast muscle	424.25 ± 14.35[b]	411.40 ± 9.88[b]	453.60 ± 11.87[b]	515.11 ± 12.90[a]
Thigh	116.20 ± 3.62[ab]	112.50 ± 2.60[b]	126.10 ± 4.14[ab]	135.28 ± 3.58[a]
Crus	79.00 ± 2.95[ab]	73.87 ± 2.31[b]	83.00 ± 2.84[ab]	90.06 ± 2.52[a]
Net chamber[1]	1,432.75 ± 28.75[b]	1,412.73 ± 31.13[b]	1,550.60 ± 42.96[ab]	1,709.39 ± 39.47[a]

[a,b]Values not marked with the same letters differ significantly ($P < 0.05$).
[1]Carcass without abdominal fat, viscera, head, and shank.

chickens at 4 wk of age [8]. However, Levenick and Leighton [3] reported that female and male turkeys grew rapidly under blue light (**BL**) until 16 wk of age, and those under red light (**RL**) and white light (**WL**) were heavier after 18 wk.

Thus, it is obvious that light affected avian growth and productive performance. However, results from previous studies are not completely consistent, especially with respect to the use of colored light. These conflicts were probably due to differences of light source, light schedule, animal species, and age of experimental animals used in different investigations. In this study, a new light source, a light-emitting diode (**LED**) lamp, was introduced to clarify effects of monochromatic light on growth and productive performance of broilers and to understand the mechanism of its effects. At present, artificial illumination (controlling light duration, light intensity, or both) is widely used to improve broilers' productive performances by using a common light source. If use of LED lamps, a new and economical monochromatic light source, can promote broiler production, it would be important to broiler producers because its use would also reduce electricity consumption.

MATERIALS AND METHODS

Animals and Animal Husbandry

A total of 276 Arbor Acre male broilers [9] were used in this study. Twelve birds were killed on posthatching d 0 for removal of organ samples to measure myofiber area. The other 264 birds were randomly housed on d 0 in 3 separate rooms. Each room contained 4 light-control cells, 1 cell per light treatment. This resulted in 22 birds per cell or replicate and 66 birds per treatment. Birds were housed at a density of 11.5 birds/m^2.

Fifteen LED lamps were installed on a plastic board (width = 2 cm, length = 1 m). The distance between lamps was 6 cm. These LED lamps were placed 10 cm above the head of broilers by attachment of the plastic board to the cage ceiling. Energy output of LED lamps was tuned through changing voltage and current by a transformer (ref. Er et al. [10]). Their voltages were 13.36 V in WL, 9.56 V in RL, 13.89 V in GL, and 14.94 V in BL, respectively. The illuminance was measured daily using automatic range luminometer [11] to make a uniform illuminance (mean 15 lx) at bird-head level in all treatment groups. All light sources were equalized on the illuminance of 15 ± 0.2 lx at bird-head level and light period of 23 h daily (23L:1D; light off at 2300 h). All broilers were exposed to BL, GL, RL, or WL by LED system [12] for 7 wk, respectively. Chicks had ad libitum access to feed and water, and diets were formulated to meet or exceed the nutrient recommendations for poultry of the NRC [13]. Animal mortality and behavior in all treatment groups were observed daily, and no significant differ-

Table 2. Area of myofiber in major pectoral muscle of broilers reared under white light (WL), red light (RL), green light (GL), and blue light (BL) (μm^2, mean ± SEM, n = 36)

Age, d	WL	RL	GL	BL
0	94.27 ± 2.33[a]	97.75 ± 2.93[a]	91.24 ± 2.71[a]	95.34 ± 2.83[a]
21	892.80 ± 18.13[b]	682.53 ± 17.38[c]	1,051.17 ± 30.23[a]	853.30 ± 15.84[b]
49	2,188.04 ± 48.68[c]	2,176.66 ± 45.00[c]	2,409.73 ± 48.59[b]	2,648.88 ± 61.95[a]

[a–c]Values not marked with the same letters differ significantly ($P < 0.05$).

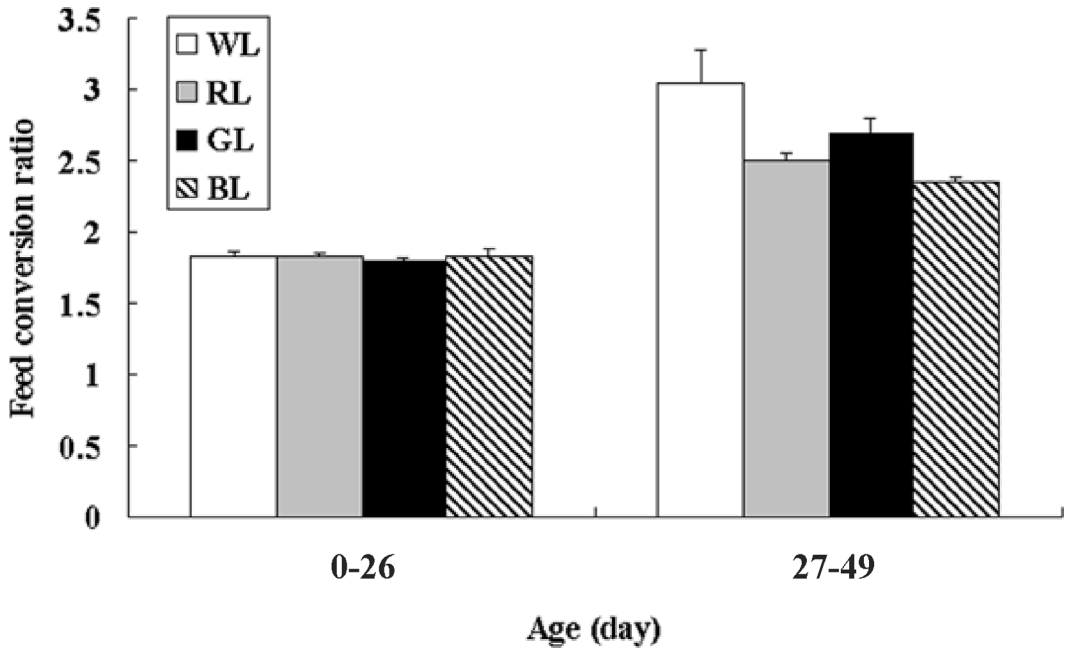

Figure 2. Feed conversion ratio of broilers reared under white light (WL), red light (RL), green light (GL), and blue light (BL) from d 0 (n = 264) to d 49 (n = 216). No significant difference was found among the various groups at different stages.

ences were found among groups. The mortalities were less than 5% during the entire experimental period.

Measurement of Productive Performance and Testosterone Level

Body weight (g) of each bird was measured daily by electronic scale at 0800 h. The feed intake (feed consumption, g) of birds per pen was recorded daily at 0800 h, and the feed conversion ratio of each pen was calculated [feed conversion ratio = feed intake (g)/net gain of BW (g)]. Carcass, net chamber (carcass without abdominal fat, viscera, head, and shank), breast muscle, thigh, and crus were weighted at the end of the experiment (d 49, n = 216).

All blood samples (n = 120) were collected from brachial vein in 0, 7, 21, 35, and 49 d at 0800 h. The testosterone concentration of plasma was examined by RIA [14].

Measurement of Myofiber Area in Major Pectoral Muscle

One chick from each replicate of each light treatment was killed under deep Nembutal anesthesia (50 μg/g of body weight) on 0, 7, 21, 35, and 49 d, respectively. Their major pectoral muscles were removed and fixed in 4% paraformaldehyde in 0.1 *M* phosphate buffer (pH 7.4, 4°C) for 48 h. Paraffin sections were made and were stained with hematoxylin and eosin. The myofiber area was measured by using Scion Image software [15].

Statistical Analysis

Data were shown as means ± SEM and were analyzed by 1-way ANOVA. Differences among groups were evaluated by least significant difference test [16]. The P values < 0.05 were considered significant.

RESULTS AND DISCUSSION

Growth and Productive Performance

Data on body weight and feed conversion were shown in Figures 1 and 2. According to alteration tendency of body weight, the growth and development of broilers were divided into 2 stages, including early period (0 to 26 d, Figure 1A) and later period (27 to 49 d, Figure 1B) in the experiment. During the early stage, body

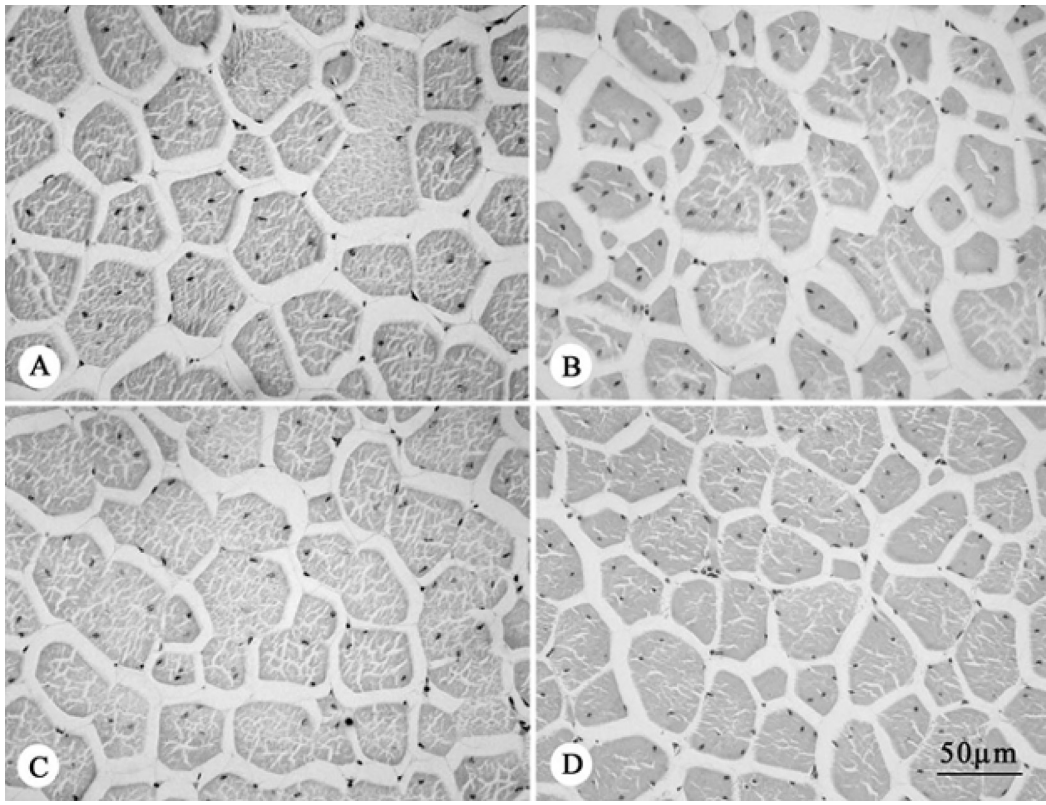

Figure 3. Morphology at d 49 of major pectoral muscle of broilers reared under white light (WL), red light (RL), green light (GL), and blue light (BL). The scale bar represents 50 μm. A: WL, the myofiber arranged orderly and the interspaces among myofibers were larger than those of GL and BL. B: RL, the area of myofiber was different and the interspaces among myofibers were larger than those of WL. C: GL, the myofiber arranged orderly. D: BL, the area of myofiber was uniform and interspaces among myofibers were smaller than those of RL and WL.

weight increased slowly in each group, but to an increasing extent was different in various treatment groups. In GL, body weight was the largest (883.96 ± 13.53 g at d 26) and the FCR was the lowest (1.80), but no significant difference was observed between GL and BL ($P > 0.05$). In contrast, the body weight increased significantly in each group during the later stage. From d 38 until the end of the experiment, broilers reared under BL had larger body weight than other groups (17.87%, $P < 0.05$) and had the lowest FCR (2.36). No significant difference in body weight was observed among GL, RL, and WL at d 49 ($P > 0.05$).

Broilers reared under BL were larger in the weights of carcass, breast muscle, thigh, crus, and net chamber at d 49 as compared with other light groups (carcass: 10.35 to 21.66%; breast muscle: 13.56 to 25.21%; thigh: 7.28 to 20.25%; crus: 8.51 to 21.92%; net chamber: 10.24 to 21.00%; $P < 0.05$, Table 1). Of these data, the weights of carcass, breast muscle, thigh, crus, and net chamber were lowest in the RL treatment.

As described above, monochromatic light could significantly affect broiler growth and development. The GL promoted broiler growth better at early stage, and the BL promoted broiler growth better at a later stage under an illumination intensity of 15 lx. A similar finding was reported by Halevy et al. [17] and Rozenboim et al. [18, 19]. However, some previous studies observed that long wavelengths (RL) promoted growth better than that of short wavelengths as reported in turkeys [3] and in Blackheaded Buntings [20]. The difference between previous reports and our results was probably due to the use of different light source, light schedule, animal

Table 3. Plasma testosterone of broilers reared under white light (WL), red light (RL), green light (GL), and blue light (BL) (pg/mL, mean ± SEM, n = 120)

Age, d	WL	RL	GL	BL
0	37.04 ± 0.51[a]	38.22 ± 0.69[a]	36.55 ± 0.37[a]	37.68 ± 0.87[a]
7	52.21 ± 1.64[b]	50.17 ± 1.20[b]	73.89 ± 0.86[a]	66.50 ± 1.02[a]
21	102.16 ± 1.10[b]	94.50 ± 1.02[b]	137.71 ± 1.90[a]	128.50 ± 1.43[a]
35	70.50 ± 0.61[b]	89.11 ± 1.33[b]	74.92 ± 0.44[b]	100.67 ± 0.68[a]
49	81.45 ± 1.36[bc]	88.27 ± 0.86[ab]	74.73 ± 0.55[c]	93.18 ± 1.55[a]

[a–c]Values not marked with the same letters differ significantly ($P < 0.05$).

species, or a confounding effect of light intensity because studies from others employed filtered light and intermittent light. However, we used LED lamps that are currently available commercially. Its major benefits were good efficiency, long operating life, moisture resistance and availability in different peak wavelengths. Although the light intensities of 4 LED lamps are different, we made a uniform illuminance (15 lx) at bird-head level in all treatment groups through changing energy output of lamps. Thus, the light intensity that projected onto broilers was uniform (15 lx) in all treatment groups. Also, our study showed the effect of monochromatic light under illumination intensity of 15 lx. These results indicated that use of LED would be helpful to improve broiler growth and productive performance if broiler producers chose the illuminations of green LED at early stage and of blue LED at a later stage according to various periods of development in broilers.

Myofiber Growth of Major Pectoral Muscle

We measured the area of the myofiber of major pectoral muscle of broilers reared under different light spectra. It was observed that the cross-section area of myofiber increased and the density of myofiber decreased significantly with increased age in all treatment groups. However, their changes were significantly different among various groups (Table 2). At d 21, the myofiber area of GL was the largest among all treatments (larger by 17.74 to 54.01% than other light groups, $P < 0.05$). On d 49, however, the myofiber area of BL became the largest (Figure 3), and it was larger by 9.92 to 21.69% than that of other light groups ($P < 0.05$).

Salomon et al. [21] considered that cross section area of muscle tissue increased with the age in avian. Our study further indicated that light stimulation could influence the myofiber growth in broiler skeleton muscle. As compared with other light groups, myofiber areas of major pectoral muscle were larger in GL at early period (0 to 26 d) and in BL at later period (27 to 49 d). These changes were in accordance with increased body weight as described above. The GL promoted growth of myofiber, which was probably due to the proliferation of skeletal muscle satellite cells and the increase of number of myofibers in GL [22].

Plasma Testosterone Level

Some reports found that photoperiod affected the plasma testosterone levels in broilers [23] but had no effect in turkeys [24]. In this study, we further measured the plasma testosterone level of broilers reared under various monochromatic lights by RIA. Results showed that monochromatic light could affect testosterone secretion (Table 3). During the early stage, plasma testosterone concentrations were higher in GL than in RL and WL (7 d: 41.52 to 47.28%; 21 d: 34.8 to 45.73%, $P < 0.05$), but no significant difference was observed between GL and BL ($P > 0.05$). In the later stage, the testosterone level of BL was higher than that of other groups (35 d: 12.97 to 42.79%; 49 d: 5.56 to 24.69%, $P < 0.05$).

It has been reported that muscle growth was regulated by hormone, neuronal innervation, and other growth factors. Of them, many reports demonstrated that testosterone regulated muscle accretion [25–27] and was essential to maintenance of muscle mass and force [28]. Our results indicated that the changes of testosterone level were in accordance with the inclinations of body weight increase and myofiber growth in broilers reared under various monochromatic lights. Our finding that blue and green lights were more effective to stimulate testosterone secretion may

reveal a mechanism by which light treatment induces myofiber growth in broilers.

CONCLUSIONS AND APPLICATIONS

1. Broiler growth and productive performance were increased when broilers were reared under green monochromatic light during the early stage and blue monochromatic light during the later stage at 15 lx.
2. Blue and green monochromatic lights promoted myofiber growth due to more effective stimulation of testosterone secretion.

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15. The major pectoral muscle was dehydrated, cleared, and embedded in paraffin. Serial sections were cut in 5 μm and mounted on gelatinized glass slides. Sections were deparaffinized in xylene and rehydrated in a graded alcohol series and were stained with hematoxylin and eosin. Photographs of myofiber were randomly taken in 5 cross-sections for each bird with microscope (BX51, Olympus, Tokyo, Japan) under 10 × magnification, and the myofiber's area was measured by using Scion Image software (Scion Image for Windows. Version Beta 4.0.2. Scion Co., Frederick, MD).

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