In the poultry production chain, the meat quality is being given priority due to rising health concerns and disease threat in humans. Meat quality has generally been evaluated in terms of appearance (i.e., flesh color), physical characteristics (i.e., muscle pH, water-holding capacity, texture, tenderness), and chemical characteristics [i.e., protein, amino acids (AA), lipids, fatty acids; Lawrie, 1991]. Currently, consuming meat with less fat and high protein is of foremost importance in nutritionally aware societies. Further, the consumption of saturated (SFA) and n-6 polyunsaturated fatty acids (PUFA) has elevated the risk of cardiovascular diseases, whereas the consumption of n-3 PUFA has been involved in reducing this incidence (Simopoulos, 2009). In poultry, the chicken thigh has been known to contain the highest concentration of PUFA (28%) and monounsaturated fatty acids (MUFA; 50%), but the lowest concentration of SFA (32%) compared with other meats (Schmid, 2011). Jakobsen (1999) reported a lower cholesterol content (60 to 90 mg/100 g) in raw chicken meat. Despite having an improved fatty acid profile in broiler meat compared with other meat species, efforts are still directed to reduce the SFA and to enrich the broiler meat with PUFA, especially emphasizing n-3 fatty acids. Another area in meat quality is the composition and proportion of AA contents. However, the question that needs to be answered is which essential AA (EAA) of meat protein is most important in broiler chickens (Matusovicova, 1986). The capacity of a protein to meet the AA requirements is dependent on the AA composition and digestibility of the protein and on the physiological, nutritional, and health status of the animal. These factors interact in a complex manner to modify the overall utilization (Pellett and Young, 1984).

Among the environmental concerns, several factors such as the rearing system (Wattanachant et al., 2002;
Od-Ton et al., 2004; Wattanachant et al., 2007), age (Lawrie, 1991; Nishimura et al., 1996; Fang et al., 1999; Nakamura et al., 2004), densities, ambient temperature, and pre-slaughter stress (Aksit et al., 2006; Bianchi et al., 2007; Lu et al., 2007) have been involved to alter meat quality in broilers. Being influential in the rearing systems, light may have influence on the growth and meat quality of broiler chickens. Earlier, the reduced lighting pattern at an immature stage of mass development in broilers has been investigated to profoundly exacerbate breast meat yield (Renden et al., 1993). Furthermore, the studies by Charles et al. (1992) suggested that broiler carcass has a lower percentage of body fat and higher percentage of body protein in high light intensity.

Light-emitting diode (LED) is becoming an alternative for future general lighting applications, with huge energy savings compared with conventional light sources because of their high efficiency and reliability (Matioli et al., 2012). In our previous study, short-wavelength LED (yellow, blue, or green) were found to be beneficial; in particular, yellow LED ameliorated growth and hematological responses in broilers (Kim et al., 2013). Likewise, the impact of monochromatic lights, such as blue-green, on the meat quality via growth and muscle development has been reported recently (Rozenboim et al., 2004; Karakaya et al., 2009; Ke et al., 2011) and is associated with promoting satellite cell myogenic processes (Cao et al., 2008; Liu et al., 2010).

In a continuation of our previous research on the effect of LED on broiler growth, the present experiment investigates the impact of varying color (wavelength) on the quality and nutritional profile of broiler meat.

**MATERIALS AND METHODS**

The experimental protocol was approved by the Committee on Animal Research and Ethics, National Institute of Animal Science, Rural Development Administration, Republic of Korea.

**Birds, Housing, and Feed**

After procurement, all the 1-d-old chicks (n = 360) were randomly (irrespective of the sex) allocated to the experimental pens. The house was divided into 6 rooms (source groups), lightproof and environmentally controlled, separated from each other by wooden chip board with 6 pens in a room. The pens in each room were separated by using a wire fence, with 10 birds in each pen. A floor space of 0.093 m² was provided for each bird. The feed and water were provided ad libitum throughout the experimental period. The room temperature was kept at 32°C for the first 3 d and then reduced to 0.5°C daily until 24°C was attained. This temperature was maintained until the termination of the experiment (i.e., d 35). The birds were fed 3 diets with 23.2, 21.2, and 19.4% CP and ME of 3,062, 3,102, and 3,155 kcal/kg in 3 growing phases [i.e., 0–2, 2–4, and 5 wk of age, respectively (Table 1)]. The diets were formulated as per the Korean Feeding Standards for Poultry (2007).

**Lighting Design, Installation, and Measurement**

The LED lamps were designed and assembled by the National Institute of Animal Science. Sixty-eight LED of the same color were installed in single line on a plastic board (width = 3 cm, length = 1 m). The electric voltage for the LED lamps was as follows: red light (RL) and yellow light (YL) = 2.2 V, white light (WL) = 3.3 V, and green light (GL) and blue light (BL) = 3.4 V. The LED lamps were provided with the same forward current of I = 20 mA. A 60-W incandescent light bulb (IBL, 2,600 to 3,200 K) as a control, and WL (2,800 to 3,200 K), BL (450 to 460 nm), RL (600 to 630 nm), GL (510 to 530 nm), and YL (580 to 590 nm) produced by LED lamps were provided as the 6 light sources. The wavelengths of LED colors were measured by Chroma Meter CL 200, Konica Minolta Sensing Inc., Tokyo, Japan. The instrument displayed the values of each light color for the x- and y-axis, which were matched with a standard chromatogram at both axis, and the resultant values were considered as the wavelength of a particular color. All light fixtures were installed above each replicate and equalized to a light intensity of 15 ± 0.2 lx at bird level. The light schedule was constant during the entire experiment, consisting of 23L:1D.

<table>
<thead>
<tr>
<th>Table 1. Dietary composition of the diets in different growing phases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
</tr>
<tr>
<td>-------------------------------</td>
</tr>
<tr>
<td>Ingredient (%)</td>
</tr>
<tr>
<td>Corn</td>
</tr>
<tr>
<td>Wheat bran</td>
</tr>
<tr>
<td>Soyabean meal</td>
</tr>
<tr>
<td>Corn gluten meal</td>
</tr>
<tr>
<td>Soyabean oil</td>
</tr>
<tr>
<td>Calcium carbonate</td>
</tr>
<tr>
<td>Calcium phosphate</td>
</tr>
<tr>
<td>Methionine</td>
</tr>
<tr>
<td>Lysine</td>
</tr>
<tr>
<td>Vitamin premix</td>
</tr>
<tr>
<td>Trace mineral premix</td>
</tr>
<tr>
<td>Salt</td>
</tr>
<tr>
<td>Binding agent</td>
</tr>
<tr>
<td>Nutrient (% or otherwise stated)</td>
</tr>
<tr>
<td>CP</td>
</tr>
<tr>
<td>ME (kcal/kg)</td>
</tr>
<tr>
<td>Ca</td>
</tr>
<tr>
<td>Available P</td>
</tr>
</tbody>
</table>

1Provided per kilogram of diet: iron, 71.6 mg; copper, 11.0 mg; manganese, 178.7 mg; zinc, 178.7 mg; iodine, 3.0 mg; selenium, 0.4 mg; vitamin A (retinyl acetate), 18,904.3 IU; vitamin D₃ (cholecalciferol), 9,480.0 IU; vitamin E (dl-α-tocopheryl acetate), 63.0 IU; vitamin K activity, 6.4 mg; thiamine, 3.2 mg; riboflavin, 9.4 mg; pantethenic acid, 34.7 mg; niacin, 126.0 mg; pyridoxine, 4.7 mg; folic acid, 1.6 mg; biotin, 0.5 mg; vitamin B₁₂, 35.4 g; choline, 956.9 mg.
Data Collection

On d 35, 12 birds from each source (2 birds per replicate) were randomly selected, killed, processed, and eviscerated in a local commercial slaughterhouse. After evisceration, the birds were apportioned by hand into commercial cuts. Left side breasts (white meat) were placed in plastic bags and refrigerated (4 to 6°C). At the laboratory, the samples were frozen at −18°C until they were analyzed.

Laboratory Analysis

Shear Force Measurement. The Warner-Bratzler (WB) measurement was done for shear force using 12 meat samples for each LED sources. At room temperature, samples (strips with 19 mm width) were sheared perpendicular to the longitudinal orientation of the muscle fibers by a TA-XT Plus Texture Analyzer (Stable Micro Systems, Surrey, UK) fitted with a 30-kg load cell and Texture Exponent 32 version 3.0.3.0 software. A TA-7 WB shear type blade was used. Test settings included a button-type trigger, 55 mm travel distance, 4 mm per second test speed, and calibration return distance of 1 mm. The maximum force measured to cut the strips was expressed in kilograms per centimeter². For each breast muscle, one strip was sheared in 2 locations and the strip heights at each shear point were recorded and used for data analysis (Zhuang et al., 2007).

Water-Holding Capacity. The water-holding capacity was evaluated 5 h after slaughter, using the methodology described by Hamm (1960). The evaluation is based on measuring water loss when a pressure is applied to the muscle. Meat cubes of 0.5 g from each of 12 meat samples were placed between 2 filter papers and 2 glass plates, and a 10-kg weight was placed on the top of the glass plate for 5 min. The difference in the breast muscle weight before and after the procedure represents the water loss. The results were expressed as a percentage of exudated water in relation to the initial sample weight.

Cooking Loss. The cooking loss was determined 5 h after slaughter in an oven prewarmed to 170°C. Twelve crude breast muscle samples for each LED source were weighed and put in trays with aluminum grills previously dried in an incubator. The trays were placed inside the oven until the sample core temperature reached 75°C. Samples were cooled at room temperature and reweighed, and cooking loss was calculated as the difference between the initial and the final sample weights.

Water, Protein, and Ash Contents. The water, protein, and ash contents were measured by the AOAC method (AOAC International, 2005) using 2 samples from each replicate (12 samples per LED treatment). Five grams of minced meat from each sample were dried in an aluminum pan at 100°C for 18 h. The samples were weighed after being cooled at room temperature in desiccators.

Total Lipid and Fatty Acid Contents. The total lipids were extracted according to the method of Folch et al. (1957) and lipid contents were determined gravimetrically from 12 samples per LED group. Total lipids were converted to fatty acid methyl esters. Fatty acid methyl esters were separated and quantified by an automated gas chromatograph (model 6890 N, GC, Agilent Technologies, Santa Clara, CA) equipped with flame ionization detectors and a 30 m × 530 μm i.d. capillary column (model HP-FFAP). The Hewlett-Packard Chem Station (Agilent Technologies, Santa Clara, CA) was used to integrate peak areas.

After obtaining individual fatty acids, the concentrations of SFA, UFA, MUFA, and PUFA were calculated. The value of total SFA was calculated by adding the analyzed values of myristic (Myri-A), palmitic (Palm-A), and stearic acid (Stea-A). Similarly, the UFA was obtained by adding the analyzed values of palmitoleic acid (Palc-A), oleic acid (Olei-A), vaccenic acid (Vacc-A), linoleic acid (Lino-A), γ-linoleic acid (γ-Lino-A), linolenic acid (Linc-A), eicosenoic acid (Eico-A), and arachidonic acid (Arac-A). The MUFA was calculated by adding analyzed palmitoleic acid, oleic acid, vaccenic acid, and eicosenoic acid values. The PUFA concentration was obtained by collecting values of Lino-A, γ-Lino-A, Linc-A, and Arac-A. Then the ratio between SFA and PUFA (SFA:PUFA) was calculated by dividing SFA with PUFA. The n-6 was calculated by adding the values of Lino-A, γ-Lino-A, and Arac-A, whereas the Linc-A was the only one analyzed n-3 fatty acid. The ratio between n-6 and n-3 (n-6:n-3) was calculated by dividing n-6 with n-3 (Linc-A).

Total Protein and AA Composition. The levels of AA in the muscles were related to 100% of dry weight. Twelve breast samples from each LED source was taken for the AA analysis. After acid hydrolysis of muscles in 6 N HCl at 110°C for 24 h, the levels of AA were determined on the basis of a color reaction between an AA and ninhydrine (oxidizing agent) using an automatic AA analyzer (AAA L-8900, manufactured by Hitachi High-Technologies Corporation, Tokyo, Japan). The following AA were monitored: Cys, Met, Asp, Thr, Ser, Glu, Gly, Pro, Ala, Val, Ile, Leu, Tyr, Phe, His, Lys, and Arg.

After analyzing all the AA present, they were then categorized as EAA and nonessential AA (NEAA). The EAA was constituted by adding the analyzed values of Cys, Met, Thr, Val, Ile, Leu, Tyr, Phe, Lys, and His, whereas the NEAA were calculated by adding Asp, Ser, Glu, Gly, Ala, Arg, and Pro. Further, the ratio between EAA and NEAA (EAA:NEAA) was calculated by dividing EAA with NEAA.

Statistical Analysis

The data were analyzed by one-way ANOVA under completely randomized design using the Statistical
Analysis System (SAS Institute Inc., 2003). There were 6 experimental units per LED group, and the mean of 2 birds per replicate served as an experimental unit for the analysis. The mean comparisons were assessed by Tukey’s test and the level of significance was based on $P < 0.001$ or otherwise stated.

## RESULTS

### Meat Quality Traits

The data obtained for different attributes (shear force, water-holding capacity, cooking loss) of breast meat quality in different LED colors is presented in Table 2. Shear force was affected by light sources ($P < 0.001$); however, the values were statistically similar to control treatment. Among LED treatments, the higher values for shear force was observed under YL. The other meat quality traits, such as water-holding capacity and cooking loss, were found to be unaffected in all LED groups.

### Chemical Contents in Meat

The data related to the chemical content analysis of breast meat are presented in Table 3. The lipid content of meat was significantly ($P < 0.001$) affected in LED and IBL (control) groups. The lowest lipid content was observed in IBL (1.67%), whereas among LED group it was highest in RL (3.10%). The other chemical contents of meat, such as water, protein, and ash contents, were not affected by any light source.

### Fatty Acid Composition

The fatty acid composition of broiler meat is presented in Table 4. The LED and IBL light affected all the fatty acid contents except Myri-A, Vacc-A, γ-Lino-A, and Eico-A ($P < 0.001$). The RL remained most effective in increasing the concentration of the Palm-A (22.30%; SFA), Palc-A (5.52%; MUFA), and Olei-A (38.30%; MUFA), but reduced the concentration of Lino-A (22.49%; PUFA-ω), Linc-A (1.88%; PUFA-ω), and Arac-A (0.32%, PUFA-ω). The concentration of Stea-A was higher (6.59%) in BL and lower in YL (5.80%), which was statistically similar to IBL (5.81%). A significantly higher (2.26%) value of Linc-A was observed in the IBL group. The concentration of Arac-A was higher in GL and IBL groups.

The collective analysis of all SFA, UFA, MUFA, PUFA, omega fatty acids, and their ratios are presented in Table 5. All the LED and IBL groups influenced the collective parameters; however, among LED treatments, RL showed the highest ($P < 0.001$) concentration of SFA (29.27%), MUFA (45.88%), and SFA:PUFA (1.18%), but the lowest concentration of UFA (70.74%), PUFA (24.86%), $n$-6 (29.98%), and $n$-3 (1.88%). The control (IBL) group equally affected the collective values of fatty acid composition. The IBL decreased the SFA (27.05%) and $n$-6:$n$-3 ratio (12.17%) but increased $n$-3 (2.26%).

### AA Composition

The analyzed values of AA of broiler meat samples are presented in Table 6. The higher values of NEAA

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### Table 2. Meat quality parameters in broiler breast meat under different monochromatic lights (n = 6)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Shear force (kg/cm²)</th>
<th>Water-holding capacity (%)</th>
<th>Cook loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WL</td>
<td>1.76 ± 0.22b</td>
<td>54.04 ± 0.31</td>
<td>17.73 ± 1.18</td>
</tr>
<tr>
<td>BL</td>
<td>1.92 ± 0.15b</td>
<td>56.06 ± 1.20</td>
<td>17.96 ± 0.51</td>
</tr>
<tr>
<td>RL</td>
<td>2.09 ± 0.11ab</td>
<td>54.99 ± 1.31</td>
<td>19.09 ± 0.39</td>
</tr>
<tr>
<td>GL</td>
<td>2.15 ± 0.13ab</td>
<td>54.58 ± 0.65</td>
<td>17.93 ± 0.65</td>
</tr>
<tr>
<td>YL</td>
<td>2.45 ± 0.09 destinations</td>
<td>55.56 ± 1.01</td>
<td>18.92 ± 1.48</td>
</tr>
<tr>
<td>IBL</td>
<td>2.33 ± 0.13ab</td>
<td>56.03 ± 0.99</td>
<td>19.75 ± 0.60</td>
</tr>
</tbody>
</table>

*Means with different superscripts in the same column differ significantly ($P < 0.001$).

1WL = white light; BL = blue light; RL = red light; GL = green light; YL = yellow light; IBL = incandescent light (control).

### Table 3. Chemical contents (%) of broiler breast meat under different monochromatic lights (n = 6)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Water</th>
<th>Lipid</th>
<th>Protein</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>WL</td>
<td>74.01 ± 0.51</td>
<td>1.83 ± 0.46b</td>
<td>22.98 ± 0.09</td>
<td>0.77 ± 0.03</td>
</tr>
<tr>
<td>BL</td>
<td>74.09 ± 0.17</td>
<td>2.09 ± 0.31b</td>
<td>22.56 ± 0.23</td>
<td>0.80 ± 0.03</td>
</tr>
<tr>
<td>RL</td>
<td>73.42 ± 0.15</td>
<td>3.10 ± 0.40b</td>
<td>22.36 ± 0.23</td>
<td>0.78 ± 0.02</td>
</tr>
<tr>
<td>GL</td>
<td>74.00 ± 0.37</td>
<td>2.22 ± 0.35ab</td>
<td>22.39 ± 0.13</td>
<td>0.82 ± 0.01</td>
</tr>
<tr>
<td>YL</td>
<td>74.23 ± 0.31</td>
<td>2.24 ± 0.40ab</td>
<td>22.54 ± 0.45</td>
<td>0.79 ± 0.02</td>
</tr>
<tr>
<td>IBL</td>
<td>74.17 ± 0.32</td>
<td>1.67 ± 0.25b</td>
<td>22.99 ± 0.29</td>
<td>0.79 ± 0.03</td>
</tr>
</tbody>
</table>

*Means with different superscripts in the same column differ significantly ($P < 0.001$).

1WL = white light; BL = blue light; RL = red light; GL = green light; YL = yellow light; IBL = incandescent light (control).

---
Table 4. Fatty acid composition (%) of broiler breast meat under different monochromatic lights (n = 6)1

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Myri-A (C14:0)</th>
<th>Palm-A (C16:0)</th>
<th>Stea-A (C18:0)</th>
<th>Palc-A (C16:ln-7)</th>
<th>Olei-A (C18:ln-9)</th>
<th>Vacc-A (C18:ln-7)</th>
<th>Lino-A (C18:2n-6)</th>
<th>γ-Lino-A (C18:3n-6)</th>
<th>Linc-A (C18:3n-3)</th>
<th>Eico-A (C20:ln-9)</th>
<th>Arac-A (C20:4n-6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WL</td>
<td>0.69 ± 0.01</td>
<td>20.91 ± 0.10ab</td>
<td>6.03 ± 0.24ab</td>
<td>4.86 ± 0.22b</td>
<td>37.02 ± 0.27b</td>
<td>1.68 ± 0.04</td>
<td>25.66 ± 0.19a</td>
<td>0.18 ± 0.01</td>
<td>2.09 ± 0.03bc</td>
<td>0.48 ± 0.02</td>
<td>0.41 ± 0.04ab</td>
</tr>
<tr>
<td>BL</td>
<td>0.70 ± 0.01</td>
<td>21.01 ± 0.24b</td>
<td>6.59 ± 0.20b</td>
<td>4.22 ± 0.15b</td>
<td>36.27 ± 0.17b</td>
<td>1.58 ± 0.02</td>
<td>26.52 ± 0.46a</td>
<td>0.16 ± 0.01</td>
<td>2.11 ± 0.04bc</td>
<td>0.37 ± 0.01</td>
<td>0.43 ± 0.01ab</td>
</tr>
<tr>
<td>RL</td>
<td>0.72 ± 0.03</td>
<td>22.30 ± 0.13a</td>
<td>6.25 ± 0.05b</td>
<td>5.52 ± 0.09b</td>
<td>38.30 ± 0.35b</td>
<td>1.58 ± 0.07</td>
<td>22.19 ± 0.12b</td>
<td>0.17 ± 0.01</td>
<td>1.88 ± 0.02d</td>
<td>0.38 ± 0.01</td>
<td>0.32 ± 0.04b</td>
</tr>
<tr>
<td>GL</td>
<td>0.69 ± 0.01</td>
<td>21.28 ± 0.20b</td>
<td>6.09 ± 0.16ab</td>
<td>4.68 ± 0.21b</td>
<td>36.88 ± 0.42b</td>
<td>1.61 ± 0.02</td>
<td>25.62 ± 0.66a</td>
<td>0.16 ± 0.01</td>
<td>2.06 ± 0.03c</td>
<td>0.45 ± 0.01</td>
<td>0.48 ± 0.04a</td>
</tr>
<tr>
<td>YL</td>
<td>0.70 ± 0.01</td>
<td>20.58 ± 0.31b</td>
<td>5.80 ± 0.16b</td>
<td>4.54 ± 0.11b</td>
<td>36.89 ± 0.26b</td>
<td>1.54 ± 0.04</td>
<td>26.69 ± 0.36a</td>
<td>0.18 ± 0.01</td>
<td>2.21 ± 0.02ab</td>
<td>0.36 ± 0.01</td>
<td>0.43 ± 0.04ab</td>
</tr>
<tr>
<td>IBL</td>
<td>0.69 ± 0.01</td>
<td>20.56 ± 0.15b</td>
<td>5.81 ± 0.11b</td>
<td>4.73 ± 0.24b</td>
<td>36.46 ± 0.17b</td>
<td>1.58 ± 0.03</td>
<td>26.80 ± 0.46a</td>
<td>0.19 ± 0.01</td>
<td>2.26 ± 0.05a</td>
<td>0.47 ± 0.01</td>
<td>0.48 ± 0.02a</td>
</tr>
</tbody>
</table>

1Myri-A = myristic acid; Palm-A = palmitic acid; Stea-A = stearic acid; Palc-A = palmitoleic acid; Olei-A = oleic acid; Vacc-A = vaccenic acid; Lino-A = linoleic acid; γ-Lino-A = γ-linoleic acid; Linc-A = linolenic acid; Eico-A = eicosanoic acid; and Arac-A = arachidonic acid.

2WL = white light; BL = blue light; RL = red light; GL = green light; YL = yellow light; IBL = incandescent light (control).

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Table 5. The composition (%) of saturated (SFA), unsaturated (UFA) monounsaturated (MUFA), polyunsaturated (PUFA), n-6, and n-3 fatty acids and their ratios in broiler meat as affected by different monochromatic lights (n = 6)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>SFA</th>
<th>UFA 2</th>
<th>MUFA</th>
<th>PUFA</th>
<th>SFA:PUFA</th>
<th>n-6</th>
<th>n-3</th>
<th>n-6:n-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>WL</td>
<td>27.62 ± 0.33b</td>
<td>72.38 ± 0.33a</td>
<td>44.04 ± 0.35b</td>
<td>28.34 ± 0.22a</td>
<td>0.97 ± 0.01b</td>
<td>26.26 ± 0.21a</td>
<td>2.09 ± 0.03bc</td>
<td>12.60 ± 0.15abc</td>
</tr>
<tr>
<td>BL</td>
<td>28.31 ± 0.43b</td>
<td>71.70 ± 0.43b</td>
<td>42.53 ± 0.34b</td>
<td>29.16 ± 0.49a</td>
<td>0.97 ± 0.03b</td>
<td>27.06 ± 0.46a</td>
<td>2.11 ± 0.04bc</td>
<td>12.84 ± 0.04a</td>
</tr>
<tr>
<td>RL</td>
<td>29.27 ± 0.13a</td>
<td>70.74 ± 0.13a</td>
<td>45.88 ± 0.28a</td>
<td>24.86 ± 0.15b</td>
<td>1.18 ± 0.003a</td>
<td>22.98 ± 0.13b</td>
<td>1.88 ± 0.02d</td>
<td>12.24 ± 0.08bc</td>
</tr>
<tr>
<td>GL</td>
<td>28.06 ± 0.30b</td>
<td>71.94 ± 0.30b</td>
<td>43.62 ± 0.46b</td>
<td>28.32 ± 0.72a</td>
<td>0.99 ± 0.04b</td>
<td>26.26 ± 0.69a</td>
<td>2.06 ± 0.03d</td>
<td>12.75 ± 0.21ab</td>
</tr>
<tr>
<td>YL</td>
<td>27.08 ± 0.45b</td>
<td>72.92 ± 0.45b</td>
<td>43.42 ± 0.38b</td>
<td>29.50 ± 0.38a</td>
<td>0.92 ± 0.02b</td>
<td>27.29 ± 0.40a</td>
<td>2.21 ± 0.02bc</td>
<td>12.40 ± 0.30abc</td>
</tr>
<tr>
<td>IBL</td>
<td>27.05 ± 0.18b</td>
<td>72.95 ± 0.18a</td>
<td>43.23 ± 0.38b</td>
<td>29.72 ± 0.48a</td>
<td>0.91 ± 0.01b</td>
<td>27.46 ± 0.43a</td>
<td>2.26 ± 0.05a</td>
<td>12.17 ± 0.44c</td>
</tr>
</tbody>
</table>

1a–d Means with different superscripts in the same column differ significantly (P < 0.001).

2WL = white light; BL = blue light; RL = red light; GL = green light; YL = yellow light; IBL = incandescent light (control).

UFA = MUFA + PUFA.
such as Gly (1.00%), Ala (1.36%), and Asp (2.16%), and EAA such as Thr (1.05%), Val (0.97%), Ile (0.94%), Lys (2.08%), and His (0.89%) were observed under WL ($P < 0.01$) compared with other LED and IBL (control) groups. The Met (0.58%), Cys (0.26%), and Pro (0.96%) contents of meat were higher in the IBL group. The Arg (1.27%) was higher under YL, whereas Ala (1.24%), Cys (0.24%), and Val (0.90%) were lower under the same lighting group. A lower content of Pro (0.83%) was observed under BL, lower content of Asp (2.03%) and Arg (1.21%) under RL, and lower content of Gly (0.91%) under GL. The concentrations of Glu, Ser, Leu, Try, and Phe in breast meat were not influenced by either LED or IBL groups.

The collective values of the EAA, NEAA, and their ratio is presented in Table 7. The WL significantly improved the EAA and NEAA concentration in chicken meat compared with other LED and IBL groups ($P < 0.001$). The EAA:NEAA was unaffected by LED or IBL groups.

### DISCUSSION

The impact of monochromatic light on meat quality and composition of broiler meat has been verified in the current experiment. Among the meat quality traits, shear force is the most direct measurement of meat tenderness/texture and its higher values are most of the time linked with coarse texture of broiler meat (Xiong et al., 2006). In the present experiment, the higher values of shear force under the YL group indicated soft muscles per se. Karakaya et al. (2009) found that the breast and drumstick muscles obtained from green-blue mix lighting had the highest penetrometer values, which indicates the softest structure of the muscles. It could further be suggested from the aforementioned results that the impact of monochromatic light on meat tenderness is related to the fast growth rate in monogastrics (Ellis et al., 1996).

The rise in breast meat lipids under RL might lead to the assumption of Bowlby (1957) that RL in-

### Table 6. Amino acid composition (%) of broiler breast meat under different monochromatic lights (n = 6)

<table>
<thead>
<tr>
<th>Item</th>
<th>WL</th>
<th>BL</th>
<th>RL</th>
<th>GL</th>
<th>YL</th>
<th>IBL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonessential amino acid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pro</td>
<td>0.90 ± 0.01abc</td>
<td>0.83 ± 0.01c</td>
<td>0.87 ± 0.04abc</td>
<td>0.95 ± 0.01ab</td>
<td>0.86 ± 0.03bc</td>
<td>0.96 ± 0.01a</td>
</tr>
<tr>
<td>Gly</td>
<td>3.54 ± 0.02a</td>
<td>3.51 ± 0.03a</td>
<td>3.39 ± 0.02b</td>
<td>3.39 ± 0.03b</td>
<td>3.39 ± 0.03b</td>
<td>3.45 ± 0.02ab</td>
</tr>
<tr>
<td>Ala</td>
<td>1.00 ± 0.01a</td>
<td>0.96 ± 0.01b</td>
<td>0.93 ± 0.01bc</td>
<td>0.91 ± 0.01c</td>
<td>0.93 ± 0.01c</td>
<td>0.93 ± 0.01c</td>
</tr>
<tr>
<td>Asp</td>
<td>1.36 ± 0.01a</td>
<td>1.32 ± 0.01ab</td>
<td>1.27 ± 0.01c</td>
<td>1.25 ± 0.01cd</td>
<td>1.24 ± 0.02e</td>
<td>1.29 ± 0.01f</td>
</tr>
<tr>
<td>Cys</td>
<td>0.91 ± 0.01a</td>
<td>0.91 ± 0.01a</td>
<td>0.86 ± 0.01b</td>
<td>0.86 ± 0.01b</td>
<td>0.87 ± 0.01b</td>
<td>0.88 ± 0.01b</td>
</tr>
<tr>
<td>Thr</td>
<td>2.16 ± 0.01a</td>
<td>2.11 ± 0.02ab</td>
<td>2.03 ± 0.01c</td>
<td>2.05 ± 0.01bc</td>
<td>2.05 ± 0.02bc</td>
<td>2.08 ± 0.01bc</td>
</tr>
<tr>
<td>Val</td>
<td>0.25 ± 0.01ab</td>
<td>0.25 ± 0.01ab</td>
<td>0.25 ± 0.01ab</td>
<td>0.25 ± 0.01ab</td>
<td>0.24 ± 0.01ab</td>
<td>0.26 ± 0.01a</td>
</tr>
<tr>
<td>Ile</td>
<td>0.56 ± 0.01ab</td>
<td>0.57 ± 0.01ab</td>
<td>0.55 ± 0.01ab</td>
<td>0.55 ± 0.01ab</td>
<td>0.55 ± 0.01ab</td>
<td>0.58 ± 0.01a</td>
</tr>
<tr>
<td>Leu</td>
<td>1.05 ± 0.01a</td>
<td>1.03 ± 0.01ab</td>
<td>0.99 ± 0.01c</td>
<td>1.00 ± 0.01d</td>
<td>1.00 ± 0.01d</td>
<td>1.01 ± 0.01d</td>
</tr>
<tr>
<td>Met</td>
<td>0.97 ± 0.01a</td>
<td>0.95 ± 0.01ab</td>
<td>0.92 ± 0.01bc</td>
<td>0.91 ± 0.01cd</td>
<td>0.91 ± 0.01cd</td>
<td>0.94 ± 0.01cd</td>
</tr>
<tr>
<td>Phe</td>
<td>0.94 ± 0.01a</td>
<td>0.92 ± 0.01ab</td>
<td>0.90 ± 0.01ab</td>
<td>0.90 ± 0.01ab</td>
<td>0.89 ± 0.01ab</td>
<td>0.92 ± 0.01ab</td>
</tr>
<tr>
<td>Glu</td>
<td>1.84 ± 0.01a</td>
<td>1.83 ± 0.02a</td>
<td>1.76 ± 0.01b</td>
<td>1.77 ± 0.01b</td>
<td>1.80 ± 0.02b</td>
<td>1.81 ± 0.01b</td>
</tr>
<tr>
<td>Arg</td>
<td>0.73 ± 0.01a</td>
<td>0.74 ± 0.01a</td>
<td>0.70 ± 0.01b</td>
<td>0.69 ± 0.01b</td>
<td>0.69 ± 0.01b</td>
<td>0.70 ± 0.01b</td>
</tr>
<tr>
<td>His</td>
<td>1.09 ± 0.03a</td>
<td>1.08 ± 0.03a</td>
<td>1.06 ± 0.01a</td>
<td>1.06 ± 0.01a</td>
<td>1.08 ± 0.02b</td>
<td>1.10 ± 0.01b</td>
</tr>
<tr>
<td>Ser</td>
<td>2.08 ± 0.06a</td>
<td>1.95 ± 0.02ab</td>
<td>1.93 ± 0.05b</td>
<td>1.84 ± 0.01b</td>
<td>1.89 ± 0.02a</td>
<td>1.89 ± 0.01b</td>
</tr>
<tr>
<td>Arg</td>
<td>0.89 ± 0.02a</td>
<td>0.80 ± 0.01bc</td>
<td>0.77 ± 0.01c</td>
<td>0.80 ± 0.01bc</td>
<td>0.78 ± 0.02c</td>
<td>0.84 ± 0.01bc</td>
</tr>
<tr>
<td>Pro</td>
<td>1.25 ± 0.01ab</td>
<td>1.23 ± 0.01ab</td>
<td>1.21 ± 0.01b</td>
<td>1.22 ± 0.01b</td>
<td>1.27 ± 0.02b</td>
<td>1.24 ± 0.01ab</td>
</tr>
</tbody>
</table>

$^a$–$^d$Means with different superscripts in the same column differ significantly ($P < 0.01$).

1WL = white light; BL = blue light; RL = red light; GL = green light; YL = yellow light; IBL = incandescent light (control).

### Table 7. The composition (%) of essential amino acids (EAA), nonessential amino acids (NEAA), and their ratio (EAA:NEAA) in broiler breast meat as affected by different monochromatic lights (n = 6)

<table>
<thead>
<tr>
<th>Attribute</th>
<th>EAA</th>
<th>NEAA</th>
<th>EAA:NEAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>WL</td>
<td>10.40 ± 0.14a</td>
<td>11.10 ± 0.06a</td>
<td>0.94 ± 0.008</td>
</tr>
<tr>
<td>BL</td>
<td>10.11 ± 0.16ab</td>
<td>10.86 ± 0.09ab</td>
<td>0.93 ± 0.005</td>
</tr>
<tr>
<td>RL</td>
<td>9.83 ± 0.06b</td>
<td>10.54 ± 0.07b</td>
<td>0.93 ± 0.009</td>
</tr>
<tr>
<td>GL</td>
<td>9.85 ± 0.03b</td>
<td>10.63 ± 0.06b</td>
<td>0.92 ± 0.004</td>
</tr>
<tr>
<td>YL</td>
<td>9.81 ± 0.08b</td>
<td>10.60 ± 0.09b</td>
<td>0.92 ± 0.004</td>
</tr>
<tr>
<td>IBL</td>
<td>10.06 ± 0.08ab</td>
<td>10.82 ± 0.06ab</td>
<td>0.93 ± 0.002</td>
</tr>
</tbody>
</table>

$^a$–$^b$Means with different superscripts in the same column differ significantly ($P < 0.001$).

1WL = white light; BL = blue light; RL = red light; GL = green light; YL = yellow light; IBL = incandescent light (control).

2EAA was constituted by adding the analyzed values of Cys, Met, Thr, Val, Ile, Leu, Tyr, Phe, Lys, and His.

3NEAA were calculated by adding the analyzed values of Asp, Ser, Glu, Gly, Ala, Arg, and Pro.
creased feeding behavior in birds that in turn caused accumulation of more lipids in meat. However, it has been suggested that access to the natural environment (fresh air and sunlight) results in differences in terms of the structural manifestations of tissues and organs, as well as in biochemical processes involved in metabolism (Bogosavljević-Bošković et al., 2006). The effect of rearing system on the nutritional profile of breast and leg muscles was also reported by Bogosavljević-Bošković et al. (2006).

It has been found in chicken meat that the UFA comprises a higher proportion compared with SFA; however, the overall lipid content of meat influences the proportionate composition of fatty acids. In the present experiment, the impact of monochromatic light is not so pronounced in increasing the PUFA content of meat and the values were better under IBL source. The higher concentration of SFA under RL is usually considered to help build low-density lipoprotein (LDL) cholesterol, also known as bad cholesterol, and is associated with a higher risk for heart disease in humans (Zock, 2006). The Lino-A, which was lower under RL in the present study, has been shown to be the most potent fatty acid in lowering serum total and LDL cholesterol (Lewis and Krikler, 1968). On the other hand, the SFA is used by n-9 desaturase to yield MUFA via various metabolic pathways (Watkins, 1991). Therefore, an optimum proportion of SFA has to be present in the body for it to be useful. Among PUFA, the omega fatty acids are of significant physiological importance, and lower values of omega fatty acids were observed under RL. In this series, Linc-A (n-3) and Lino-A (n-6) are essential fatty acids. The long chain n-6, Arac-A, can be synthesized from Lino-A. The lower concentration of Arac-A under RL supports our findings of a lower concentration of Lino-A and Line-A with the same source (RL). The other long-chain n-3 fatty acids, eicosapentaenoic acid and docosahexaenoic acid (DHA), can be synthesized from Linc-A. Recent research indicated that DHA plays an important role in the regeneration of the visual pigment rhodopsin, which is critical in the visual transduction system that converts light hitting the retina to visual images in the brain (SanGiovanni and Chew, 2005). The brain then coordinates the stimulus to excite the pituitary gland to secrete the necessary hormones (Banerjee, 1992; Lewis and Morris, 2000). In this study DHA was not analyzed; however, the higher value of Linc-A could itself explain the light sensitivity under RL and in turn higher PUFA values.

It has been stated that the substitution of SFA with MUFA or PUFA can reduce LDL cholesterol concentration in blood plasma (Mensink and Katan, 1989). The ratio of SFA:PUFA was found to be higher under RL, indicating its adverse impact on healthy meat with the lowest concentrations of omega fatty acids. An interaction between n-3, n-6, and SFA had been described by Wood and Enser (1997); as n-3 fatty acid concentrations in muscles increased, those of n-6 declined and SFA concentration remained unchanged, illustrating the competition that exists between n-6 and n-3 fatty acids for inclusion in lipid molecules.

Per Simopoulos (2009), the balance of n-6:n-3 fatty acid is an important determinant in decreasing the risk of coronary heart disease. A combination of higher n-3 and lower n-6 fatty acid is said to be a balanced n-6:n-3 ratio. Furthermore, a lower ratio of n-6:n-3 is more desirable in reducing the risk of any of the chronic diseases (Simopoulos, 2009). The general average recommendation for reducing the chance of coronary heart disease in humans is an n-6:n-3 ratio of 5:1 to 4:1 in the diet (Canada Health and Welfare, 1990; Food and Agricultural Organization, 1994; Okuyama et al., 1997; British Nutrition Foundation, 1999). The lowest n-6:n-3 ratio in the present study was found to be higher than the recommended ratio of 5:1 to 4:1. This also indicates that light does not influence the n-6:n-3 ratio; rather, the dietary sources modified the useful fatty acid composition of meat. Poultry meat could provide between 2.7 and 3.5 times the amount of n-3 PUFA per edible portion of white and dark meats, respectively, compared with an equal-sized portion of canned tuna fish (Ayerza et al., 2002). Moreover, dietary n-3 compete with the n-6 family of dietary PUFA for incorporation into all cell membranes (Healy et al., 2000; Calder, 2006). In a study of the Arabidopsis plant, the expression of the FAD7 gene encoding an n-3-fatty acid desaturase was proposed to be light responsive by Nishiuichi et al. (1995). Also, Kis et al. (1998) stated that the saturation level of photosynthetic membranes is primarily regulated via modulated expression of desaturases by a light-dependent signaling pathway rather than by changes in the ambient temperature of the environment. In the present experiment, the higher n-6:n-3 ratio under BL indicating its potent role in defining the quality of broiler meat; however, the lowest value of n-6:n-3 ratio and higher value of n-3 under IBL highlighting not to forget the importance of IBL in improving fatty acid composition and health prospect of broiler meat. The changes in the fat components and their ratios were influenced by monochromatic lights and IBL groups; however, how the changes occurred is still inconclusive and needs further research.

Similarly, the LED sources did not prove to be as effective as IBL in affecting the sulfur-containing AA (Met and Cys). In the present study, this might be the reason for the rise in the protein content (%) of meat in IBL group as the Met is the first limiting AA and the values were better under IBL source. The highest n-6:n-3 ratio under WL might help to prevent ocular abnormalities and improve welfare of the birds under the full spectrum of light as suggested by Maddocks et al. (2001). The AA composition of meat basically represents the protein quality. The protein quality is said to be good if the essential to nonessential balance is appropriate. In the present study the values of AA (NEAA and EAA) in meat differed under WL, suggesting that the utilization
and AA availability improved in the birds reared under WL. Under WL it might be possible that birds were in a less stressed state; Maddocks et al. (2001) indicated that the absence of light negatively influenced chicken welfare and suggested that the full light spectrum (i.e., white light) is better for the birds’ welfare. Moreover, the higher AA concentration (%) under WL indicated a positive role of monochromatic light on meat quality in the present experiment. Prayitno et al. (1997) stated that more body activity can affect the behavior of birds and composition of meat. Therefore, it can be inferred that under WL the birds might remain more active, which leads to higher AA accumulation in meat.

In conclusion, the LED in poultry housing management is advantageous over traditional incandescent light because of its energy- and cost-effectiveness. In the present experiment, light produced by LED responded similarly to the IBL in influencing nutrient contents of meat. Moreover, LED is not decisive in improving the fatty acid composition of meat. However, the role of IBL in reducing n-6:n-3 ratio and enhancing n-3 cannot be neglected. Among LED, WL is helpful in improving EAA and NEAA contents of broiler meat.

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Nakamura, Y. N., H. Iwamoto, N. Shiba, H. Miyachi, S. Tabata, and S. Nishimura. 2004. Growth changes of the collagen content and AA availability improved in the birds reared under WL. Under WL it might be possible that birds were in a less stressed state; Maddocks et al. (2001) indicated that the absence of light negatively influenced chicken welfare and suggested that the full light spectrum (i.e., white light) is better for the birds’ welfare. Moreover, the higher AA concentration (%) under WL indicated a positive role of monochromatic light on meat quality in the present experiment. Prayitno et al. (1997) stated that more body activity can affect the behavior of birds and composition of meat. Therefore, it can be inferred that under WL the birds might remain more active, which leads to higher AA accumulation in meat.

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