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Effect of different lighting sources on the performance of broiler breeder hens

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Abstract The present study aimed to evaluate the effects of using light-emitting diode (LED) lamps versus incandescent/tungsten (Inc) bulbs on broiler breeder hens' productive performance during the brooding and rearing periods (25 weeks), as well as the first 15 weeks of production. A total of 46600 one-day-old Arbor Acres Plus breeder chicks were placed in eight enclosed houses and randomly/evenly divided into two groups (four houses for each group): birds raised under yellow LED lighting, and birds raised under orange Inc lighting. Several traits have been studied to determine productive performance, including body weight at different ages, body weight gain, feed consumption, feed conversion ratio, mortality rate, uniformity, age and weight at sexual maturity, egg number, egg production rate, egg number per bird, egg weight, and egg mass. According to the findings, using LED lighting instead of Inc lighting during the rearing period resulted in a significant improvement in all studied traits, and this positive effect continued until the production period, yielding excellent results for all studied production traits. LED lighting proved to be an effective source of lighting in broiler breeders' houses.

Keywords: Arbor Acres Plus breeder, egg production, LED, mortality, uniformity, welfare

1. Introduction

Better management and welfare for poultry, as well as the provision of a suitable environment, are required prerequisites for better expressing their genetic potential (El-Sabrout et al 2022a). Scientists and breeders face a difficult challenge in determining the ideal environmental conditions for animals considering existing environmental changes. Breeders must adopt new technologies to meet the current demand, enabling them to increase production at a reduced cost with less negative impacts on the environment. Most of these production technologies focus on enhancing traditional inputs such as air, water, diet, and lighting. Lighting needs further investigation as a contributing factor in improving bird welfare and productivity (Soliman and El-Sabrout 2020). Light is an important aspect in poultry production since breeders want their animals to reach their full genetic potential. The wavelength/color, intensity, photoperiod, and light source are all important considerations in poultry lighting management (Çapar Akyuz and Onbasilar 2018; Soliman and El-Sabrout 2020).

Recent advancements in lighting technology provide new opportunities for improving traditional lighting programs within chicken houses. Traditional light bulbs have gradually been replaced by LED lamps in the last ten years (Gongruttananun and Guntapa 2012; Santana et al 2014; El-Sabrout et al 2022b). LED is not a 21st century invention, it emerged in the 1960s and was developed to keep pace with the needs of the times (Hassan et al 2013). New LED lamps are currently known worldwide due to their high luminous efficiency, long life, and friendliness to the environment (Liu et al 2010; Hassan et al 2013; El-Sabrout et al 2022b). Valentine et al (2010) showed that LED lamps required 12 times less electricity consumption than 60 W incandescent (Inc) light bulbs that have the same luminosity. In addition, LED lamps are 5 times smaller than a 15 W fluorescent light (FL). An LED bulb has a lifespan that is 8 times longer than that of an FL and 50 times longer than that of an Inc bulb (Liu et al 2010). The main advantage of the LED is the energy savings (80% less energy is wasted than with Inc bulbs and 50% less than with Fl), longer shelf life and color diversity, as shown by Molino et al (2015). As the use of LED lights increases, the understanding of proper applications in various housing types should be increased. However, the beneficial effects of using LED lamps in broiler houses have been reported in several previous studies (Kim et al 2013; Mendes et al 2013; Soliman and El-Sabrout 2020), including their positive impact on growth performance and final body weight. Furthermore, LED lighting improved behavioral activities and increased egg production yield as well as reduced electric energy costs in layer houses (Rozenboim et al 2004; El-Sabrout et al 2022b). Otherwise, data on the effect of light sources on broiler breeder (parents) performance are lacking, particularly the effects of employing LED lamps in broiler breeder houses on egg production, uniformity, and welfare.

The primary purpose of broiler breeder husbandry and management is to produce eggs with high-quality chicks. Since breeder fertility and production are highly sensitive to surrounding environmental conditions, breeder hens must be housed in optimal conditions throughout their life stages. Therefore, this study was carried out to compare the impact

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of LED lamps vs Inc bulbs on broiler breeder hens' productive performance throughout the brooding and rearing periods (25 weeks), as well as the first 15 weeks of production.

2. Materials and Methods

2.1. Animal ethics

All procedures and husbandry guidelines were performed according to the experimental animal care committee ethics of Alexandria University (AU 082209203106).

2.2. Experimental design

The present study was carried out at Cairo Poultry Company for broiler breeders (Alexandria, Egypt) to compare the productivity of Arbor Acres Plus broiler breeder hens during the 25 weeks of brooding and rearing phases and the first 15 weeks of production under two different lighting sources: LED lamps and Inc bulbs. A total of 46600 one-day-old Arbor Acres Plus breeder chicks were placed in eight enclosed houses. They were randomly and equally divided into two groups (four replicates/houses for each group) throughout the brooding and rearing stages: birds raised under LED lighting (yellow color) and birds raised under Inc lighting (orange color) (served as a control). Then, all birds were raised under LED lamps during the production stage. The experiment lasted 40 weeks.

2.3. Housing and feeding

The experimental houses are environmentally controlled (closed system) and continually monitored 24 hours a day. Management conditions were similar for all houses throughout the whole experimental period. A super starter diet of 23% protein was offered for breeder hens during the first 7 days, and then a starter diet of 19% protein was used for 3 weeks, depending on the handbook of strain recommendations. Thereafter, the grower diet (16% protein) was provided in the 5th week.

2.4. Productive performance parameters

2.4.1. Body weight

The average body weight (BW) for all chicks used at receiving time was 38.43 g. A 5% random sample of individual birds from each house was weighed weekly using a digital balance (BW-2050 - sensitive 1 g). Weight is taken before morning feed. The weights were recorded at the 1st, 5th, 10th, 15th, 20th, and 25th weeks of age.

2.4.2. Body weight gain

The average weekly body weight gain (WBWG) was estimated in grams by subtracting the individual initial live weight from the final live weight in a certain week. The values were recorded during the 5th, 10th, 15th, 20th, and 25th weeks of age.

2.4.3. Feed consumption

The house feed consumption was recorded at weekly intervals. The residual feed was obtained at the end of the same week, and the amount of feed consumed (g/bird/period) was calculated. The values were recorded during the 1st, 5th, 10th, 15th, 20th, 25th, 30th, 35th, and 40th weeks of age.

2.4.4. Feed conversion ratio

The feed conversion ratio (FCR) was calculated at weekly intervals (1st, 5th, 8th, 10th, 15th, 20th, and 25th weeks of age) by dividing the average chick feed consumption per week by the average chick body weight in the same week.

2.4.5. Mortality rate

Dead birds were collected throughout the day and counted at 7:00 the next morning. The calculation was performed by dividing the total number of dead birds in a certain week by the total number of birds at the beginning of the week. The mortality rate (MR) was recorded daily and expressed weekly as percentages during the 1st, 5th, 10th, 15th, 20th, 25th, 30th, 35th and 40th weeks of age.

2.4.6. Uniformity percentage

The uniformity percentage (UP) was determined during the 1st, 5th, 10th, 15th, 20th, and 25th weeks of age according to the following equation:

Total number of sample birds - (number of birds with a higher weight than average + number of birds with a lower weight than average)/total number of sample birds **×** 100.

2.5. Egg production traits

2.5.1. Age and weight at sexual maturity

At 5% egg production in each house, the age and weight of the birds were recorded.

2.5.2. House egg number

The house egg number (HEN) of each house was recorded daily. HEN was expressed weekly during the 25th, 30th, 35th, and 40th weeks of age. However, the overall mean represents all studied production weeks (15 weeks).

2.5.3. Egg production rate

The total egg number was recorded weekly and divided into 7 days to obtain the average daily egg number of a house. The previous number was divided by the total number of birds at the beginning of the week to obtain the egg production rate (EPR) values (hen-house egg production, HHEP). The EPR was expressed weekly during the 25th, 30th, 35th, and 40th weeks of age.

2.5.4. Weekly egg per bird

The total egg number was recorded weekly (25th, 30th, 35th, and 40th week of age) and divided by the total number of birds at the beginning of the week to generate the weekly egg per bird (WEB) values.

2.5.5. Egg weight

On the last day of every production week (25th, 30th, 35th, and 40th weeks of age), 3% (at least 240 eggs) of the eggs produced in each house were weighed. Egg weight (EW) was recorded in grams using a digital balance.

2.5.6. Egg mass

The egg mass (EM) value describes the relationship between the egg production rate and egg weight. The EM values (g/bird/day) were determined weekly at the end of the 25th, 30th, 35th, and 40th weeks of age according to Yavuz and Kalinowski's (2014) equation, as follows:

EM = (average hen week egg production × average egg weight)/100.

2.6. Statistical analysis

Data were analyzed using variation statistical methods (SAS 2002). The test statistic for a two-sample independent *t* test is calculated by taking the difference in the two sample means and dividing by either the pooled or not pooled estimated standard error according to McMullen (1939), as follows:

$$t = \frac{(\overline{x}_1 - \overline{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

where:
$\overline{x}_1$ and $\overline{x}_2$: the average values of each of the sample sets.
μ_1 and μ_2: the theoretical values of each of the sample sets.
S_1^2 and S_2^2: the variance of each of the sample sets.
n_1 and n_2: number of records in each sample set.

3. Results

3.1. Productive performance parameters

3.1.1. Body weight

Body weight (BW) values of breeder hens at different weeks of the rearing period, as affected by two sources (types) of lighting, are presented in Table 1. The results showed significant differences in BW values at the 5th ($P \leq 0.05$), 15th ($P \leq 0.01$), 20th ($P \leq 0.01$), and 25th ($P \leq 0.01$) weeks of age, while there was no significant ($P > 0.05$) difference at the 1st week of age (brooding period). Birds raised under LED lighting had significantly ($P \leq 0.01$) heavier BW compared to those raised under Inc lighting.

Table 1 Means and standard errors (M±SE) of body weight (g) at different studied ages of Arbor Acres Plus breeder hens raised under two sources of light.

Age	LED	Tungsten	Significance
Placement	38.43± 2.10		
1st week	118.75 ± 0.75	114.50 ± 0.65	NS
5th week	540.25^a ± 3.70	521.50^b ± 5.80	*
10th week	1015.80 ± 5.04	1026.00 ± 4.02	NS
15th week	1541.75^a ± 4.00	1513.25^b ± 4.60	**
20th week	2196.25^a ± 6.25	2160.00^b ± 7.00	**
25th week	3027.50^a ± 11.06	2966.50^b ± 5.24	**
Age	LED/LED	Tungsten/LED	Significance
30th week	3411.25^a ± 8.86	3334.50^b ± 4.57	***
35th week	3507.00^a ± 8.42	3428.75^b± 4.39	***
40th week	3593.75^a ± 1.79	3500.25^b ± 4.19	***

^{a,b} Means having different litters in the same row are significantly different at ($P \leq 0.05$), ($P \leq 0.01$), and ($P \leq 0.001$). NS: not significant.

The BWs of breeder hens at different weeks of the production period are also presented in Table 1. Birds raised under yellow LED lighting during the brooding, rearing, and production stages (40 weeks) (LED/LED group) had significantly ($P \leq 0.001$) heavier BW than those raised under orange Inc lighting during the brooding and rearing stages (25 weeks) and then yellow LED lighting during the production stage (15 weeks) (Inc/LED group). Furthermore, the overall mean BW values (40 weeks) for the LED/LED group were significantly ($P \leq 0.001$) higher (6.4%) than those for the Inc/LED group. In general, the increase in BW for hens exposed to LED lighting was consistently higher during the rearing stage than during the production stage.

3.1.2. Body weight gain

Body weight gain (WBWG) values of breeder hens during different studied weeks of the rearing period, as affected by two sources of lighting, are presented in Table 2. The results showed significant ($P \leq 0.05$) differences in WBWG values during the 25th week of age, while there were no significant ($P > 0.05$) differences at all other studied rearing weeks. Birds raised under LED lighting had significantly higher WBWG (13.31%) during the 25th week of age compared to those raised under Inc lighting.

The WBWG of breeder hens during different weeks of the production period, as affected by two sources of lighting, are presented in Table 2. The results showed significant differences in WBWG values during the 25th ($P \leq 0.05$) and 40th ($P \leq 0.01$) weeks, while there were no significant ($P >$

0.05) differences during the 30th and 35th weeks. However, the overall mean value of WBWG for those of the LED/LED group during all studied weeks (40 weeks) was significantly ($P \leq 0.05$) higher (3.7%) compared to those of the Inc/LED group.

3.1.3. Feed consumption

Weekly feed consumption (WFC) values of breeder hens during different weeks of the rearing period, as affected by two sources of lighting, are presented in Table 3. The results showed significant ($P \leq 0.05$; $P \leq 0.01$; $P \leq 0.001$) differences in WFC values during all studied week intervals. Birds raised under LED lighting had significantly lower WFC values during the 5th, 10th, 15th, 20th, and 25th weeks of age compared to those raised under Inc lighting. The WFC of hens during different weeks of the production period is also presented in Table 3. The results showed highly significant ($P \leq 0.01$; $P \leq 0.001$) differences in WFC values during the 25th, 30th, and 40th weeks, while there was no significant ($P > 0.05$) difference at the 35th week. The overall mean WFC values for those of the LED/LED group during all studied weeks (40 weeks) were significantly ($P \leq 0.01$) higher (2.3%) than those of the Inc/LED group.

Table 2 Means and standard errors (M±SE) of weekly body weight gain (g) at different studied ages of Arbor Acres Plus breeder hens raised under two sources of light.

Age	LED	Tungsten	Significance
1st week	--	--	--
5th week	100.50 ± 5.1	99.20 ± 6.80	NS
10th week	93.25 ± 2.20	96.25 ± 2.10	NS
15th week	177.00 ± 13.08	174.50 ± 8.17	NS
20th week	131.25 ± 9.50	130.50 ± 14.50	NS
25th week	183.00^{a} ± 1.47	161.50^{b} ± 3.20	*
Age	LED/LED	Tungsten/LED	Significance
30th week	25.00 ± 0.91	24.75 ± 0.48	NS
35th week	15.25 ± 0.63	13.25 ± 1.11	NS
40th week	18.00^{a} ± 0.91	13.25^{b} ± 0.63	**

^{a,b} Means having different litters in the same row are significantly different at ($P \leq 0.05$) and ($P \leq 0.01$). NS: not significant.

Table 3 Means and standard errors (M±SE) of weekly feed consumption (g) at different studied ages of Arbor Acres Plus breeder hens raised under two sources of light.

Age	LED	Tungsten	Significance
1st week	189^{a} ± 8.5	154^{b} ± 4.1	***
5th week	252^{b} ± 11.3	266^{a} ± 7.1	**
10th week	378^{b} ± 0.0	385^{a} ± 0.0	*
15th week	504^{b} ± 0.0	518^{a} ± 0.0	**
20th week	679^{b}± 0.0	693^{a} ± 0.0	**
25th week	910^{b} ± 0.0	952^{a} ± 0.0	***
Age	LED/LED	Tungsten/LED	Significance
30th week	1085^{a} ± 0.0	1043^{b} ± 0.0	***
35th week	1135 ± 0.0	1155 ± 0.0	NS
40th week	1148^{b} ± 0.0	1162^{a} ± 0.0	**

^{a,b} Means having different litters in the same row are significantly different at ($P \leq 0.05$), ($P \leq 0.01$), and ($P \leq 0.001$). NS: not significant.

3.1.4. Feed conversion ratio

Feed conversion ratio (FCR) (kg feed/kg egg) values of breeder hens during different studied weeks of the rearing period, as affected by two sources of lighting, are presented in Table 4. The results showed highly significant ($P \leq 0.01$; $P \leq 0.001$) differences in FCR values during all studied week intervals. The FCR of hens during different weeks of the production period is also presented in Table 4. The results showed highly significant differences in FCR values during the 25th ($P \leq 0.001$), 35th ($P \leq 0.001$), and 40th ($P \leq 0.01$) weeks, while there was no significant ($P > 0.05$) difference at the 30th week. Birds in the LED/LED group had significantly ($P \leq 0.001$) better FCR values (4.5%) than those in the Inc/LED group.

3.1.5. Mortality rate

The weekly mortality rate (WMR) values of breeder hens during different weeks of the rearing period, as affected by two sources of lighting, are presented in Table 5. The results showed significant differences in WMR values during the 1st, 5th, 15th, 20th, and 25th weeks of age, with different significance levels. The WMRs of breeder hens during different weeks of the production period are also presented in Table 5. The results showed highly significant ($P \leq 0.01$ and $P \leq 0.001$) differences in WMR values during all studied weeks of the production period. Regarding overall mean values for all studied weeks (40 weeks), birds in the LED/LED group had significantly ($P \leq 0.001$) lower WMRs (60%) than those in the Inc/LED group.

Table 4 Means and standard errors (M±SE) of the feed conversion ratio of Arbor Acres Plus breeder hens raised under two sources of light at different studied ages.

Age	LED	Tungsten	Significance
1st week	1.34^{a} ± 0.01	1.30^{b} ± 0.01	**
5th week	1.90^{b} ± 0.01	2.09^{a} ± 0.02	**
10th week	2.64^{b} ± 0.01	2.74^{a} ± 0.01	**
15th week	3.25^{b} ± 0.01	3.42^{a} ± 0.01	***
20th week	3.66^{b} ± 0.01	3.85^{a} ± 0.01	***
25th week	4.01^{b} ± 0.01	4.25^{a} ± 0.00	***
Age	LED/LED	Tungsten/LED	Significance
30th week	18.96 ± 0.19	16.09 ± 3.36	NS
35th week	18.70^{b} ± 0.10	19.50^{a} ± 0.15	**
40th week	17.58^{b} ± 0.03	18.18^{a} ± 0.08	***

^{a,b} Means having different litters in the same row are significantly different at ($P \leq 0.01$) and ($P \leq 0.001$). NS: not significant.

3.1.6. Uniformity percentage

The uniformity percentage (UP) values of breeder hens during different weeks of the rearing period, as affected by two sources of lighting, are presented in Table 6. The results showed highly significant ($P \leq 0.01$ and $P \leq 0.001$) differences in UP values during all studied week intervals. The UP of breeder hens during different studied weeks of the production period are also presented in Table 6. The results showed highly significant ($P \leq 0.01$ and $P \leq 0.001$) differences in UP values during the 25th, 35th, and 40th weeks, while there was no significant ($P > 0.05$) difference at the 30th week. The LED/LED group had significantly higher UP values than the Inc/LED group. Furthermore, the overall mean UP values for those of the LED/LED group during all studied weeks (40 weeks) were significantly ($P \leq 0.01$) higher (5.75%) than those of the Inc/LED group.

Table 5 Means and standard errors (M±SE) of weekly mortality rate (%) of Arbor Acres Plus breeder hens raised under two sources of light at different studied ages.

Age	LED	Tungsten	Significance
1st week	0.43^{b} ± 0.04	0.63^{a} ± 0.04	**
5th week	0.09^{b} ± 0.04	0.14^{a} ± 0.02	*
10th week	0.09 ± 0.02	0.09 ± 0.01	NS
15th week	0.09^{b} ± 0.02	0.17^{a} ± 0.10	**
20th week	0.07^{b} ± 0.02	0.12^{a} ± 0.02	*
25th week	0.04^{b} ± 0.01	0.15^{a} ± 0.02	**
Age	LED/LED	Tungsten/LED	Significance
30th week	0.05^{b} ± 0.01	0.31^{a} ± 0.03	***
35th week	0.01^{b} ± 0.01	0.23^{a} ± 0.02	***
40th week	0.08^{b} ± 0.02	0.23^{a} ± 0.03	**

^{a,b} Means having different litters in the same row are significantly different at ($P \leq 0.05$), ($P \leq 0.01$), and ($P \leq 0.001$). NS: not significant.

Table 6 Means and standard errors (M±SE) of uniformity percentage (%) of Arbor Acres Plus breeder hens raised under two sources of light at different studied ages.

Age	LED	Tungsten	Significance
5th week	93.30^{a} ± 0.90	88.00^{b} ± 0.85	***
10th week	92.34^{a}± 0.21	87.15^{b} ± 0.75	***
15th week	92.91^{a} ± 0.24	83.75^{b} ± 1.03	***
20th week	92.55^{a} ± 0.52	87.78^{b} ± 0.29	***
25th week	92.68^{a} ± 0.31	89.12^{b} ± 1.05	**
Age	LED/LED	Tungsten/LED	Significance
30th week	86.68 ± 0.40	86.55 ± 1.00	NS
35th week	86.93^{a} ± 0.43	83.00^{b} ± 0.41	***
40th week	77.25^{a} ± 0.63	69.75^{b} ± 1.60	**

^{a,b} Means having different litters in the same row are significantly different at ($P \leq 0.01$) and ($P \leq 0.001$). NS: not significant.

3.2. Egg production traits

3.2.1. Age and Weight at Sexual Maturity

The age at sexual maturity (ASM) of breeder hens (at 5% egg production), as affected by two sources of lighting, is presented in Table 7. The results showed highly significant ($P \leq 0.001$) differences in ASM values. Birds raised under LED lighting had significantly earlier ASM than those raised under Inc lighting (175 and 182 days, respectively).

The weight at sexual maturity (WSM) of breeder hens is also presented in Table 7. The results showed highly significant ($P \leq 0.001$) differences in WSM values. Birds raised under LED lighting had significantly higher WSM than those raised under Inc lighting (3235.0 and 3119.3 g, respectively).

3.2.2. House egg number

The house egg number (HEN) of breeder hen houses during different weeks of the production period, as affected by two sources of lighting, is presented in Table 7. The results showed highly significant differences ($P \leq 0.01$ and $P \leq 0.001$) in HEN values during all studied weeks of the production period. The LED/LED group had significantly higher HEN values during the 25th, 30th, 35th, and 40th weeks of age than the Inc/LED group. Furthermore, the overall mean HEN values for LED/LED lighting during all production weeks (15 weeks) were significantly ($P \leq 0.001$) higher (15%) than those of the Inc/LED group.

3.2.3. Egg production rate

The egg production rate (EPR) values of breeder hen houses during different studied weeks of the production period, as affected by two sources of lighting, are presented in Table 8. The results showed significant differences ($P \leq 0.05$ and $P \leq 0.001$) in EPR values during all studied weeks of the production period. Birds in the LED/LED group had significantly higher EPR values during the 25th, 30th, 35th, and 40th weeks of age (10.85, 85.63, 83.95, and 78.88%, respectively) than those in the Inc/LED group (3.95, 83.73, 79.73, and 75.15%, respectively). Generally, the overall mean EPR values for those of the LED/LED group during all production weeks (15 weeks) were significantly ($P \leq 0.001$) higher (9.5%) than those of the Inc/LED group.

Table 7 Means and standard errors (M±SE) of age and weight at sexual maturity, and house egg number of Arbor Acres Plus breeder hens raised under two sources of light.

Age and weight at sexual maturity			
Traits	LED	Tungsten	Significance
Age of sexual maturity (day)	$175.0^{b} \pm 0.28$	$182.0^{a} \pm 0.32$	***
Weight at sexual maturity (g)	$3235.0^{a} \pm 5.72$	$3119.3^{b} \pm 4.92$	***

House egg number			
Age	LED/LED	Tungsten/LED	Significance
25th week	$4354.50^{a} \pm 328.7$	$733.25^{b} \pm 432.7$	***
30th week	$34162^{a} \pm 341.2$	$32083^{b} \pm 555.6$	**
35th week	$33436^{a} \pm 398.2$	$30116^{b} \pm 492.3$	***
40th week	$31332^{a} \pm 352.3$	$28047^{b} \pm 385.7$	***
Overall mean	$29888^{a} \pm 1018.5$	$25977^{b} \pm 1154.6$	***

^{a,b} Means having different litters in the same row are significantly different at ($P \leq 0.01$) and ($P \leq 0.001$).

3.2.4. Weekly eggs per bird

The weekly eggs per bird (WEB) values of breeder hens during different weeks of the production period, as affected by two sources of lighting, are presented in Table 8. Birds in the LED/LED group had significantly ($P \leq 0.05$ and $P \leq 0.001$) higher WEB values during the 25th, 30th, 35th and 40th weeks of age (0.76, 5.99, 5.88 and 5.52 eggs, respectively) than those in the Inc/LED group (0.13, 5.86, 5.58 and 5.26 eggs, respectively). Furthermore, the overall mean WEB values for those of the LED/LED group during all production weeks (15 weeks) were significantly ($P \leq 0.001$) higher (11%) than those of the Inc/LED group.

3.2.5. Egg weight

The egg weight (EW) values of breeder hen houses during different studied weeks of the production period, as affected by two sources of lighting, are presented in Table 9. The results showed significant ($P \leq 0.01$, $P \leq 0.001$) differences in EW values during the 30th, 35th, and 40th weeks of the production period, while there was no significant ($P > 0.05$) difference at the 25th week. Birds in the LED/LED group had significantly higher EW during the 30th, 35th, and 40th weeks of age (57.25, 61.58 and 65.30 g, respectively) than those in the Inc/LED group (53.63, 59.20 and 63.93 g, respectively). Furthermore, the overall mean EW values for those of the LED/LED group during all production weeks (15 weeks) were significantly ($P \leq 0.01$) higher (3.7%) than those of the Inc/LED group.

3.2.6. Egg mass

The egg mass (EM) values of breeder hen houses during different weeks of the production period, as affected by two sources of lighting, are presented in Table 9. The results showed highly significant ($P \leq 0.01$ and $P \leq 0.001$) differences in EM values during all studied weeks of the production period. Birds in the LED/LED group had significantly higher EM during the 25th, 30th, 35th and 40th weeks of age (5.47, 49.02, 51.69 and 51.51 g/bird/day, respectively) than those in the Inc/LED group (0.92, 44.89, 47.20 and 48.04 g/bird/day, respectively). Furthermore, the overall mean EW values for those of the LED/LED group during all production weeks were significantly ($P \leq 0.001$) higher (10%) than those of the Inc/LED group.

Table 8 Means and standard errors (M±SE) of egg production rate and weekly egg per bird of Arbor Acres Plus breeder hens raised under two sources of light.

Egg production rate (%)			
Age	LED/LED	Tungsten/LED	Significance
25th week	10.85^a ± 0.72	3.95^b ± 1.13	***
30th week	85.63^a ± 0.45	83.73^b ± 0.59	*
35th week	83.95^a ± 0.26	79.73^b ± 0.31	***
40th week	78.88^a ± 0.41	75.15^b ± 0.09	***
Overall mean	74.94^a ± 2.56	68.42^b ± 3.04	***
Weekly egg per bird			
Age	LED/LED	Tungsten/LED	Significance
25th week	0.76^a ± 0.05	0.13^b ± 0.09	***
30th week	5.99^a ± 0.03	5.86^b ± 0.04	*
35th week	5.88^a ± 0.02	5.58^b ± 0.02	***
40th week	5.52^a ± 0.03	5.26^b ± 0.01	***
Overall mean	5.23^a ± 0.17	4.71^b ± 0.21	***

^{a,b} Means having different litters in the same row are significantly different at ($P \leq 0.05$) and ($P \leq 0.001$).

Table 9 Means and standard errors (M±SE) of egg weight and egg mass of Arbor Acres Plus breeder hens raised under two sources of light.

Egg weight (g)			
Age	LED/LED	Tungsten/LED	Significance
25th week	50.48 ± 0.17	49.20 ± 0.38	NS
30th week	57.25^a ± 0.56	53.63^b ± 0.82	**
35th week	61.58^a ± 0.36	59.20^b ± 0.48	***
40th week	65.30^a ± 0.11	63.93^b ± 0.28	**
Overall mean	58.83^a ± 0.55	56.71^b ± 0.59	**
Egg mass (g/bird/day)			
Age	LED/LED	Tungsten/LED	Significance
25th week	5.47^a ± 0.35	0.92^b ± 0.55	***
30th week	49.02^a ± 0.64	44.89^b ± 0.63	**
35th week	51.69^a ± 0.32	47.20^b ± 0.50	***
40th week	51.51^a ± 0.33	48.04^b ± 0.27	***
Overall mean	44.74^a ± 1.65	40.62^b ± 1.64	***

^{a,b} Means having different litters in the same row are significantly different at ($P \leq 0.01$) and ($P \leq 0.001$). NS: not significant.

4. Discussion

The objective of the current study was to investigate the impact of raising broiler breeder hens under two different lighting sources, during the 25 weeks of brooding and rearing stages and the first 15 weeks of production, on productive performance. To our knowledge, this is the first study that has addressed this investigation.

The broiler breeder hen's reproductive life starts from the rearing stage which is considered a critical period in her life and significantly impacts the production stage. A broiler breeder's productive life is divided into three major phases: the first phase (sexual maturation) lasts until the laying of the first egg, the second phase begins with the end of the previous phase and continues until peak production, and the third phase begins with the end of the previous phase and lasts until the end of peak production. Each previous stage/phase needs ideal light management to achieve top production efficiency. Lighting is considered an important exogenous environmental factor that directly affects bird productivity, behavior, and well-being (Onbasilar et al 2007; Parvin et al 2014; Yang et al 2016; Soliman and El-Sabrout 2020). The efficacy of lighting is to achieve the best possible productive performance of birds and to ensure suitable welfare for them (Škrbić et al 2012). Choosing a good light source for lamps allows for maximum growth and efficiency while reducing stress (Archer 2015). However, LED lamps have different wavelengths (colors); thus, there are conflicting reports on their impact on poultry performance (Karakaya et al 2009). Additionally, few studies have been conducted on breeder chickens to investigate the light source effect on their productive performance and welfare, therefore, the current study was conducted. Certain current findings may be inconsistent with some previous results, which could be due to the use of different light sources or the age of the bird under investigation.

4.1. Productive performance parameters

4.1.1. Body weight

The present results showed that yellow LED lighting stimulated the BW of broiler breeder hens more than orange Inc lighting, which is in line with the findings of Huth and Archer (2015). Birds raised under LED lighting had significantly heavier BW at different ages of breeding (brooding, rearing, and production) compared to those raised under Inc lighting. These results are in agreement with the findings of Felts et al (1990), Mendes et al (2013), and Nissa et al (2018) who mentioned that light sources affect bird growth performance and weight. They also reported that birds exposed to LED lighting had the best feed conversion rate and body weight gain. LED lighting has been recognized as a novel source of monochromatic lighting and a feasible alternative to other conventional light sources for improving broiler growth and health (Parvin et al 2014; Wu et al 2022). According to Soliman and El-Sabrout (2020) and El-Sabrout et al (2022b), light sources influence two main components of light: wavelength (color) and intensity (brightness), which highly impact several biological and physiological processes in the bird body, such as hormone secretion and the synthesis of important nutrients, as well as the behavioral activities of birds. Light affects a bird's biological clock via the pituitary gland, which affects the regulation of growth hormones and metabolism processes via the thyroid glands (Lewis and Morris 2006; Wilson and Lindstrom 2011; Baxter et al 2014; Soliman and El-Sabrout 2020). In the current study, broiler breeder chicks were exposed to two different light sources: yellow LED and orange Inc Yellow lighting color is considered a medium wavelength (~570 nm) that positively affects birds' feed intake, growth, and health, while orange lighting color (~620 nm) increases birds' behavioral activities (El-Sabrout et al 2022b). Furthermore, LED lamps result in better feed conversion, behavior, and welfare when compared to conventional bulbs, consequently, they improve the productivity of birds (Mohamed et al 2014; Huth and Archer 2015).

4.1.2. Body weight gain

The light source has an important impact on some birds' productive traits, such as feed conversion efficiency and body weight gain, and some behavioral activities, such as feeding, drinking, walking, and resting (Olanrewaju et al 2019; Mohamed et al 2020; Soliman and El-Sabrout 2020). The present study showed that yellow LED lighting has better WBWG values than orange Inc lighting. Light color stimulates growth hormone secretion, feed consumption, metabolic processes, vitamin D_3 synthesis, and skeletal development, which directly affect growth performance, such as body weight gain (Cao et al 2012; Elkomy et al 2019; Soliman and El-Sabrout 2020; Rana and Campbell 2021; El-Sabrout et al 2022b). The current results are consistent with several previous studies (such as Cao et al 2012; Olanrewaju et al 2015; Hesham et al 2018) that indicated that light wavelength seems to boost bird growth and weight. Furthermore, understanding the effect of light on the behavior of broilers is important, as it can affect bird performance. LED lamps provide an approximation of daylight compared to the spectral gaps of other lighting sources, and they can reduce stress and fear in reared birds compared to other traditional lightings (Mohamed et al 2014; El-Sabrout and Khalil 2017). Heshmatollah (2007) reported that when chickens had the ability to select among red, orange, yellow, or green lights, they spent significantly more time beneath green light, and their second preference was yellow light. Firouzi et al (2014) indicated that birds reared under yellow light had the best performance compared to other lighting colors.

When compared to the rearing period, the increase in WBWG was reduced throughout the production period. This fluctuation of WBWG in the rearing period is in agreement with Ingram et al (2007), and it may be due to the practices carried out by the operator, especially during the rearing period, by limiting or increasing the feed provided, in an attempt to reach the recommendations of appropriate weight and homogeneity as in the strain guide to reach the desired results in the production period.

4.1.3. Feed consumption

Lighting impacts birds' behavioral activities including feed intake and feed consumption (Lesuisse et al 2017; Olanrewaju et al 2018; Nissa et al 2018). Additionally, the light source influences lighting color, which in turn influences feed consumption (Soliman and El-Sabrout 2020; El-Sabrout et al 2022b). In the current study, birds raised under LED lighting had significantly lower WFC values during the 5^{th}, 10^{th}, 15^{th}, 20^{th}, and 25^{th} weeks of age compared to those raised under Inc lighting. Birds raised under LED lighting also had significantly ($P \leq 0.01$) lower WFC as an overall mean of all rearing weeks compared to those raised under Inc lighting. According to Nissa et al (2018), long wavelength light, such as orange and red lights, reaches the hypothalamus, making the birds more active and hence increasing feed consumption, while short and medium wavelengths can decrease feed intake and consumption (Kamanli et al 2015). However, the results showed that the increasing trend of WFC during the rearing weeks for the Inc group was approximately equal, while it was oscillating in the production period due to the change that occurred in the lighting source (changing from Inc to LED).

4.1.4. Feed conversion ratio

The current findings revealed that the lighting source had a substantial impact on FCR during the rearing period, with a better tendency for those raised under LED lighting. Birds reared under LED lighting exhibited considerably lower overall mean FCR of all rearing weeks than those reared under Inc lighting. The present results are in agreement with the previous findings of Huth and Archer (2015), Archer (2015), Kim et al (2013), and Nissa et al (2018), who also reported lower FCR in birds reared under LED lighting compared to other light sources. According to Huang et al. (2013) and El-Sabrout et al. (2022b), light sources can impact the pineal gland that releases the highest levels of melatonin, which is responsible for the periodicity of FC as well as the enhancement of behaviors related to the night-day cycle. Yang et al. (2016) reported that LED lighting had superiority over the other sources of light regarding birds' FCR. Therefore, the use of LED lamps in poultry houses is highly recommended to maximize profits, especially with the gradual increase in the prices of feed ingredients worldwide (Ahmed et al 2019). On the other hand, Long et al (2016) reported that LED lamps are an excellent way to reduce electric costs. However, the FCR (kg feed/kg eggs) for the Inc/LED group oscillated during the production period compared to the rearing period, which could be attributed to the transition of hens from Inc lighting to LED lighting.

4.1.5. Mortality rate

Birds raised under LED lighting had significantly lower WMR values than those raised under Inc lighting during the rearing period. The present results also showed a lower WMR during the whole experimental period for the LED/LED group than for the Inc/LED group, except during the 10th week, since both groups had nearly equal WMR percentages. These results reflect that the Arbor Acres Plus breeder hens were more comfortable (less stressed) and calmer (less aggressive behavior) under LED lighting compared to birds raised under Inc lighting during the rearing period. Lewis and Morris (2006), Mendes et al (2010), Sadrzadeh et al (2011), Firouzi et al (2014), Zhang et al (2014), Mousa-Balabel et al (2017), Abdel-Azeem and Borham (2018), Soliman and El-Sabrout (2020), Wu et al (2022) and Horodincu and Solcan (2023) reported that light source and color (wavelengths) can affect birds' behavioral activities, health, immunity, and mortality. Similarly, Kamanli et al (2015) revealed that LED lights reduced the mortality rate of birds. Ahmed et al (2019) also found that birds exposed to LED lighting had a lower mortality rate than those exposed to other lighting sources. Since yellow lighting has a shorter wavelength than orange lighting, birds exposed to yellow lighting tend to behave less aggressively and engage in cannibalism than those exposed to orange lighting. These findings can explain the superiority of LED lighting over Inc lighting in the present study with respect to the WMR results of broiler breeder hens.

4.1.6. Uniformity percentage

Birds raised under LED lighting had significantly higher UP (better values) compared to those raised under Inc lighting during the rearing period. The LED group had more than 90% UP during the rearing period. The present results showed that LED lighting enhanced the uniformity of Arbor Acres Plus breeder hens, which is a reflection of the positive effect of LED lighting. Kamanli et al (2015) and Wei et al (2020) revealed that LED lighting can improve birds' growth performance and flock uniformity during the brooding and rearing stages. In agreement, Ozkan and Simsek (2022) found that light management significantly influenced birds' uniformity. Furthermore, the results showed the superiority of the LED/LED group with respect to UP over the Inc/LED group throughout the production period. It is critical to maintain hens within a narrow BW range, as higher flock uniformity has a lower variability in reproductive performance as indicated by Robinson et al (1996) and Hocking (2004).

4.2. Egg production traits

The value of good lighting in broiler breeder housing is very critical. An appropriate light source can have a positive impact on a variety of features, including sexual maturity, production uniformity, and stress behavior (Geurts 2018). The light source is one of the factors that influence bird reproduction and production performance (Felts et al 1990; Kamanli et al 2015; Rana and Campbell 2021; El-Sabrout et al 2022b). The current results showed that the light source/color during the brooding and rearing stages of broiler breeders' lives affects their productivity. Raising birds under yellow LED lighting showed better productive results compared to orange Inc lighting. The bird eye can discriminate light color, and different light wavelengths can affect egg production and quality (Er et al 2007). Light affects numerous physiological processes in birds and the visible spectrum emitted by the light source has an impact on egg production and quality; some wavelengths may be more stimulating than others (Svobodová et al 2015). Wei et al (2020) found that yellow light color encouraged sexual organ (oviduct and ovary) growth, advanced the age of sexual maturation, and improved layer chicken production uniformity. In addition, LED lamps had a positive effect on the albumen index, which resulted in the improvement of egg quality. This can be attributed to the influence of LED lighting on the endocrine system, which plays a role in the formation of egg albumen. An increase in the albumen quality of eggs may influence hatching results (El-Aggoury et al 1991).

4.2.1. ASM and WSM

The hens' sexual maturity age strongly affects their laying performance, and the optimal ages of sexual maturity produce the maximum possible egg output (Lewis et al 2004; Cui et al 2019; Farghly et al 2019). In the present study, birds raised under yellow LED lighting had earlier ASM compared to those raised under orange Inc lighting despite having higher WSM values in some interval weeks because there were within the standard WSM of the breed at sexual maturing age, otherwise, Inc lighting birds were slightly lower than this average. However, the relationship between the sexual maturity age (age at first egg) and BW of chickens has a different magnitude in the literature. Higher BW at the end of rearing, independent of light source, caused early sexual maturity, whereas a lower BW delayed sexual maturity, as found by Fattori et al (1991), Renema et al (2001a,b) Hocking (2004) and Ekmay et al (2012). Additionally, Ciacciariello (2003) indicated that the egg production traits of broiler breeders are significantly influenced by lighting management, especially during the rearing period. Classen (2003) reported that light color has a stimulating effect on growth and sexual maturity. In addition, it affects hen behavior and reproduction (Lewis and Morris 2000; Min et al 2012; Huber-Eicher et al 2013). In particular, monochromatic light sources (such as those produced by LED lamps) have significant effects on birds' sexual maturity and egg production rate (Min et al 2012; Hassan et al 2013). Light source/color impacts hen egg productivity through the influence of some waves on the bird's eye retina and others on the pituitary and pineal glands (Prescott and Wathes 1999; El-Sabrout et al 2022b).

4.2.2. HEN, EPR, WEB, EW, and EM

Birds in the LED/LED group had significant increases in HEN, EPR, WEB, EW, and EM compared to those in the Inc/LED group. Light sources influence light quality and photostimulation which impact hen reproductive performance, egg production yield, egg weight, egg mass, and egg quality (Er et al 2007; Min et al 2012; Liu et al 2018; Su et al 2021; Poudel et al 2022). Some light colors may be more affecting than others and each light source used in poultry houses has a different visible spectrum (Borille et al 2013; El-Sabrout et al 2022b). The results of the current study showed that birds were stimulated differently depending on the source of light. These stimulations have a significant impact on the release of specific hormones, aggressive behavior, and egg production (Er et al 2007; Huber-Eicher et al 2013; Borille et al 2013). Moreover, Lewis et al (2003) and Vasdal et al (2022) revealed that broiler breeders respond to light differently than laying hens. Because of the selection pressure employed to boost the egg production rate in laying hens, laying hens have the potential to generate a higher EPR than broiler breeders, but broiler breeders' eggs remain heavier. In both types, egg weight increases with age, although the rate of increase is higher in broiler breeders (Sakomura et al 2019). However, the results of the current study are consistent with those reported by Raziq et al (2021) who found major improvement in all studied egg production traits of LSL hens reared under LED lamps compared to those reared under Inc and FL lamps. Additionally, they found that LED light improves hens' physiological response and welfare aspects. LED lamps emit a spectrum that is most similar to the spectral sensitivity of birds (Prescott and Wathes 1999), making the birds more comfortable and performing better. Furthermore, Verza et al (2017) and Leigh et al (2017) reported that LED lamps are an efficient source to reduce electric costs in commercial layer and broiler breeder houses without affecting hen performance. On the other hand, the conversion rate of Inc bulbs from electrical energy to lighting energy is low, since they produce a large amount of heat, provide a lower durability, and increase the production costs (Jordan and Tavares 2005; Burrow 2009; Borrile et al 2013; Mendes et al 2013). From the previous findings, LED lamps are an excellent light source for encouraging birds' performance in indoor houses that have automatically controlled environments (Yang et al 2016), and their lighting considered economical.

5. Conclusions

According to the current findings, using yellow LED lighting instead of orange Inc lighting during the rearing period resulted in a significant improvement in all studied traits, and this positive effect continued until the production period, yielding better results for all studied production traits, and indicating significant economic benefits for applying this procedure. LED lighting proved to be an effective source of lighting in broiler breeders' houses for sustainable production. Therefore, the current study strongly recommends using yellow LED lighting in broiler breeders' houses during the brooding, rearing, and production stages.

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Ethical considerations

This study was evaluated and approved by the experimental animal care committee ethics of Alexandria University.

Conflict of interest

The authors declare that there are no conflicts of interest related to this publication.

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