INTRODUCTION

Various factors play important roles in influencing hatchability efficiency and growth performance during embryonic and post-hatch life, such as genetic, egg characteristics and incubation environment (Christensen, 1995; Nestor and Noble, 1995; Narushin and Romanov, 2002; Petek et al., 2003; Abiola et al., 2008). Light is one of the environmental factors that improves embryonic growth and hatchability performance of avian eggs (Fairchild and Christensen, 2000; Shafey and Al-Mohsen, 2002). Cooper (1972) stated that pouls hatched from eggs exposed to fluorescent lights appeared to be more active than pouls incubated and hatched in dark. Light-induced acceleration of embryonic development in ovo depends on the amount of light that reaches the embryo (Ghatpande et al., 1995). The light incubation accelerates hatching time compared to dark incubations in meat breeder eggs (Al-Mohsen and Shafey, 2004). Shafey (2004) found that light incubation increased daily embryonic growth (mg/d) and hatchability percentage by 3.90 and 5.90%, respectively of layer breeder eggs when compared with the dark incubation.

However, some disagreement in the literature was reported regarding the effect of light incubation on hatchability performance and physiological responses during incubation and post-hatching. Isakson et al. (1970) reported negative effect of light on glucose metabolism...
in light-treated compared with dark-treated embryos. Bowling et al. (1981) found that light exposure during incubation reduced hatchability percentage of White Leghorn eggs. Zakaria (1989) reported no improvement in hatchability percentage of meat-type breeder eggs incubated under light.

On the other hand, many studies have focused on the effect of light incubation on acceleration of hatching time and hatchability percentage, but few workers have studied the hormonal and metabolic changes of embryos and performance of chicks after hatch. The aims of the present study were to evaluate (i) the influence of light regime during incubation period on embryonic growth and hatchability percentage, (ii) some physiological characters in embryos incubated in light and (iii) the influence of light incubation on performance of chicks after hatch.

MATERIAL AND METHODS

The experimental work was carried out at the Poultry Farm, Department of Animal Production, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. A total of 1400 fertile eggs produced by Japanese quail hens were used in this study. Two force-draft incubators were used for incubation of eggs. Eggs were numbered and weighed individually and randomly divided into two groups. The first group was set in incubator at dark, while the second was set at light. White fluorescent light was used (one-tube, 20 watt) during the incubation period. The light intensity ranged from 620-835 lux at the surface of the fertile eggs as measured with a luximeter. All eggs were incubated under the same conditions of ambient temperature (37.5°C) and relative humidity (60%) in both incubators. Eggs were turned every 2-hr, and they were transferred to hatcher on day 14 of incubation under the same incubator condition of light regime. From day 14 to complete hatching the temperature and relative humidity were 37°C and 65%, respectively. Two incubation trials were done at 10 and 14 weeks of hen’s age. The second trial was devoted completely to study of embryonic growth, blood metabolism, hormonal assay and chick’s performance after hatch.

Studied Traits

1. Embryonic growth and development

In the second trial, 120 eggs per treatment were removed for determination of weight of embryos and gibelts (liver, heart and gizzard) on day 12 and day 16 of incubation. Eggs were broken open and embryos were separated and weighed individually and then the albumen and yolk sac were separated and weighed individually. The absolute and relative weights of embryos and gibelts were calculated.

2. Hatchability and embryonic mortality

At hatching all live and dead chicks were counted. The unhatched eggs were opened and classified either as being infertile or embryonic dead. The embryonic mortality was classified into four groups, the 1st group was early dead embryos (EDE) from 1-5 days, the 2nd group was late dead embryos (LDE) from 6-15 days, the 3rd group was dead in shell (DIS) from 16-17 days of incubation period, and the last group was pipped dead embryos (PDE) (Yakimenko, et al., 2002). Fertility was estimated as percentage of fertile eggs to total number of eggs set. Hatchability was calculated as the percentage of total hatched chicks to the number of fertile eggs.

3. Plasma hormonal assay and biochemical parameters of embryos

One hundred blood samples were collected from embryos kept in dark or light incubation (50 each) at 12 and 16 days of incubation (25 in each) in heparinized tubes. Blood samples were centrifuged at 3000 rpm for 15 min. and plasma was stored at -20°C for further analysis. Plasma T\(_{3}\) and T\(_{4}\) concentrations (ng/dl) were determined by enzymatic immunoassay (ELIZA) kits (BioCheck, Inc. Foster City, USA). Plasma total protein, albumen, glucose, total lipids, cholesterol and triglycerides were determined calorimetrically by using available commercial kits from Egyptian Company for Biotechnology (S.A.E., Cairo). The globulin values were calculated by subtracting the values of albumen from the corresponding values of total protein.

4. Performance after hatching

One hundred and eighty unsexed one-day-old quail chicks from both dark and light treatments were used to evaluate the chicks performance after hatching. Ninety chicks from every treatment were individually weighed and randomly distributed into three replicates (30 chicks each). The chicks were kept under normal brooding conditions in batteries cages (100x50x50cm) throughout the experimental period (6 weeks). Both food and water were provided ad-libitum. The ration contained 24% CP and 3000 Kcl(ME)/kg. Individual live body weights and feed intake were recorded weekly until 6 weeks of age, in addition, body weight gain and feed conversion were calculated during the same periods.

Statistical Analyses

Data were analyzed using the General Linear Model (GLM) procedure of SAS (SAS Institute Inc., 1998). Least Square Means (LSM) were calculated and Least Square Differences (LSD) among means were tested.
RESULTS

1. Embryonic Growth and Development

The effects of incubation status and day of incubation on embryonic growth and development are presented in Table 1. Light incubation increased (P≤0.01) relative embryo body weight and absolute and relative giblets weights (liver, heart and gizzard) compared with dark incubation. With advancing days of incubation, absolute and relative weight of embryos and giblets were higher (P≤0.0001) at day 16 than day 12 of incubation. There were significant (P≤0.0001) interaction between incubation status and day of incubation on embryonic growth. Embryos kept in dark had the heaviest absolute and relative weight at day 16 of incubation, but the lightest values were obtained in the same treatment at day 12 of incubation. On the other hand, embryos kept in light incubation and day 16 of incubation had the heaviest absolute and relative giblets weights, but the lightest values were found in dark group at day 12 of incubation.

2. Hatchability Percentage and Embryonic Mortality

Results in Table 2 showed that treatments had a significant effect on hatchability percentage and embryonic mortality. Eggs incubated under light regime had superior (P≤0.0001) hatchability percentage (HP) and lower (P≤0.05) late dead embryos (LDE), dead in shell (DIS) and pipped dead embryos (PDE) percentage than those incubated under dark. Eggs obtained at older age in trial 2 had higher HP and EDE (P≤0.041), and lower LDE and PDE (P≤0.05) than eggs used in trial 1. There was a significant interaction between incubation treatment and trials on hatchability and embryonic mortality. Eggs incubated under light and trial 2 had the highest value of HP and the lowest values of LDE, DIS and PDE.

3. Chicks Performance after Hatch

Body weights, weight gain, feed intake, feed conversion and mortality rate from hatching to 6-week-old of quail chicks as affected by incubation treatment are shown in Table 3. Results revealed that chicks produced from light incubation were heavier (P≤0.0001) in body weight at one-day-old and 6-week of age (P≤0.0001) and higher weight gain (P≤0.0001) from hatch to 6 weeks of age than those produced form dark incubation. The best results of feed conversion were realized from chicks hatched under light incubation (P≤0.05) compared with those hatched under dark incubation during 0-6 weeks of age. Treatments had no significant effects on feed intake and mortality rate through 0-6 weeks of age.

4. Biochemical Parameters of Quail Embryos at Day 12 and Day 16 of Incubation

Plasma total protein, albumen and globulin

Results in Table 4 indicated that light incubation resulted in a significant (P≤0.0001) increase of plasma total protein, albumen and globulin by 27, 50 and 18%, respectively compared to dark incubation. There was
a significant (P≤0.0001) increase in total protein and globulin at day 12 of incubation, however, albumen increased at day 16 of incubation. The interaction between incubation treatment and age of embryo had a significant (P≤0.0001) effect on these traits. The highest values of total protein, albumen and globulin were found in light group at day 12 of incubation, but the lowest values were obtained in dark incubator and day 12 of incubation for total protein and albumen, but the lowest globulin value was found in light group at day 12 of incubation.

**Plasma glucose concentration**

Results in Table 4 showed that embryos kept in light incubation had a significant (P<0.0001) increase in plasma glucose concentration by 83% in comparison with those kept in dark incubation. With the progress of day of incubation, embryos at day 16 increased their plasma glucose by 193% compared to day 12 of incubation. Also, plasma glucose concentration was significantly affected by the interaction between incubation status and day of incubation. The highest level was found in the light group at day 16 of incubation, but the lowest level was in the dark group at day 12 of incubation.

**Plasma total lipids, cholesterol and triglycerides**

Plasma total lipids, cholesterol and triglycerides of embryos differed significantly (P≤0.0001) under different treatments (Table 4). Embryos kept in the light incubation showed significant (P≤0.0001) increases in plasma total lipids, cholesterol and triglycerides concentration by 29, 28 and 55%, respectively compared to those kept in the dark incubation. With the progress of day of incubation,
### Tab. 4: Plasma biochemical constituents of embryos at day 12 and day 16 of incubation as affected by dark and light regimes

<table>
<thead>
<tr>
<th>Main effect</th>
<th>No.</th>
<th>Total protein (g/dl)</th>
<th>Albumen (g/dl)</th>
<th>Globulin (g/dl)</th>
<th>Glucose (mg/dl)</th>
<th>Total lipids (mg/dl)</th>
<th>Cholesterol (mg/dl)</th>
<th>Triglycerides (mg/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incubation status (I)</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dark</td>
<td>50</td>
<td>2.33±0.1b</td>
<td>0.68±0.1b</td>
<td>1.65±0.1b</td>
<td>77.51±1.2b</td>
<td>521.37±12.3b</td>
<td>163.22±7.2b</td>
<td>212.54±14.0b</td>
</tr>
<tr>
<td>Light</td>
<td>50</td>
<td>2.97±0.1b</td>
<td>1.02±0.2b</td>
<td>1.95±0.2b</td>
<td>141.75±1.3c</td>
<td>671.42±13.5c</td>
<td>208.74±8.4a</td>
<td>328.71±15.4a</td>
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<td>0.0001</td>
<td>0.0121</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td><strong>Day of incubation (D)</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>50</td>
<td>2.86±0.1b</td>
<td>0.79±0.1b</td>
<td>2.07±0.1b</td>
<td>55.87±0.81a</td>
<td>486.12±12.4b</td>
<td>79.25±4.8b</td>
<td>247.52±9.2b</td>
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<tr>
<td>16</td>
<td>50</td>
<td>2.45±0.1b</td>
<td>0.91±0.2b</td>
<td>1.53±0.1b</td>
<td>163.38±1.21a</td>
<td>706.07±13.6a</td>
<td>292.72±8.4a</td>
<td>293.73±3.2a</td>
</tr>
<tr>
<td><strong>P.Value</strong></td>
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<td>0.0001</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dark</td>
<td>12</td>
<td>25</td>
<td>1.93±0.1b</td>
<td>0.53±0.2b</td>
<td>1.39±0.2b</td>
<td>48.62±1.4d</td>
<td>410.56±12.4d</td>
<td>51.81±8.7d</td>
</tr>
<tr>
<td>Light</td>
<td>12</td>
<td>25</td>
<td>2.73±0.2b</td>
<td>0.83±0.3b</td>
<td>1.91±0.1b</td>
<td>106.38±2.0b</td>
<td>631.76±11.7b</td>
<td>274.64±12.0b</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>25</td>
<td>3.78±0.1b</td>
<td>1.04±0.1b</td>
<td>2.74±0.1b</td>
<td>63.11±1.3b</td>
<td>561.68±10.9b</td>
<td>106.71±7.9b</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>25</td>
<td>2.16±0.2b</td>
<td>1.00±0.1b</td>
<td>1.15±0.2b</td>
<td>220.39±2.0b</td>
<td>780.39±12.4a</td>
<td>310.80±12.0b</td>
</tr>
<tr>
<td><strong>P.Value</strong></td>
<td></td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0452</td>
<td>0.0312</td>
<td>0.0001</td>
<td>0.0014</td>
</tr>
</tbody>
</table>

a,b,c,d Means within column not sharing a common superscript differ significantly (P≤0.05)

### Tab. 5: Plasma T₃ and T₄ concentrations of embryos at day 12 and day 16 of incubation as affected by dark and light regimes

<table>
<thead>
<tr>
<th>Main effect</th>
<th>No.</th>
<th>T₃ (ng/dl)</th>
<th>T₄ (ng/dl)</th>
<th>T₃/T₄</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incubation status (I)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dark</td>
<td>50</td>
<td>260.16±5.2b</td>
<td>693.75±15.64</td>
<td>0.37±0.01b</td>
</tr>
<tr>
<td>Light</td>
<td>50</td>
<td>375.52±7.16a</td>
<td>687.69±14.62</td>
<td>0.54±0.02a</td>
</tr>
<tr>
<td><strong>P.Value</strong></td>
<td></td>
<td>0.0001</td>
<td>0.0631</td>
<td>0.0001</td>
</tr>
<tr>
<td><strong>Day of incubation (D)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>50</td>
<td>308.12±6.33b</td>
<td>695.37±16.64</td>
<td>0.44±0.02b</td>
</tr>
<tr>
<td>16</td>
<td>50</td>
<td>326.35±8.64a</td>
<td>686.19±14.19</td>
<td>0.48±0.02a</td>
</tr>
<tr>
<td><strong>P.Value</strong></td>
<td></td>
<td>0.0001</td>
<td>0.0655</td>
<td>0.0011</td>
</tr>
<tr>
<td><strong>Interaction effect (IxD)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dark</td>
<td>12</td>
<td>25</td>
<td>290.37±6.23b</td>
<td>698.19±14.97</td>
</tr>
<tr>
<td>Light</td>
<td>12</td>
<td>25</td>
<td>227.81±5.14a</td>
<td>689.42±15.97</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>25</td>
<td>325.19±7.34a</td>
<td>692.54±14.12</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>25</td>
<td>425.39±8.34a</td>
<td>682.94±13.97</td>
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<tr>
<td><strong>P.Value</strong></td>
<td></td>
<td>0.0001</td>
<td>0.0666</td>
<td>0.00061</td>
</tr>
</tbody>
</table>

a,b,c,d Means within column not sharing a common superscript differ significantly (P≤0.05)

Embryos at day 16 had increased plasma total lipids, cholesterol and triglycerides compared to day 12 of incubation. There was a significant (P≤0.0001) interaction between incubation status and day of incubation on plasma total lipids, cholesterol and triglycerides concentration. Embryos of the light group at day 16 of incubation had the highest values, but dark group at day 12 of incubation had the lowest values.

5. Plasma T₃ and T₄ Assay of Quail Embryos at 12 and 16 Days of Incubation

Table 5 showed highly significant (P≤0.0001) differences between treatments and day of incubation on plasma T₃ level and T₄/T₃ ratio. Plasma T₃ concentration and T₄/T₃ ratio increased when embryos kept at light incubation by 44 and 46%, respectively compared with those kept at dark incubation. Day of incubation increased (P≤0.0001) the level of T₃ and T₄/T₃ ratio. On the other hand, plasma T₄ level and T₃/T₄ ratio were significantly affected by the interaction between incubation status and day of incubation. The highest level of T₃ and T₃/T₄ ratio were obtained in the light group at day 16 of incubation, but the lowest values were obtained in the dark group at day 12.
of incubation. The main effect of treatments and day of incubation and their interaction had no significant effect on plasma T\textsubscript{4} concentration.

DISCUSSION

Results from the present study clearly showed that incubation under light regime influenced differently the embryonic growth, hatchability percentage and chicks performance after hatch. Light regime incubation improved significantly the embryonic growth, hatchability percentage and chicks performance after hatching when compared with the dark incubation. These results are in agreement with other reports (Cooper, 1972; Ghatpande et al., 1995; Shafey and Al-Mohsen, 2002; Shafey, 2004) who found that light regime incubation enhanced chicken embryonic growth and hatchability percentage, and also the chicks hatched under light regime incubation appeared to be more active when compared with those hatched under dark incubation. These improvements mainly related to physiological and metabolic responses to light during embryonic development. Avian embryos tend to float to the top of the yolk to a position just under the egg shell, where they are exposed to the light penetrating through the egg shell. The amount of light reaching the developing embryos triggers the stimulatory effect and consequently the amount of growth acceleration (Ghatpande et al., 1995). Results showed clear physiological and metabolic responses to light via activation of thyroid gland and increase biochemical constituents in blood plasma of developing embryos (Table 4 & 5).

Plasma T\textsubscript{4} concentration (Table 5) increased in embryos kept in light regime incubation by 44% compared with those kept at dark incubation, this increment indicates a hyperthyroid activity under light regime. Many researchers reported that light plays an important role in the development and growth of birds by the regulation of the function of the hypothalamus-pituitary-thyroid axis via eyes and extra-retinal photoreceptors, the hypothalamus area secrete TSH which cause production and secretion of thyroid hormones (Ottenweller and Hedge, 1982; Jerry, 1984; Wittkowski et al., 1988). Serum TSH, T\textsubscript{3}, and T\textsubscript{4} concentrations increased significantly during the light period of the daily cycle and decreased during the dark period of the cycle in rats (Ottenweller and Hedge, 1982; Jerry, 1984; Laakso et al., 1990).

These results are in a good agreement with Decuypere et al. (2005) who stated that high thyroid hormone concentrations during embryonic development appear to be stimulating a variety of developmental and metabolic processes necessary for successful hatching. Also, with the findings of Christensen (1995) who reported that physiological doses of thyroxine and triiodothyronine of 50 and 25 ng, respectively, injected at day 25 of incubation significantly improved hatchability in turkey embryos. In addition, EL-Nagar et al. (2005 & 2007) found that hatchability improved, embryonic mortality decreased and weight of one-day-old chicks increased significantly compared to control by the administration of thyroxine to Japanese quail hens and hens of local strain.

Moreover, the results reflected metabolic responses to light via increase in biochemical constituents of blood plasma in embryos under light regime. These embryos had significant (P<0.0001) increases in plasma biochemical parameters such as total protein, albumen, globulin, glucose, total lipids, cholesterol and triglycerides by 27, 50, 19, 83, 29, 28, and 55%, respectively compared to those kept at dark incubation. This indicates that light regime helps to increase the metabolic rate in developing embryos. This may in turn increase embryonic plasma T\textsubscript{3} levels. Many investigators found positive correlation between thyroid hormones and metabolic rate, development and differentiation of chicken embryos (Decuypere et al., 2005; Lu et al., 2007). Thyroid hormones (THs) have multiple effects on vertebrate metabolism and development. In homeothermic animals, THs regulate basal metabolic rate and are essential for the maintenance of high and constant body temperature. The effect of THs on protein and lipid metabolism is of a biphasic nature: in low physiological concentrations they are anabolic while at higher concentrations they are catabolic. During development THs stimulate both growth and differentiation (or maturation). Their action can be direct, indirect or permissive. Most of the actions of THs seem to be dependent on the binding to a nuclear thyroid hormone receptor (Zation et al., 1993; Decuypere et al., 2005).

A study suggests that thyroid hormones can activate GH synthesis and synergistically stimulate GH expression with glucocorticoids in rat pituitary cell lines (Yaffe and Samuels, 1984). However, thyroid hormones appear to require glucocorticoids to regulate GH gene expression and somatotroph differentiation in fetal animals. Chicken embryonic pituitary cells in culture indicate that the synergistic actions of glucocorticoids and thyroid hormones occur directly on the somatotroph precursor population to induce an increase in the absolute abundance of GH-producing cells (Liu et al., 2003).

Other researchers reported that light incubation improves embryonic growth by induced gene expression during the growth process which probably produces particular gene products (proteins, enzymes or regulatory molecular substances) (Ghatpande et al., 1995). Also, Rozenboim et al. (1999) reported that lighting elevated embryonic plasma androgens, enhancing protein synthesis and reducing protein breakdown (Bates et al., 1987).
CONCLUSIONS

In conclusion, the results of this study indicated that light regime incubation improved embryonic growth, hatchability percentage and chicks performance after hatching by increasing production and release of thyroid hormones, especially T₃, which is responsible for elevating embryonic metabolic rate. This is apparent via mobilization of biochemical constituents in blood of developing embryos.

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REFERENCES


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