Introduction

Environmental conditions influence hatchability of ostrich eggs as these include the length of the storage period, temperature, humidity, gaseous environment, and orientation of the eggs (MELLET, 1993). There is a decrease in hatchability of the egg during storage (MEDEHOF, 1992). A study in poultry (BUTLER, 1991) suggests that longer storage delays hatch time and reduces chick quality and growth rate. However, species variation exists. For example, KOSIN (1964) has indicated that chicken eggs when stored for 14 days show a severely reduced hatchability, whereas hatchability of Bobwhite quail eggs may only be slightly affected (WILSON, 1984). Very little research has been conducted on the effects of storage length on the hatchability of ostrich eggs. Due to the exceedingly high price of fertile ostrich eggs it was not possible to conduct storage experiments with large numbers of eggs. DEEMING (1993) found that storage for longer than seven days will result in a gradual decline in hatchability with a significant reduction after 14 days. By contrast, GONZALEZ et al. (1999) determined that ostrich eggs can be stored for a minimum of 10 days without negatively impacting on hatchability.

In the wild, ostrich adults are capable of incubating up to 22 eggs per nest. Oviposition in ostriches is approximately at 2-d intervals. The eggs laid early in a nest thus typically remain in the nest for 2 to 3 weeks before being incubated naturally (BERTRAM and BURGER, 1981) and all eggs in the clutch hatch at the same time. In the wild, the ambient temperature reaches 30–40 °C during the day and in the sun may exceed even 50 °C. As already mentioned, an exposure of eggs to direct sun significantly decreases the hatchability of eggs, thus leading to a considerable variability within one nest. However, in some cases despite high air temperature hatchability reaches even over 80% (HORBANCZUK, 2002) if the period from the laying of the first egg to the time when the ostrich starts sitting does not exceed 7–10 days and if the birds protect the eggs from full sun exposure. BRAKE et al. (1994) suggest that this is caused by differences between eggs in albumen quality. The first eggs in the clutch have a superior viscosity of albumen and can withstand longer storage and higher temperatures than the later eggs.

In the ostrich at the start and end of the laying season, storage may be even longer in order to ensure that sufficient ostrich eggs are set (DEEMING and AR, 1999). In addition, when the number of eggs laid on the farm is small, this period may even be extended to 14 days. Therefore, it is important to research the effects of the storage period on hatchability results.

The aim of the study was to further investigate the effects of preincubation storage of ostrich eggs on hatchability, egg weight loss, length of incubation and chick weight at hatching.

Materials and methods

Two hundred and ten ostrich (Struthio camelus) eggs were collected from seven trios of Black-Necked genotype (purebred of Struthio camelus camelus x Struthio camelus australis) aged 7 to 8 years, during April to August in the Research and Application Farm of the University.

The breeders were fed daily with 2 kg/bird a pelleted ostrich breeder ration (18% crude protein, 2,450 kcal ME). Water was supplied ad libitum. Additionally 500 g fresh alfalfa was supplied for each bird per day.

The nests of the ostriches were checked 2 times a day for the presence of eggs and eggs were collected. After collection each egg was coded immediately with the date of lay and then was transferred to a storage room. The eggs were dry cleaned after collection and placed horizontally on the wooden floor which was specially prepared and which allows air circulation. Eggs were regularly turned around their own axis every day during the storage period. The eggs were stored for 1–2, 3–4, 5–6, 7–8, 9–10 days at 16–18 °C and 70% relative humidity. Eggs were set in the same incubator 6 times during the laying period. The eggs were weighted individually on an electronic balance with ±0.01 g precision and sanitised in paraformaldehyde before setting. Thereafter, they were incubated in a Masalles 2600-1 incubator1 at a temperature of 36.5 °C and 30% relative humidity for 38 days. The eggs were turned at an angle of ±45° every hour. The eggs were candled on 14th day during the incubation period. Inertile eggs and those eggs in which the embryos had died early were removed from the machine. Viable eggs were candled again on 38th day of the incubation and those exhibiting embryonic mortality were determined and removed. Then they were opened and examined macroscopically for the time of embryonic mortality. Viable eggs were weighed individually on an electronic balance with ±0.01 g precision in order to determine the weight loss during the incubation period and were transferred to a hatcher Masalles 1300-N maintained at 36 °C and 40% relative humidity until hatching. Any eggs remaining at day 41 were candled to determine development and hatching.

1 Masalles Commercial, S.A., Ripolet, Barcelona, Spain

University of Uludag, Faculty of Agriculture, Dept. of Animal Science, Gorukle, Bursa, Turkey
of the embryos. Hatching was allowed to be as natural as possible. The weight of every chick hatched was determined using an electronic balance with ±0.01 g precision and the length of the incubation was determined individually. Infertility and embryonic mortality were recorded individually and totalled for storage groups.

The effects of different lengths of storage applications on the hatchability of fertile eggs and the incidence of embryonic mortality were revealed. Moreover, the relations between different storage length applications and egg weight loss, chick hatch weight and the length of the incubation period were determined. The experiment was subjected to analysis of variance (SAS, 1989), utilizing ANOVA procedures for balanced data. Analysis for percentage data were conducted after an arc sine transformation of the data. Significant differences among treatment means were determined by Duncan's multiple range test.

**Results**

The effects of different length of egg storage prior to incubation on hatchability of fertile eggs and embryonic mortality at different stages are shown in Table 1.

The effect of storage length on hatchability of fertile eggs was found to be significant (P < 0.01). Hatchability declined with storage length, for maximum hatchability less than 7 d of egg storage appears to be best.

Early and late embryonic mortality were significantly (P < 0.01) effected by length of egg storage. Embryonic mortality tended to increase with storage length of up to 7–8 days.

The effects of storage length on weight loss, length of incubation and chick weight at hatching were significant (P < 0.05). Egg weight loss increased with increased storage length. The chick weight tended to decline in relation to storage length of up to 7 days (P < 0.05). Length of incubation was effected by storage length (P < 0.05). It was longer for the ones that were stored for 9–10 days. The chick weight at hatching tended to decline in relation with storage time up to 7 days.

**Discussion**

The present study shows that maximum hatchability was obtained when eggs were stored up to 7 day before incubation. Early embryonic mortality also tended to slightly increase with storage length up to 7 days, thereafter was a sharp increase in the proportion of early and late embryonic mortality. It is common practice in poultry industry today to avoid extending the pre-setting storage period beyond the 7th day (Mayes and Takeballi, 1984).

Excessive storage is detrimental. Evidence of necrosis and regressive changes in the blastoderm even at 13 °C has been reported (Mathé and Laughlin, 1979). Some researchers have reported a decline in hatchability after 7 d of storage by as much as 5%/d (Hodgetts, 1981; Mayes and Takeballi, 1984). In contrast, Olyuem and George (1972), reported that storage for 4 to 6 d tended to improve hatchability of fertile eggs. DeeMing (1996) found that for 12–14 days of storage there was only 50% hatching of fertile eggs, and this was associated with high early mortality. Wilson et al. (1997) found a similar decline in hatchability of eggs stored for 3, 4–6, 7–9, 10–12 or 13–15 days, the best hatchability was obtained for eggs stored for 4 to 6 days. Ar and GEFEN (1998) suggest that ostrich eggs may benefit from a storage period of only 3–4 days. Storage length increased the reduction in hatchability and was usually associated with an increase in early embryonic mortality. Horbanczuk (2000) determined that highest hatchability from fertile eggs was obtained when they were stored not longer than 7 days. Midterm embryonic mortality was quite uncommon and obviously there was no link to storage length (Badley, 1998; Ar and GEFEN, 1998). These findings are in accordance with present results. By contrast, NAHM (2001) found that storage length as long as 19 days did not affect ostrich egg hatchability with the mucin coat remaining on the egg shell. KocAN (1993) states that storing of ostrich eggs for 4 to 6 d tends to improve results similar to eggs stored for 5 days or less. Bertram and Burg (1981) found that storage for approximately 8 d resulted in a numerical increase in hatchability in storage for approximately 3 d.

When eggs are stored for a long period, a reduction in albumen quality and hatchability of eggs is observed. The first eggs in the clutch have the highest quality of albumen, which retains its desirable physical properties for a longer period than that of the last eggs. Albumen pH increased with storage time and it reaches a pH of 9.5 after long term storage (Goodrum et al., 1989) which is far above the optimum. The most important effect of albumen quality appears to be on early embryonic mortality (Brake et al., 1993). For ratti eggs Brake et al. (1997)

**Table 1. Effects of different egg storage lengths on incubation results (mean ± SEM)**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Storage Length [d]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-2</td>
</tr>
<tr>
<td>Total Eggs [n]</td>
<td>42</td>
</tr>
<tr>
<td>Egg Weight (g)</td>
<td>1461 ± 21.8</td>
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<tr>
<td>Fertility (%)</td>
<td>66.7 ± 3.71</td>
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<tr>
<td>Hatchability of Fertile Eggs (%)</td>
<td>71.4 ± 2.70°</td>
</tr>
<tr>
<td>Early Embryonic Mortality (%)</td>
<td>10.7 ± 1.68c</td>
</tr>
<tr>
<td>Middle Embryonic Mortality (%)</td>
<td>3.57 ± 0.87</td>
</tr>
<tr>
<td>Late Embryonic Mortality (%)</td>
<td>14.3 ± 2.78b</td>
</tr>
<tr>
<td>Egg Weight Loss (%)</td>
<td>11.0 ± 2.83c</td>
</tr>
<tr>
<td>Chick Hatch Weight (g)</td>
<td>975 ± 19.1e</td>
</tr>
<tr>
<td>Chick Weight /Initial Egg Weight (%)</td>
<td>66.8 ± 1.38b</td>
</tr>
<tr>
<td>Incubation Length (h)</td>
<td>1012 ± 16.8a</td>
</tr>
</tbody>
</table>

a, b, c: Values within same lines with no common letter differ significantly * P < 0.05; ** P < 0.01
The effects of storage length on hatchability of fertile eggs was found to be significant (P < 0.01). Hatchability declined with storage length, for maximum hatchability at least 7 d of egg storage appears to be best. Hatchability of fertile eggs was determined as 71.4, 72.4, 70.4, 65.4 and 60.7% for the storage length groups, respectively. Early embryonic mortality rates (10.7, 10.3, 11.1, 15.4, 17.9%; P < 0.01) and late embryonic mortality rates (14.3, 13.8, 14.8, 15.4 and 17.9%; P < 0.01) were also found to be significant for the storage length groups, respectively. Egg weight loss increased with increased storage length (P < 0.05). Egg weight loss up to day 38 of incubation averaged 12.99% for eggs that hatched. The effects of storage length on chick weight at hatching and length of incubation was also found to be significant (P < 0.05). The chick weight tended to decline in relation with storage time up to 7 days. Chick weight at hatching averaged 66.8% and 65.0% of initial egg weight for the 1–2 to 9–10 d storage length, respectively.

**Keywords**

Ostrich, hatching eggs, storage length, hatchability, incubation length, chick weight

**Zusammenfassung**

Das Ziel der vorliegenden Studie war, den Einfluss der Lagerdauer von Straußeneiern vor der Brut auf die Schlußfrate, den Ge­wichstverlust der Eier während der Brut, die Brutdauer und das Kükenwichtigkeit beim Schlüpfen zu untersuchen. Hierzu wurden ins­gesamt 210 Straußeneier bei 18 °C über 10 Tage (1–2, 3–4, 5–6, 7–8, 9–10) gelagert. Es wurden signifikante Einflüsse der Lager­dauer auf die Schlußfähigkeit der befruchten Eier festgestellt (P < 0.05). Die Schlußfrate ging mit der Lagerdauer zurück, die maximale Schlußfrate wurde bei einer Lagerdauer von weniger als 7 Tagen erzielt. Die Schlußfraten betrugen 71.4, 72.4, 70.4, 65.4 und 60.7% für die verschiedenen Lagerungsstufen. Die frühe (10.7, 10.3, 11.1, 15.4, 17.9%; P < 0.05) und späte embryonale Sterblichkeit (14.3, 13.8, 14.8, 15.4, 17.9%; P < 0.05) wurde ebenfalls über die Lagerungsdauer beeinflusst. Der Gewichtsver­luste der Eier nahm mit der Lagerdauer signifikant zu (P < 0.05). Der Gewichtsverlust betrug bis zum 38. Brutttag durchschnittlich 13.0% für Eier, aus denen dann Küken schlüpften. Ferner wurden Effekte der Lagerdauer auf die Kükenwichtigkeit beim Schlüpfen und die Brutdauer ermittelt (P < 0.05). In der Tendenz ging das Kü­kenwichtigkeit bis zum 7. Lagerungstag zurück. Das Kükenwichtig beim Schlüpf lag bei 66.8% des Ausgangsge wichts für eine Lager­dauer von 1–2 Tagen und bei 65.0% für eine Lagerdauer von 9–10 Tagen.

**Stichworte**

Strauß, Bruteier, Lagerdauer, Schlußfrate, Brutdauer, Kükenwichtig

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Correspondence: Assoc. Prof. Dr. Umran Sahin, Department of Animal Science, Faculty of Agriculture, University of Uludag, Gonukle, Bursa, 16059, Turkey; e-mail: umran@uludag.edu.tr