EDUCATION AND PRODUCTION

Effects of Short Storage Conditions and Broiler Breeder Age on Hatchability, Hatching Time, and Chick Weights

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ABSTRACT An experiment was conducted to assess how hatching performance is affected by breeder age and egg holding environment during short-term storage. Response variables analyzed were egg weight loss up to 18 d of incubation, viability (hatchability of fertile eggs), embryonic mortality, hatching time, and weight of male and female chicks, at hatching and at the end of incubation. The trials involved a total of 2,250 hatching eggs from each of two commercial broiler breeder flocks of the same strain (Avian) but of different ages (32 to 34 and 48 to 50 wk). Eggs were stored for 0, 1, or 2 d in the egg storage room or in the setter room. The hatching times of the chicks were recorded at 4-h intervals during the period from 478 to 494 h postincubation, and at 514 h, when incubation was terminated and all chicks were removed from the hatcher. In eggs from younger hens, viability was not influenced by preincubation storage; in older hens, viability of eggs not submitted to storage was higher ($P < 0.05$) by 3 to 6 percentage points than that of stored eggs. Hatching times were not affected by age of the hen, whereas male chicks tended to hatch, on average, about 3 h later than females. Chick weights at hatching and at removal from the hatcher were similar for both sexes, but females experienced a higher ($P < 0.05$) weight loss in that interval. Eggs incubated on the day of lay tended to hatch, on average, later than stored eggs (especially when compared to eggs submitted to 1 d storage), and produced heavier chicks.

(*Key words*: egg storage, broiler breeder, hatchability, hatching time, chick weights)

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INTRODUCTION

Hatchability and chick quality are influenced by preincubation storage conditions, e.g., the length of time eggs are stored, temperature, humidity, gaseous environment, and the orientation and positional changes of the eggs. Long-term storage has been deeply investigated, and it is well known that it depresses hatchability, prolongs incubation time, and can affect chick quality adversely. An extensive review of this subject is given by Proudfoot (1969), Mayes and Takeballi (1984), Butler (1991), and Meijerhof (1992).

Few studies have been published in the literature about short-term storage of eggs, and conflicting results have been presented concerning the time the egg has the highest hatching potential between laying and setting in incubation. For example, a statement often heard is that "an egg is at its maximum hatching potential the moment it is laid" (Walsh, 1993:1), but Brake (1995) stated that eggs set fresh, without a period of storage, hatch later and are poorer than average, whereas Meijerhof (1992) concluded that fertile eggs can be stored for several days without a major loss in hatchability when appropriate conditions are maintained. As small improvements in the hatchability of broiler breeder eggs can result in important economic gains, further studies are needed to clarify this question.

On the other hand, it has been reported that a high proportion of early-hatched chicks are female (Williams *et al*., 1951; Zawalsky, 1962; Ichinoe, 1973; Mather and Laughlin, 1976; Burke, 1992), and that dehydration due to the length of time between hatching and removal of the chick from the hatcher (Tullett and Burton, 1982; Hager and Beane, 1983) might produce lighter females. However, discrepancies in previous studies can be found, as recently discussed by Burke (1992).

The purpose of this study was to examine the effects of different conditions of short-term preincubation storage of eggs from broiler breeder flocks with different ages on hatchability of fertile eggs, hatching time, and chick weight. Sex differences in hatching time and chick weights were also investigated.

MATERIALS AND METHODS

An experiment was carried out over a period of 3 wk in the Spring of 1995, using eggs from two commercial broiler breeder flocks of the same strain (Avian male

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and Avian feather-sexable strain female), of two age groups (32 to 34 and 48 to 50 wk of age) and housed in different farms at a density of 0.21 m^2 per bird. The flocks, each approximately 30,000 females, were reared and maintained during lay under standard management conditions.

Daily records of low and high in-house air temperatures were maintained; these ranged from 14 to 18 C and 16 to 19 C for the younger and older flock, respectively. Separate-sex feeding was carried out (McDaniel, 1985), with the same feed provided to both sexes, as diets used by the breeder hen appear to have no detrimental effects on male performance (Laughlin, 1988; Waldroup, 1993; NRC, 1994). The birds were fed a mash broiler breeder ration (16.50% CP, 2,800 kcal ME/kg, 3.10% calcium, 0.35% available phosphorus), formulated to meet or exceed NRC (1994) requirements. Water was available for *ad libitum* consumption.

Eggs were automatically collected[2] on a single day during 3 consecutive wk at 32, 33, and 34 wk of age (younger flock) and at 48, 49, and to 50 wk of age (older flock). As the two flocks were kept in different farms, the effects of age that were analyzed actually reflect the joint effect of flock age and housing conditions. Nevertheless, major environmental conditions such as temperature and feeding were identical in the two poultry houses. Furthermore, the fact that three samples were taken per house would tend to reduce any temporary effects specific to a given poultry house, and the major interest was in testing treatment differences within age group, rather than strictly establishing comparisons among ages.

Eggs laid between 1000 and 1200 h were collected, placed in incubator trays, and received at the hatchery at approximately 1300 h. Then eggs from both flocks were culled to remove those that were cracked, very dirty, misshapen, or of extreme size (those weighing less than 48 g or more than 70 g). After removing culled eggs, 750 eggs were randomly collected from each flock, individually marked, weighed to the nearest 0.1 g, fumigated, and randomized into five groups of 150 eggs each; one group was set in the incubator on the same day (no storage, CTL), whereas the other four groups were stored for either 1 or 2 d, two groups in the hatching egg cooler (ES1 and ES2, for 1- and 2-d storage, respectively) at 16 C and 79% relative humidity, and two groups in the setter room (SR1 and SR2, for 1- and 2-d storage, respectively) at 21 C and 63% relative humidity (Table 1).

The 150 eggs sampled in each week-storage treatment-flock age combination were placed on the same tray, and trays from different treatments were randomly placed in one quadrant (front right), on the same trolley, which was then filled with other eggs. Each week, incubation took place on 3 consecutive d (Day 0 for CTL, Day 1 for ES1 and SR1, Day 2 for ES2 and SR2). Therefore, eggs from the same treatment representing both ages were placed on the same single-stage incubator, but eggs from different treatments had to be set in identical incubators, for a total of nine machines (three machines per week). Previous results obtained in the same hatchery (Reis and Soares, 1993) indicate that machines did not represent a significant source of variation for hatchability of total eggs set and viability of fertile eggs. Furthermore, environmental conditions were automatically monitored; thus, it can be assumed that similar conditions were maintained in all the machines. Quadrant and trolley positions were the same in all settings to reduce possible position effects. The eggs were prewarmed in the incubator for 10 h at around 24 C and 65% relative humidity, just before the incubation period, which took place in an electronically controlled, single-stage incubator (Model 576).[2] All eggs were fumigated in the incubator on the day of setting. The eggs were turned hourly through 90° and incubated according to the conditions summarized in Table 2.

On the 18th d of incubation, all eggs were candled. "Clear" eggs were removed and broken out for macroscopic examination, in order to determine early

TABLE 1. Summary of preincubation experimental conditions

Treatment[1]	Storage		
	Time	Average temperature	Relative humidity
	(d)	(C)	(%)
CTL	0		
ES1	1	16	79
SR1	1	21	63
ES2	2	16	79
SR2	2	21	63

[1]CTL = no storage (control); ES1 and ES2 = storage in the hatchery egg store for 1 and 2 d, respectively; SR1 and SR2 = storage in the setter room for 1 and 2 d, respectively; all eggs were prewarmed at 24 C and 65% relative humidity for 10 h.

TABLE 2. Incubating temperatures

Incubation time	Dry bulb temperature	Wet bulb temperature
(h)	(C)	
Setter		
0 to 48	37.8	30.0
49 to 192	37.6	29.4
193 to 336	37.5	29.4
337 to 360	37.4	29.4
361 to 417	37.3	29.4
Transfer		
418 to 419	. . .[1]	. . .[1]
Hatcher		
420 to 444	36.9	30.0
445 to 469	36.9	31.1
470 to 516	36.8	32.2

[1]Eggs transferred at room temperature and humidity (approximately 24 C and 55% relative humidity).

[2]Vencomatic b.v., Eersel, The Netherlands.

TABLE 3. Least squares means and tests of significance for egg weight variables by age class by storage conditions

Egg weight variables[1]	Age	Preincubation storage						Significance[3]		
			Egg storage room		Setter room					
		CTL[2]	1 d (ES1)	2 d (ES2)	1 d (SR1)	2 d (SR2)	Pooled	A	T	A × T
	(wk)									
Loss, g	32 to 34	6.85 ± 0.06^{b}	7.28 ± 0.06^{a}	6.81 ± 0.06^{b}	7.18 ± 0.06^{ac}	7.07 ± 0.06^{c}	7.04 ± 0.03^{x}	*	*	
	48 to 50	7.47 ± 0.06^{df}	7.68 ± 0.06^{e}	7.31 ± 0.06^{ad}	7.57 ± 0.06^{ef}	7.46 ± 0.06^{df}	7.50 ± 0.03^{y}			
	Pooled	7.16 ± 0.04^{xz}	7.48 ± 0.04^{y}	7.06 ± 0.04^{x}	7.37 ± 0.04^{uy}	7.27 ± 0.04^{tu}				
	n	817	801	802	798	801	4,019			
Loss, %	32 to 34	11.32 ± 0.09^{bc}	12.07 ± 0.09^{f}	11.19 ± 0.09^{b}	11.88 ± 0.09^{ef}	11.75 ± 0.09^{de}	11.64 ± 0.04^{x}	*	*	*
	48 to 50	11.17 ± 0.09^{b}	11.54 ± 0.09^{cd}	10.91 ± 0.09^{a}	11.31 ± 0.09^{bc}	11.15 ± 0.09^{ab}	11.22 ± 0.04^{y}			
	Pooled	11.24 ± 0.07^{x}	11.80 ± 0.07^{y}	11.05 ± 0.07^{z}	11.59 ± 0.07^{t}	11.45 ± 0.07^{t}				

$^{a–f}$Means for the same trait and effect, or combination of effects, with no common superscript differ significantly ($P < 0.05$).

$^{t–x}$Pooled means with no common superscript differ significantly ($P < 0.05$).

[1]Egg weight loss from oviposition to transfer at 18 d of incubation.

[2]CTL = no storage (control).

[3]A = age; T = treatment.

*$P < 0.05$.

dead (< 7 d) and infertile. Remaining fertile eggs were individually weighed in order to determine weight loss during incubation. The eggs with apparently living embryos were transferred to hatcher baskets and randomly distributed in the front part of the same trolley. The hatcher (Model 192)[3] was maintained according to the conditions outlined in Table 2.

The hatcher was opened at 478, 482, 486, 490, and 494 h of incubation and any chicks that had fully emerged from eggs were removed, wing-banded, weighed to the nearest 0.1 g, and placed again in the hatcher. All chicks were removed at 514 h postincubation, individually weighed to the nearest 0.1 g, and feather-sexed. The eggs that failed to hatch were broken out, examined macroscopically, and assigned to one of the following categories: mid-dead (8 to 18 d), late dead (after 19 d), pips (i.e., pipped shell but not emerged), and contaminated eggs (i.e., rots). From the data, viability (number of saleable chicks hatched per number of fertile eggs set × 100) was calculated from the sample of 450 setting eggs per age class by treatment combination.

Statistical Analysis

Viability of fertile eggs (n = 4,419), as well as mortality at different stages of incubation (1 to 7, 8 to 18, 19 to 21 d, pipped and contaminated eggs), were coded as 0 or 1 and these codes submitted to analysis of variance with a linear model including the effects of sampling week (three classes), age of the hen (two classes), preincubation treatment (five classes), and the interaction between age and treatment. The same model was used to analyze egg weight loss during incubation, both in grams and as a percentage of initial weight. In both cases, analyses were conducted with The General Linear Models procedure (PROC GLM) of SAS® (SAS Institute, 1985).

Hatching times of the chicks born alive (n = 4,001) were assumed to follow a Weibull distribution (Lawless, 1982) with a probability density function for hatching:

$$h(t) = \lambda\beta(\lambda t)^{\beta-1} \exp[-(\lambda t)^{\beta}]$$

and cumulative proportion of hatched eggs described by:

$$S(t) = \exp[-(\lambda t)^{\beta}]$$

where t is the number of hours after incubation; λ and β are scale and shape parameters, respectively. Counting of hatched eggs started at 478 h postincubation, and at this time about 16% of the eggs had already hatched. Therefore a type I left censoring existed (Lawless, 1982); some eggs were known to have hatched before 478 h, but the exact time was unknown. The data on hatching times were thus analyzed with PROC LIFEREG of SAS®, considering a type I left censoring and assuming a Weibull distribution.

Chick initial and final weights, as well as weight loss, were analyzed with models including the effects of week of collection, flock age, and either hatching time, preincubation treatment, or sex (as hatching time was considered to be an integral part of sex and preincubation treatment differences), using PROC GLM of SAS®. Additionally, chick weight loss was regressed on the number of hours between hatching and removal from the incubator.

RESULTS AND DISCUSSION

Egg Weight Loss

Average initial weights of hatched eggs were 60.6 and 67.0 g ($P < 0.01$) for younger and older hens, respectively; transfer weights for the same ages were 48.9 and 53.9 g ($P < 0.01$). Egg weight loss during incubation, both in grams and percentage of initial egg weight, was affected by age and storage treatment and, in the latter trait, by the interaction among these two factors (Table 3).

[3]Petersime n.v., Zulte, Belgium.

TABLE 4. Least squares means and tests of significance for hatchability of fertile eggs and embryonic mortality at different stages, by age class by storage conditions combinations

		Preincubation storage							
			Egg storage room		Setter room			Significance[2]	
Character	Age	CTL[1]	1 d (ES1)	2 d (ES2)	1 d (SR1)	2 d (SR2)	Pooled	A T	A × T
	(wk)								
Hatch of fertile eggs, %	32 to 34	91.2 ± 1.4^{abd}	90.6 ± 1.4^{abc}	92.4 ± 1.4^{bd}	90.6 ± 1.4^{abc}	92.1 ± 1.4^{abd}	91.4 ± 0.6		†
	48 to 50	94.3 ± 1.4^{d}	91.2 ± 1.4^{abd}	88.7 ± 1.4^{ac}	90.1 ± 1.4^{abc}	89.3 ± 1.4^{abc}	90.7 ± 0.6		
	Pooled	92.7 ± 1.0	90.9 ± 1.0	90.6 ± 1.0	90.5 ± 1.0	90.7 ± 1.0			
Embryonic mortality, %									
Days 0 to 7	32 to 34	6.3 ± 1.1^{ab}	6.7 ± 1.1^{ab}	5.3 ± 1.1^{a}	4.2 ± 1.1^{a}	5.9 ± 1.1^{ab}	5.7 ± 0.5		†
	48 to 50	4.3 ± 1.1^{a}	5.8 ± 1.1^{ab}	8.6 ± 1.1^{b}	6.9 ± 1.1^{ab}	5.9 ± 1.1^{ab}	6.3 ± 0.5		
	Pooled	5.3 ± 0.8	6.2 ± 0.8	7.0 ± 0.8	5.6 ± 0.8	5.9 ± 0.8			
Days 8 to 18	32 to 34	1.3 ± 0.5	1.1 ± 0.5	0.9 ± 0.5	1.8 ± 0.5	1.6 ± 0.5	1.3 ± 0.2		
	48 to 58	0.2 ± 0.5	1.4 ± 0.5	0.5 ± 0.5	1.6 ± 0.5	1.1 ± 0.5	1.0 ± 0.2		
	Pooled	0.8 ± 0.4	1.3 ± 0.4	0.7 ± 0.4	1.7 ± 0.4	1.4 ± 0.4			
Days 19 to 21	32 to 34	0.9 ± 0.5^{ab}	1.3 ± 0.5^{ab}	0.5 ± 0.5^{ab}	1.6 ± 0.5^{b}	0.2 ± 0.5^{a}	0.9 ± 0.2		
	48 to 50	0.7 ± 0.5^{ab}	0.5 ± 0.5^{ab}	1.6 ± 0.5^{b}	0.5 ± 0.5^{ab}	2.7 ± 0.5^{c}	1.2 ± 0.2		*
	Pooled	0.8 ± 0.3	0.9 ± 0.3	1.0 ± 0.3	1.0 ± 0.3	1.5 ± 0.3			
Pipped	32 to 34	0.2 ± 0.4	0.2 ± 0.4	0.9 ± 0.4	1.8 ± 0.4	0.2 ± 0.4	0.7 ± 0.2	†	
	48 to 50	0.2 ± 0.3	0.9 ± 0.4	0.5 ± 0.4	0.9 ± 0.4	0.9 ± 0.4	0.7 ± 0.2		
	Pooled	0.2 ± 0.3^{x}	0.6 ± 0.3^{x}	0.7 ± 0.3^{xy}	1.3 ± 0.3^{y}	0.6 ± 0.3^{x}			
Contaminated	32 to 34	0.0 ± 0.1	0.0 ± 0.1	0.0 ± 0.1	0.0 ± 0.1	0.0 ± 0.1	0.0 ± 0.0^{x}	†	
	48 to 50	0.2 ± 0.1	0.2 ± 0.1	0.2 ± 0.1	0.0 ± 0.1	0.0 ± 0.1	0.1 ± 0.0^{x}		
	Pooled	0.1 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.0 ± 0.1	0.0 ± 0.1			

$^{a–d}$Means for the same trait and effect, or combination of effects, with no common superscript differ significantly ($P < 0.05$).

^{x,y}Pooled means with no common superscript differ significantly ($P < 0.05$).

[1]CTL = no storage (control).

[2]A = age; T = treatment.

†$P < 0.10$.

*$P < 0.05$.

Eggs from older hens tended to loose more weight in grams but less in percentage when compared to eggs from younger birds. The present results agree well with the observations obtained by Kirk *et al.* (1980), North and Bell (1990), and Roque and Soares (1994), who reported that proportional weight loss decreased slightly with flock age, probably because of the associated increase in egg weight, as larger eggs have less shell area per unit of interior egg weight than do smaller eggs. In addition, the present results show that the mean weight loss of the eggs up to 18 d of incubation, expressed as a percentage of the initial egg weight, was about 11.5%, corresponding approximately to the optimal water loss prescribed to obtain the highest hatchability (Tullett, 1981; Peebles, 1986; Davis *et al.*, 1988). Eggs stored for 1 d experienced a higher weight loss up to 18 d of incubation ($P < 0.05$) than eggs not stored or stored for 2 d. This was unexpected, because egg weight loss during a very short holding period under usual storage conditions is probably small enough to be neglected (Becker *et al.*, 1968). Considering that eggs stored for 1 d hatched earlier than eggs not stored or stored for 2 d (Table 5), one can speculate that the earlier embryonic development occurring in those eggs up to 18 d of incubation resulted in higher metabolic heat, which may increase egg temperature, and consequently water vapor pressure, inside the egg (Ar, 1991). Therefore, evaporative water loss from eggs stored for 1 d was likely to be higher. In addition, at the same incubation stage, the more advanced embryo produced a higher amount of metabolic water (Ar and Rahn, 1980), which may also have contributed to the incubation water loss.

Hatchability Performance

Fertility was 99.2 and 97.2%, in eggs from the younger (32 to 34 wk of age) and older (48 to 50 wk of age) flocks, respectively. Hatchability results for fertile eggs (Table 4)

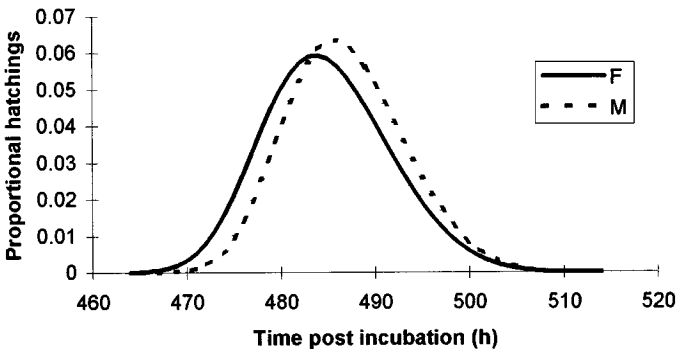

FIGURE 1. Distribution of hatching times by chick sex. (F = female, M = male).

TABLE 5. Chicks hatching time distribution

Incubation time	Treatment[1]										Sex				Age			
	CTL		ES1		ES2		SR1		SR2		Female		Male		32 to 34 wk		48 to 50 wk	
(h)		(%)		(%)		(%)		(%)		(%)		(%)		(%)		(%)		(%)
<478	87	(10.7)	201	(25.3)	46	(5.7)	171	(21.5)	135	(16.9)	423	(19.5)	217	(11.9)	315	(15.5)	325	(16.5)
482	99	(12.2)	95	(12.0)	118	(14.7)	135	(17.0)	124	(15.6)	355	(16.3)	216	(11.8)	273	(13.4)	298	(15.1)
486	171	(12.1)	184	(23.2)	267	(33.2)	195	(24.5)	201	(25.2)	573	(26.3)	445	(24.4)	515	(25.3)	503	(25.6)
490	198	(24.4)	212	(26.7)	238	(29.6)	160	(20.1)	210	(26.4)	508	(23.4)	510	(27.9)	523	(25.7)	495	(25.1)
494	160	(19.8)	73	(9.2)	94	(11.7)	91	(11.4)	83	(10.4)	211	(9.7)	290	(15.9)	262	(12.9)	239	(12.1)
514	95	(11.8)	29	(3.7)	41	(5.1)	44	(5.5)	44	(5.5)	105	(4.8)	148	(8.1)	144	(7.1)	109	(5.5)
Total	810		794		804		796		797		2,175		1,826		2,032		1,969	
Median	487		484		488		483		485		484		487		486		486	

[1]CTL = no storage (control); ES1 and ES2 = storage in the hatchery egg store for 1 and 2 d, respectively; SR1 and SR2 = storage in the setter room for 1 and 2 d, respectively.

were affected by the interaction between age and storage conditions ($P \leq 0.10$). In younger hens, all storage conditions resulted in similar viability, whereas in older hens viability was significantly ($P \leq 0.05$) better in CTL than for other treatments, with a superiority of about 4 to 6 percentage points, except for ES1, for which the difference was of about 3 percentage points ($P = 0.11$). These findings are consistent with the conclusion of other researchers (Kirk *et al.*, 1980; Meijerhof, 1994), who suggested that, where there is an option, eggs from younger flocks should be stored rather than those from older flocks. Present results also suggest that, under the conditions of this investigation, eggs from older flocks have their maximum hatchability at the time of lay, whereas eggs from younger flocks can hatch reasonably well when stored for a short period.

As can be seen from Table 4, the decline in hatchability of fertile eggs from the older flock caused by preincubation storage is explained by an increase in embryonic mortality until 18 d of incubation. These results could be explained by differences in albumen quality. The older flock might have initially lower albumen quality (Sauveur, 1988), and storing the eggs at 16 or 21 C probably allowed the albumen quality to decline (Walsh, 1993) to a point at which CO_2 may escape too quickly, which would compromise the buffering capacity of the egg (Heath, 1977). Therefore, as suggested by Walsh (1993), the loss of CO_2 may cause too rapid of a change in the acid-base balance of the embryo, resulting in death.

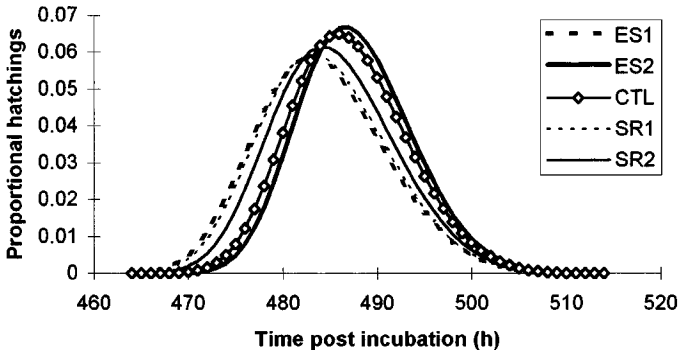

FIGURE 2. Distribution of hatching times by storage treatment. ES1 and ES2 = storage in the hatchery egg store for 1 and 2 d, respectively; CTL = no storage (control); SR1 and SR2 = storage in the setter room for 1 and 2 d, respectively.

Hatching Time

Table 5 shows the number of eggs hatched in each time period, by storage treatment, sex of the chick, and age of the hen. As mentioned before, observations started at 478 h, at which time about 16% of the eggs were already hatched; thus, the data were treated as type I left censored, assuming a Weibull distribution.

The probabilities of hatching by time are shown in Figure 1 by sex of the chicks and in Figure 2 for the different storage treatments. Corresponding cumulative hatchings are presented in Figures 3 and 4. The distributions by age of the hen were nearly identical for the two ages considered; therefore, results are not shown. Female chicks hatched earlier than males, with a difference of about 3 h between peak hatching times. These observations are supported by previous reports (Williams *et al.*, 1951; Zawalsky, 1962; Ichinoe, 1973; Mather and Laughlin, 1976; Burke, 1992) that have also clearly demonstrated the precocity of female embryos. The comparison of storage treatments (Figures 1 and 3) indicates that eggs submitted to 1 d storage (ES1 and SR1) hatched about 3 h earlier than eggs not stored, whereas eggs in treatment ES2 were the latest to hatch (about 1 h after the CTL treatment). These results suggest that storage of eggs for only 1 d, either at 16 or 21 C, was insufficient to completely arrest the development of the embryo. On the other hand, egg storage at the lower temperature for 2 d was sufficient to retard embryonic development, which compensated for the growth expected in the 1st d, such that the hatching pattern was very similar to that observed for eggs incubated on the day of laying (Figure 1). Thus, the commercial hatcheryman's rule of thumb, "1 d storage adds 1 h to incubation time" (Anonymous, 1991:4) is probably not correct for eggs stored for a short period of time before incubation.

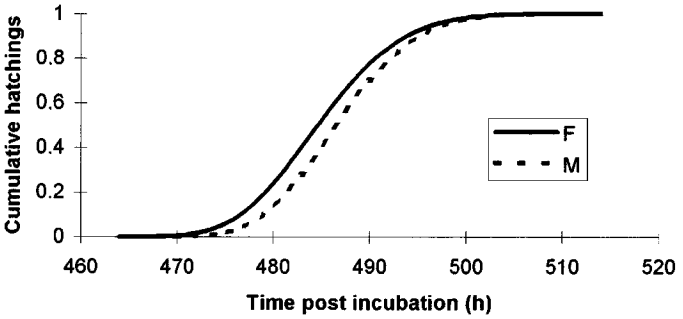

FIGURE 3. Cumulative hatchings by sex. (F = female, M = male).

Chick Weights

Male and female chicks had similar ($P > 0.05$) initial and final weights (Table 6), but weight loss between hatching and removal at 514 h postincubation was slightly higher in females ($P < 0.05$), because these chicks had to wait a longer period between hatching and chick removal. Hatching time had a significant effect upon initial and final weights, as well as upon weight loss until chick removal. Generally, earlier hatched chicks had higher initial weight and weight loss, but lower final weight. Chicks from the older flock had higher initial and final weights, as well as weight loss. The linear regression coefficient of weight loss on the number of hours between hatching and removal was 0.109 ± 0.003 g ($P < 0.01$), a clear indication that dehydration takes place between emergence and removal, resulting in weight losses of as much as 10% in early hatched chicks. Hager and Beane (1983) also quantified this loss, noting a similar reduction in chick weight (ca. 10%) for those hatched at 486 and 492 h postincubation and held in the hatcher up to 522 h. Burke and Sharp (1989) reported that male embryos were significantly heavier than females at 18 d of incubation. However, when body weight of day-old chicks (when removed from the hatcher) is considered, conflicting results can be found in the published literature. Some authors (Godfrey and Jaap, 1952; Zawalsky, 1962; Khan *et al*., 1975; Whiting and Pesti, 1983) found male chicks to be heavier than females, but others found no sex differences in body weight of day-old chicks (Jull and Quinn, 1925; Morris *et al*., 1968; Marks, 1985, 1986; Burke, 1992), as was found in our experiment. Probably, the main reason for the discrepancies between studies is the different length of the time between hatching and removal, as it will have a large effect on the degree to which the chicks had dehydrated and "fluffed up". Therefore, as females, on average, tend to hatch earlier than males, differences in the time spent in the hatcher will affect differently chick weight depending on the sex. Different genetic background may also explain some disagreements between investigations, as Burke *et al.* (1990) found a significant difference among sexes in body weight of day-old poults of one strain, whereas the difference in another strain did not become significant until 6 wk of age.

Initial chick weights (Table 6) were affected by treatment ($P < 0.10$) even though differences among treatments were small, with a slight superiority for chicks from eggs submitted to ES2 when compared to ES1 and SR2. Final weights were significantly higher in chicks

TABLE 6. Least squares means for chick weights, by hatching time, sex, and preincubation storage, and sex and flock age

Variable	Initial weight	Final weight	Weight loss
	(g)		
Hatching time			
478 h	46.4 ± 0.17[a]	41.6 ± 0.15[a]	4.8 ± 0.04[a]
482 h	47.0 ± 0.18[b]	42.4 ± 0.16[b]	4.6 ± 0.05[b]
486 h	46.6 ± 0.13[ab]	42.5 ± 0.12[b]	4.1 ± 0.03[c]
490 h	46.8 ± 0.13[b]	43.2 ± 0.12[c]	3.6 ± 0.03[d]
494 h	46.9 ± 0.19[b]	43.8 ± 0.17[d]	3.1 ± 0.05[e]
514 h	44.4 ± 0.27[c]	44.4 ± 0.24[c]	
Treatment[1]			
CTL	46.6 ± 0.15[ab]	43.0 ± 0.14[b]	4.0 ± 0.04[a]
ES1	46.4 ± 0.15[a]	42.4 ± 0.14[a]	4.1 ± 0.04[b]
ES2	46.9 ± 0.15[b]	43.1 ± 0.14[b]	4.0 ± 0.04[a]
SR1	46.5 ± 0.15[ab]	42.6 ± 0.14[a]	4.2 ± 0.04[b]
SR2	46.4 ± 0.15[a]	42.7 ± 0.14[a]	4.0 ± 0.04[a]
Sex			
Male	46.5 ± 0.10[a]	42.8 ± 0.09[a]	3.7 ± 0.03[a]
Female	46.6 ± 0.09[a]	42.7 ± 0.08[a]	3.9 ± 0.03[b]
Flock age			
32 to 34 wk	44.1 ± 0.08[a]	40.6 ± 0.07[a]	3.7 ± 0.02[a]
48 to 50 wk	49.1 ± 0.08[b]	45.0 ± 0.07[b]	4.4 ± 0.02[b]
Tests of significance[2]			
Time effect	**	**	**
Treatment effect	†	**	**
Sex effect	NS	NS	*
Age effect	**	**	**

[a–d]Means for the same trait and effect with no common superscript differ significantly ($P < 0.05$).

[1]CTL = no storage (control); ES1 and ES2 = storage in the hatchery egg store for 1 and 2 d, respectively; SR1 and SR2 = storage in the setter room for 1 and 2 d, respectively.

†$P < 0.10$.

*$P < 0.05$.

**$P < 0.01$.

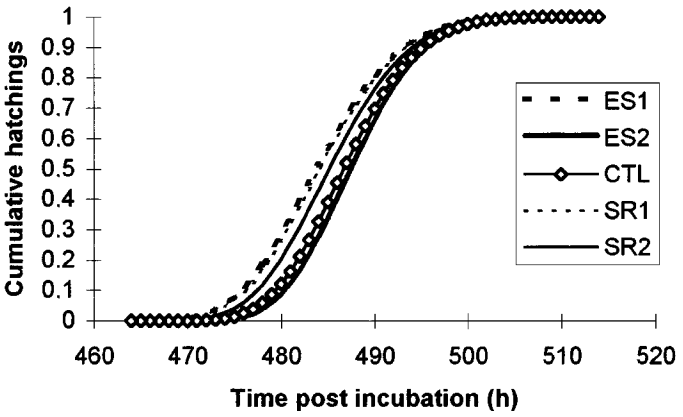

FIGURE 4. Cumulative hatchings by storage treatment. ES1 and ES2 = storage in the hatchery egg store for 1 and 2 d, respectively; CTL = not storage (control); SR1 and SR2 = storage in the setter room for 1 and 2 d, respectively.

from ES2 and CTL, which, together with SR2, had the lowest weight loss between hatching and removal. These results are probably due to the shorter length of time between hatching and removal for these treatments.

In conclusion, the results reported here suggest that, when single-stage incubators are used, hatchability in broiler hens can be improved if eggs are incubated as soon as they are laid, especially in older flocks.

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