

# Research Note: Interaction between hatching time and chick pull time affects broiler live performance

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**ABSTRACT** This study investigated the effects of broiler chick hatching time and pull time on subsequent live performance. Hatching eggs were obtained from commercial broiler breeder flocks of Ross 308 at 29 and 30 wk of age in trials 1 and 2, respectively. Eggs were incubated in 2 identical setters on 2 consecutive days. In both trials, portion of the eggs (9,600), incubated on the first day of set, were assigned to delayed-pull (DP) treatment, and the other portion of the eggs (9,600), incubated on the second day of set, were assigned to normal-pull (NP) treatment. The hatching period was divided into 3 hatching time groups, and chicks were classified as hatching in the early (478 to 490 h), middle (490 to 496 h), or late period (496 to 510 h of incubation). At 510 h of incubation based on the NP set date, all chicks were transferred to a broiler research house. A total of 7,200 and 8,400 chicks within 2 chick pull time treatments  $\times$  3 hatching time groups were raised in trials 1 and 2, respectively. The primary difference between the DP and NP treatments was an additional 24 h holding period in the hatcher for the DP group. Therefore, chick BW was higher at placement in the NP treatment than in the DP treatment ( $P < 0.001$ ). However, this advantage disappeared by

7 d, and the average BW did not differ between the DP and NP treatments at 41 d. Chick pull time did not affect feed consumption or feed conversion ratio (FCR) at 41 d. Similar to pull time, hatching time did not impact BW, feed consumption or FCR at 41 d. However, for mortality and European Production Efficiency Index (EPEI) at 41 d, a hatching time  $\times$  pull time interaction was observed ( $P < 0.001$ ). Mortality was higher and EPEI was lower in late hatch chicks than in chicks hatched early and middle in the NP treatment, whereas for chicks in the DP treatment, mortality and EPEI did not differ among the hatching time groups. These data indicated that the DP treatment, which held the chicks for an additional 24 h in the hatcher under optimum conditions, produced a lower initial BW accompanied by a period of compensatory weight gain through 41 d, and no differences ( $P > 0.05$ ) in live performance occurred due to the holding time in the hatcher. Overall, sending the late hatched chicks to the broiler house shortly after hatching increased their mortality and negatively affected their live performance (as measured by EPEI), unlike holding early hatched chicks for a relatively long time after hatching (50 h) in the hatcher.

**Key words:** hatching time, pull time, body weight, feed consumption, mortality

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## INTRODUCTION

The hatching process of commercial chicks is highly synchronized, especially when the chicks are from the same genetic line. However, even under optimum

conditions of artificial incubation, there has always been natural biological variation when commercial broiler chicks emerge from their eggshells (hatching time). In a commercial setting, chicks commonly hatch within a 24- to 36-h time period and chick pull time (incubation time) of approximately 510 h, which are considered optimal for the complete hatching of the incubated eggs. When the pull time is delayed, the posthatch holding period of the chicks in the hatcher is increased. Thus, early hatched chicks spend a longer time within the incubator without feed or water access than chicks that emerge from the egg later in the hatching period. It has been reported that chicks either held in the hatcher for an extended time after hatching or not pulled until all of

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the chicks have hatched can become susceptible to dehydration, which can lead to reduced growth and lack of uniformity of the flock on the broiler farm (Wyatt et al., 1985; Vieira and Moran, 1999; Careghi et al., 2005). Nevertheless, several studies have indicated that holding chicks in the hatcher for 24 h does not clinically dehydrate chicks or affect their live performance (Casteel et al., 1994; Joseph and Moran, 2005; Almeida et al., 2006; Lamot et al., 2014). Furthermore, a recent study (Özlü et al., 2020) demonstrated that a posthatch holding period for up to 40 h after hatching under optimum conditions had no detrimental effects on final live performance.

The metabolism of chicks hatching early or late in the hatch window seems to differ, and they may respond differently to early posthatch conditions (Careghi et al., 2005; Van de Ven et al., 2011; Lamot et al., 2014). Late hatched chicks appear to benefit from direct feed access after hatching compared to chicks that hatched in the early and middle hatching times (Careghi et al., 2005). However, Lamot et al. (2014) and Özlü et al. (2018) reported that early hatching chicks exhibited a different developmental and growth pattern than did middle or late hatching chicks, which may simply be related to differences in initial appetite.

Unfortunately, the posthatch holding time is not always well defined in the literature. In some of the early studies, the effect of the posthatch holding time was confounded by the feed access time, and others ignored the hatching time (time spent in the incubator). The current study was conducted to examine the interaction effect of hatching time and pull time on broiler live performance.

## MATERIALS AND METHODS

The experimental procedures used in these experiments were approved by the University of Ankara Institutional Animal Care and Use Committee (Ankara, Turkey).

### *Hatching Eggs and Incubation*

Hatching eggs were obtained from commercial broiler breeder flocks of Ross 308 at 29 and 30 wk of age in trials 1 and 2, respectively. In both trials, the hatching eggs were stored for 2 to 3 d at 18°C and 75% relative humidity (RH). A total of 19,200 hatching eggs were incubated in 2 identical incubators (Petersime, Zulte, Belgium) on 2 consecutive days in a commercial hatchery (Beypilic Inc., Bolu, Turkey) in each trial. Half of the total eggs (9,600 eggs) were incubated on the first day of set and were identified as delayed pull (DP) treatment, and the other half (9,600 eggs) were incubated on the second day of set and were identified as normal pull (NP) treatment in each of 2 trials. The rest of the trays in the incubators (with a maximum capacity of 57,600 eggs) were filled with hatching eggs from different flock ages that were not part of the experiment to ensure uniform air flow across the eggs.

A standard single-stage incubation program was used with a gradually decreasing machine set point temperature of 38.1°C at embryonic day (E) 1 of incubation to 37.0°C at E19. RH was 70% during the first 10 d of incubation (minimum ventilated) and then ventilated to maintain 40% RH until E19. Eggs were turned 90° on an hourly basis until E19, at which time they were transferred to hatching baskets (64 baskets) and placed in a hatcher. In addition, 64 hatching baskets without eggs (empty baskets) were also placed in each hatcher. Thus, half of the baskets were full of eggs (150 eggs/basket), and the others were empty. The hatcher temperature was initially set to 37.2°C and gradually decreased to 36.4°C over 3 d (until E21) in both trials.

### *Chick Management and Experimental Design*

The hatching period was divided into 3 hatch times in the DP and NP treatments in both trials. The early hatching time was defined as 478 to 490 h, the middle hatching time was 490 to 496 h, and the late hatching time was 496 to 510 h. At the end of both the early and middle hatching times, hatched chicks that were fairly dry and had closed navels were counted and placed back inside different (empty) hatcher trays, where they awaited the final pull.

In the current study, the length of the incubation period was 510 h and 534 h in the NP and DP treatments, respectively, and the primary difference between the DP and NP treatments was that the DP treatment remained in the hatcher for an additional 24 h at  $36.4 \pm 0.4^\circ\text{C}$  and  $53 \pm 2\%$  RH before pull time. During the holding period (24 h), the hatcher air temperature was programmed to maintain the optimal chick body temperature (40.0 to 40.5°C).

In both trials, the average posthatch holding periods in the hatcher for early, middle and late hatched chicks in the DP treatment were 50, 41, and 31 h, respectively. In the NP treatment, the average posthatch holding time in the hatcher of chicks in the early group was 26 h, that of the chicks in the middle group was 17 h and that of the chicks in the late group was 7 h. At 510 h of incubation based on the NP set date, both treatments of chicks were removed from the hatchers, selected as saleable (clean, dry, and without deformities) chicks, counted, feather-sexed, vaccinated, and transferred to a broiler research house within 4 h in both trials. Chicks from all groups were placed in the house and had access to feed and water immediately.

In total, 83.1% and 83.8% of the chicks were hatched from the NP and DP treatments in trial 1, respectively. In trial 2, 85.6% of the chicks were hatched from the NP and 85.3% of the chicks were hatched from the DP treatments. In trial 1, 23% of the total chicks hatched in the early hatching period, 44% hatched in the middle hatching period, and 33% hatched in the late hatching period. Similarly, 27%, 49%, and 24% of the total chicks hatched in the early, middle and late, respectively, in trial 2.

For each hatching time group per pull time treatment, a total of 7,200 and 8,400 chicks were assigned to 6 or 7 replicate pens of 100 male and 100 female chicks (15.4 chicks/m<sup>2</sup>) within 2 chick pull time treatments from the hatcher (DP and NP treatments) × 3 hatching periods (early, middle, and late) in trials 1 and 2, respectively.

### Grow-Out Housing and Management

The grow-out period of the experiment was carried out in an experimental broiler house (Beypilic Inc., Bolu, Turkey) with automatic ventilating and heating systems. The chicks were reared in 36- and 42-floor pens with new wood shavings under uniform management conditions throughout the experimental period in trials 1 and 2, respectively. Feed was weighed and distributed using an automatic feeding system at the pen level. Each pen (6.5 × 2.0 m) was equipped with 4 feeder pans and 2 drinker lines with 20 nipple drinkers to provide feed and water for ad libitum consumption. Additional chick feeder pans and drinkers were placed in each pen for the first 7 d.

The brooding facilities were preheated for 24 h before chick placement to achieve a stable and uniform litter temperature. At the time of chick placement, the litter temperature was 33°C, which gradually decreased to 20°C by 21 d of age and remained at that level until slaughter at 41 d of age. The chicks received continuous light (24 L: 0 D), and the light intensity at the pen level was 20 lux during the growing period. Feeds were formulated based on corn-soybean meal. Starter and grower diets were fed for 0 to 10 d and 11 to 24 d, respectively. The finisher diet was fed for 25 to 41 d. The starter feeds were produced in crumble form, while the other feeds were manufactured in pellet form (3.5 mm in diameter). The diets for each feeding period were formulated to meet or exceed the demands of broiler chickens according to the recommendations of the breeder company until slaughter weight was reached at 41 d.

### Broiler Live Performance Measurements

Body weights were measured at 0, 7, and 41 d of age by bulk weighing in each pen. Feed consumption was calculated by the difference in feed offered and feed remaining on a pen basis at 7 and 41 d. The feed conversion ratio (FCR) was calculated based on feed intake divided by body weight gain (BWG) for 0 to 7 d and 0 to 41 d. Mortality was recorded twice daily in each pen. From the performance data, the European Production Efficiency Index (EPEI) was also calculated by the following formula:

$$EPEI = \frac{BW \text{ (kg)} \times \text{Liveability (\%)}}{\text{Production period length (d)} \times FCR \text{ (g/g)}} \times 100$$

### Statistical Analyses

In both trials, a floor pen of 100 male and 100 female chicks at placement time constituted a replicate, and there were a total of 36 or 42 replicate pens used for trials 1 or 2, respectively. Hatching time and pull time were the main effects in the 3 × 2 factorial design with 13 (6 and 7 replicate pens in trials 1 and 2) replicate pens per interaction cell. The data of both trials were analyzed together using the GLM procedure in SAS (SAS version 9.1; SAS Institute, Cary, NC). The model used to analyze the effects of body weight, body weight gain, feed consumption, feed conversion ratio, mortality, and EPEI was as follows:  $Y_{ijk} = \mu + PT_i + HT_j + (PT \times HT)_{ij} + e_{ijk}$ , where  $\mu$  was the overall mean,  $PT_i$  was the pull time (DP or NP),  $HT_j$  was the hatching time (early, middle, or late),  $(PT \times HT)_{ij}$  was the interaction between pull time and hatching time, and  $e_{ijk}$  was the residual error term. When the means of the GLM were statistically different, means were compared using least squares or Duncan's test for multiple comparisons. Statements of significant differences were based upon  $P \leq 0.05$ .

## RESULTS AND DISCUSSION

### Body Weight

The effects of hatching time and pull time on BW are presented in Table 1. No interactions were observed between hatching time and pull time for BW ( $P > 0.05$ ) during the growing period.

In the current study, the DP treatment was held in the hatcher approximately 24 h longer than the NP treatment. Therefore, chicks in the DP treatment weighed 6.7% less than those in the NP treatment at placement ( $P < 0.001$ ). However, this advantage for NP treatment was no longer evident 7 d after being introduced to feed and water, and no effect of pull time was found for BW at 41 d (Table 1). In contrast to our findings, several previous studies have demonstrated that the longer that chicks remained in hatcher, the more they suffered from dehydration, which negatively affected their subsequent growth and mortality (Wyatt et al., 1985; Pinchasov and Noy, 1993; Vieira and Moran, 1999). However, in these early studies, in addition to the posthatch holding period, a second treatment included feed access time. This introduced a confounding factor and may be misleading. In the current study, we consider the day the chicks are housed in the farm as their first day of life, regardless of the interval between hatching and housing, and all chicks were able to access feed and water at the same time, which is common practice in the industry.

In the present study, it was clearly observed that BW decreased in the DP treatment at placement time, as chicks remained 24 h longer in the hatcher however, pull time had no influence on the final 41 d BW. This finding is in agreement with the study of Casteel et al. (1994), who found that chicks held for 24 h after hatching in the

**Table 1.** Body weight (BW), feed consumption (FC) and feed conversion ratio (FCR) of broilers at 41 d of age according to hatching time and pull time in 2 trials.

Pull time <sup>1</sup>	Hatching time <sup>2</sup>	--- (BW, g) ---			--- (FC, g) ---		--- (FCR, g/g) ---	
		0 d	7 d	41 d	0–7 d	0–41 d	0–7 d	0–41 d
DP		34.07 <sup>b</sup>	179.7	2574	156.8 <sup>a</sup>	4064	1.077	1.600
NP		36.52 <sup>a</sup>	180.7	2571	153.1 <sup>b</sup>	4075	1.062	1.608
SEM <sup>3</sup>		0.065	0.60	8.1	1.00	16.8	0.007	0.004
	Early	34.18 <sup>c</sup>	180.4 <sup>a</sup>	2570	156.2 <sup>a</sup>	4081	1.069	1.609
	Middle	35.17 <sup>b</sup>	182.3 <sup>a</sup>	2577	156.5 <sup>a</sup>	4063	1.064	1.599
	Late	36.55 <sup>a</sup>	178.0 <sup>b</sup>	2570	152.1 <sup>b</sup>	4064	1.075	1.604
	SEM <sup>3</sup>	0.079	0.74	9.9	1.22	20.6	0.009	0.005
<i>P</i> value								
Pull time		<0.001	0.250	0.804	0.011	0.648	0.149	0.192
Hatching time		<0.001	<0.001	0.836	0.019	0.786	0.680	0.359
Pull time × hatching time		0.390	0.096	0.535	0.357	0.356	0.994	0.284

<sup>a-c</sup>Means in the same column with different superscripts differ significantly ( $P \leq 0.05$ ).

<sup>1</sup>Pull Time: Incubation time was 510 for normal pull (NP) and 534 h for delayed pull (DP) treatment. The primary difference between the DP and NP treatment was an additional 24 h holding period in the hatcher for the DP treatment.

<sup>2</sup>The early hatching time was 478 to 490 h, the middle hatching time was 490 to 496 h, and the late hatching time was 496 to 510 h.

<sup>3</sup>SEM for a mean of 13 pens (6 pens or 7 pens of 100 male plus 100 female chicks at placement in trial 1 or 2, respectively).

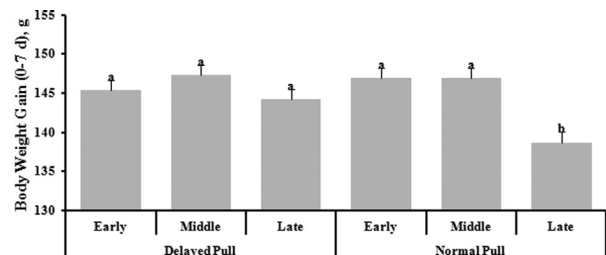
machine before placement weighed 5% less than those placed immediately at the time of placement, but their BW was similar in both groups by 43 d of age when the birds were weighed at the same age relative to placement on feed and water. Moreover, [Blake et al. \(2013\)](#) conducted a similar experiment in bobwhite quails and reported that holding chicks for an additional 24 h reduces the initial BW, but the held chicks responded with compensatory gain and had a greater BW at 28 d compared to the control. In a recent study ([Özlu et al., 2020](#)) in our laboratory, a posthatch holding period for up to 40 h after hatching under optimum conditions had no detrimental effects on final live performance. When the body temperature is maintained at an optimum level, the duration between hatching and arrival at the farm becomes less important because dehydration is prevented, mainly because of yolk sac utilization ([Bergoug et al., 2013](#); [Hamissou Maman et al., 2019](#)).

It has been reported that chick weight at pull time was significantly influenced by hatching time, as chicks that hatched early lost BW while waiting and subsequently weighed less than later hatching chicks at pull time ([Wyatt et al., 1985](#); [Careghi et al., 2005](#); [Joseph and Moran, 2005](#); [El Sabry et al., 2013](#); [Özlu et al., 2018](#)). In addition, [El Sabry et al. \(2013\)](#) divided chicks into two hatching time groups (early and late), with a mean difference of 15 h, and reported that early hatched chicks were not able to compensate for their posthatch BW loss and weighed less at 35 d of age. However, in the study of [El Sabry et al. \(2013\)](#), chick sex was not accounted for; therefore, this might create a disadvantage in final BW for early hatched chicks compared to late hatched chicks, as females hatched earlier than males ([Van de Ven et al., 2011](#)).

In the current study, BW at placement was higher in the late hatched chicks than in those that hatched early ( $P < 0.001$ ), with chicks in the middle hatching group being intermediate and significantly different from the other groups ( $P < 0.001$ ). However, early and middle hatched chicks exhibited greater ( $P < 0.001$ ) BW than late hatched chicks at 7 d.

For BW gain between placement and 7 d, an interaction of pull time × hatching time was observed ( $P < 0.05$ ; [Figure 1](#)). From placement to day 7, late hatched chicks held in the hatcher for the shortest period (average 7 h) after hatching gained less BW than chicks hatched in the early and middle times in the NP treatment, whereas no differences between hatching times were observed for the DP treatment. This corresponds with previous studies ([Lamot et al., 2014](#); [Özlu et al., 2018](#); [Deines et al., 2021](#)) that found that BW gain during the first 7 d was significantly lower in the late hatching than in the early and middle chicks and can be explained by late hatched chicks spending the shortest time without feed and water, being less mature in development at the moment of placement compared to the other groups. Thus, chicks continue to develop by investment in organ development and growth of the digestive system, regardless of the presence of feed, as yolk sac reserves are used for this purpose ([Almeida et al., 2006](#); [Lamot et al., 2014](#)).

In the current study, the BW differences among the hatching time groups disappeared, and the BW was similar for chicks from different hatching time groups at 41 d ([Table 1](#)). This finding was consistent with the findings of [Joseph and Moran \(2005\)](#), [Almeida et al. \(2006\)](#),



**Figure 1.** Body weight gain of broiler chickens from placement to 7 d of age in 2 trials. Groups with different letters are significantly different at  $P < 0.05$ . Pull time: Incubation time was 510 for normal pull (NP) and 534 h for delayed pull (DP) treatment. The primary difference between the DP and NP treatment was an additional 24 h holding period in the hatcher for the DP treatment. The early hatching time was 478 to 490 h, the middle hatching time was 490 to 496 h, and the late hatching time was 496 to 510 h.

and Deines et al. (2021), who found that holding early hatched chicks in the hatcher for up to 12, 24, and 24 h had no effect on BW at 41 to 42 d of age when compared with the BW of late hatched chicks Clark et al. (2017). reported that hatching time did not impact BW, average daily gain, feed efficiency, or period of livability at any time between 0 and 48 d of age. However, the broilers that had hatched early were heavier ( $P < 0.01$ ) at 63 d than those that had hatched in the middle or late period. Moreover, in a study by Özlü et al. (2018), early hatched chicks, which spent the longest time without feed and water after hatching (36 h), had a lower BW than late hatched chicks (8 h) at placement time, but opposite of the placement time, the BW was higher for early hatched chicks than the late hatched chicks at 35 d ( $P < 0.05$ ).

### **Feed Consumption and Feed Conversion Ratio (FCR)**

The effects of the hatching time and pull time on feed consumption and the FCR are shown in Table 1. No interactions between hatching time and pull time were found for feed consumption and FCR at 7 and 41 d.

In the current study, the NP treatment consumed less feed than the DP treatment during the first week ( $P = 0.011$ ), but there were no significant differences in feed consumption at 41 d of age for pull time.

There was a significant increase in feed consumption in the early and middle hatching compared with the late hatching group at 7 d ( $P = 0.019$ ). The late hatched chicks in the NP treatment, which were held for a shorter period in the hatcher, consumed 6 g less feed than the late hatched chicks in the DP treatment at 7 d (data not shown). These findings are consistent with the BW gain during the first week, as shown in Figure 1, which clearly demonstrated a negative effect among the late hatched chicks in the NP treatment, resulting in reduced feed consumption at 7 d. This was in agreement with the studies by Lamot et al. (2014), Özlü et al. (2018), and Deines et al. (2021), who observed that late chicks consumed less feed at 7 d compared to early and middle hatch chicks.

In the current study, in both the pull time and hatching time groups, chicks held for shorter periods in the hatcher consumed less feed during the first 7 d. A possible explanation for this is that early utilization of the yolk could have produced a more metabolically mature chick with a stronger and more aggressive appetite (Chamblee et al., 1992). In the current study, the later hatch chicks in the NP treatment that were held for the shortest period (7 h) in the hatcher possibly did not have enough time to absorb enough yolk and were not ready to consume feed aggressively at placement time, unlike the early hatched chicks.

In this study, for the overall period at 41 d, there were no significant differences in feed consumption, similar to previous studies (Joseph and Moran, 2005; Almeida et al., 2006; El Sabry et al., 2013; Deines et al., 2021).

The FCR at 7 and 41 d was not affected by the pull time or by the hatching time. Effects on FCR due to hatching time have also not been apparent at market age in other studies (Joseph and Moran, 2005; Almeida et al., 2006; El Sabry et al., 2013).

### **Mortality**

Some previous studies have shown that chicks remaining in hatchers longer became dehydrated and exhibited increased early rearing mortality compared with those removed soon after hatching (Hamdy et al., 1991; Pinchasov and Noy, 1993). Furthermore, Vieira and Moran (1999) showed that 24-h delays in housing increased total mortality, primarily due to inaccessibility of feed and water, resulting in dehydration and a shortage of available energy. In contrast to previous findings, in our study, mortality, a direct indicator of flock health and welfare, was not affected by pull time at 7 d. In addition, DP chicks were held under optimum conditions in which the vent temperature was kept in the ideal range (40.0 to 40.5°C) during the 24 h holding period and had no evidence of dehydration. However, Hamissou Maman et al. (2019) reported that day-old chicks with high body temperatures (42.6°C) exhibited 3 times higher BW loss than the chicks in the control (40.0°C) group during the 12 h posthatch handling period that negatively affected subsequent growth and mortality. On the other hand, mortality was affected by hatching time and was greater in late hatched chicks than in early and middle hatched chicks ( $P = 0.007$ ) at 7 d (Table 2).

At 41 d, an interaction between pull and hatching time was observed for mortality ( $P < 0.001$ ; Table 2). Mortality was higher in late hatch chicks than in chicks hatched early and middle in the NP treatment, whereas for chicks in the DP treatment, no differences in mortality were observed among hatching times. However, mortality was higher in all hatching time in DP treatment than the early and middle hatching times in NP treatment. The highest and lowest percentages of mortality were found in late (8.48%) and early (4.62%) hatched chicks in the NP treatment, respectively. A similar trend was also found in a study reported by Özlü et al. (2018), in which late hatched chicks exhibited higher mortality even when their holding period was shorter than that of early hatched chicks. This might be explained by the increased risk of possible bacterial contamination of incompletely healed navels in late hatched chicks that sending to the broiler house shortly after hatching.

### **European Production Efficiency Index (EPEI)**

An interaction between hatching time and pull time was found for the EPEI at 41 d ( $P < 0.001$ ) (Table 2). In the NP treatment, the EPEI was significantly lower in late hatch chicks than in the early and middle hatch groups, whereas the EPEI was not affected by hatch time in the DP treatment.

**Table 2.** Mortality and European production efficiency index (EPEI) of broilers at 41 d of age according to hatching time and pull time in 2 trials.

Pull time <sup>1</sup>	Hatching time <sup>2</sup>	Mortality		EPEI 41 d
		0-7 d	0-41 d	
DP		1.45	6.71	366.1
NP		1.17	6.22	365.8
SEM <sup>3</sup>		0.13	0.25	1.39
	Early	1.14 <sup>b</sup>	5.64 <sup>b</sup>	367.6 <sup>a</sup>
	Middle	1.07 <sup>b</sup>	5.99 <sup>b</sup>	369.7 <sup>a</sup>
	Late	1.72 <sup>a</sup>	7.76 <sup>a</sup>	360.4 <sup>b</sup>
	SEM	0.16	0.30	1.70
DP	Early	1.50	6.66 <sup>b</sup>	363.9 <sup>b</sup>
	Middle	1.25	6.43 <sup>bc</sup>	367.7 <sup>ab</sup>
	Late	1.60	7.04 <sup>b</sup>	366.6 <sup>ab</sup>
NP	Early	0.79	4.62 <sup>d</sup>	371.3 <sup>a</sup>
	Middle	0.89	5.56 <sup>cd</sup>	371.8 <sup>a</sup>
	Late	1.83	8.48 <sup>a</sup>	354.2 <sup>c</sup>
	SEM	0.22	0.43	2.40
<i>P value</i>				
Pull time		0.117	0.166	0.885
Hatching time		0.007	<0.001	<0.001
Pull time × hatching time		0.112	<0.001	<0.001

<sup>a-d</sup>Means in the same column with different superscripts differ significantly ( $P \leq 0.05$ ).

<sup>1</sup>Pull Time: Incubation time was 510 for normal pull (NP) and 534 h for delayed pull (DP) treatment. The primary difference between the DP and NP treatment was an additional 24 h holding period in the hatcher for the DP treatment.

<sup>2</sup>The early hatching time was 478 to 490 h, the middle hatching time was 490 to 496 h, and the late hatching time was 496 to 510 h.

<sup>3</sup>SEM for a mean of 13 pens (6 pens or 7 pens of 100 male plus 100 female chicks at placement in trial 1 or 2, respectively).

On the other hand, early hatched chicks exhibited higher EPEI in the NP than in the DP treatment (371.3 *vs.* 363.9%). An inverse pattern of EPEI was observed for late hatch chicks. Late hatch chicks in the NP treatment exhibited a lower EPEI than the late hatch chicks in DP (354.2 *vs.* 366.6%). This was caused by the differences in mortality that as being held in the hatcher longer increased the mortality for early hatched chicks but decreased it for late hatch chicks at 41 d. This current study demonstrated that chicks that had experienced a delayed pull time (534 h *vs.* 510 h) under optimum conditions exhibited a lower initial BW but could grow well until slaughter age at 41 d, and no differences ( $P > 0.05$ ) in live performance occurred due to holding time in the hatcher. Overall, sending the late hatch chicks to the broiler house shortly after hatching, judged by their mortality at 41 d, affects their live performance (**EPEI**) negatively unlike holding early hatched chicks for a relatively long time after hatching (50 h) in the hatcher.

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## DISCLOSURES

All authors declare that this research was conducted in the absence of any commercial or financial

relationships that could be construed as a potential conflict of interest.

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