Effects of hatch window and nutrient access in the hatcher on performance and processing yield of broiler chicks reared according to time of hatch

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ABSTRACT The effects of hatch window and hatching basket nutrient availability on organ weights, performance, and processing yield of broilers were investigated. Eggs were hatched in illuminated hatchers. At the end of each hatch window period (**HWP**), hatched chicks were placed into control (**CTL**) hatching baskets with no nutrients or baskets providing access to feed and water (**FAW**). This resulted in 6 treatments in a factorial arrangement of 3 HWP (early, middle, or late) and 2 basket types (CTL or FAW). Chicks remained in experimental baskets until 504 h and were then subjected to a 4 h holding period at the hatchery without nutrient access. Subsequently, 1,500 hatched chicks were reared in floor pens for 42 d with 5 replicate pens per treatment. Common diets and water were provided ad libitum. Bird weights and feed consumption were recorded weekly. Individual bird weights were taken at 21 and 42 d. At 43 d, 14 males from each pen were processed. There was an interaction between HWP and basket type on placement BW ($P = 0.028$) and BW change in the hatcher ($P < 0.001$). The HWP influenced BW at hatch ($P = 0.007$), 7 d ($P < 0.001$), and 14 d ($P < 0.001$) and FI at 7 d ($P < 0.001$) and 14 d ($P = 0.002$). Chicks from FAW baskets were heavier ($P < 0.001$) than those from CTL baskets at 7 d; afterward, they were similar ($P > 0.05$) in BW. Yolk and liver weights were similar ($P > 0.05$) between basket treatments at 3 d posthatch. No differences ($P > 0.05$) in FCR, mortality, or processing were observed between basket treatments. Interestingly, early hatching chicks were lightest at hatch but subsequently had higher FI and BWG. These findings indicate that hatcher nutrient access may reduce weight loss in the hatcher, especially for early hatching chicks, but had no influence on subsequent performance or processing yields beyond 7 d.

Key words: early feeding, nutrient access, hatch window, hatcher, broiler

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INTRODUCTION

Once a chick hatches it remains in the hatcher for a variable amount of time depending on several factors, with the hatch window being the most influential. Hatch window refers to the time, from the first hatched egg to the last, that is required for all eggs that are laid in a clutch or set together in a hatcher to hatch. This spread of hatch affects early development and has been shown to be impacted by many factors including the age of parent flock (Almeida et al., 2008), length and environmental conditions of egg storage (Mather and Laughlin, 1977; Tona et al., 2003), incubation parameters and chick communication (Tong et al., 2013), and homogeneity or heterogeneity of the eggs. Commercially produced broilers generally have a 24 to 48 h hatch window, and a shorter time is preferred to avoid problematic dehydration of early hatchers. The commonly regarded 21 d of incubation (**doi**), or 504 h of incubation (**hoi**), period varies in true duration and the chick typically leaves the egg prior to this point, allowing it sufficient time to dry off and mature to an ambulatory chick within the hatcher. After processing at the hatchery (e.g., sexing, counting, vaccinating, boxing) chicks are then transported to the farm, where feed and water are typically first available. Clearly, earlier hatching chicks have a longer delay in access to exogenous nutrients than their later hatching counterparts. Indeed, Careghi et al. (2005) suggested that the beginning of delays in feed access should be determined from the time of hatch and not when the hatch is pulled.

It is well documented that chicks subjected to extended holding periods in the hatchery or other extended delays in access to feed and water will have hindered immediate and long term performance (Noy and Sklan, 1997; Vieira and Moran, 1999;

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Bigot et al., 2003). Compared to chicks placed after pull of hatch, chicks remaining in the hatcher for an additional 24 h were lighter and lost approximately 5% BW during that time (Casteel et al., 1994). Similarly, Pinchasov and Noy (1993) found that chicks and poults lost approximately 10% of their initial weight when fasted during a holding period of 48 h after hatch, and that weight loss was primarily due to degradation of the yolk sac during the first 48 h posthatch. The process of hatching is very energetically demanding, and afterward the chick must transition from endogenous to exogenous nutrients. This process is accompanied by the appropriate morphological and physiological changes of the chick's gastrointestinal tract (Noy and Sklan, 1997) and may be enhanced with early feeding.

Several approaches to early feeding, including in ovo and hatcher feeding, have been investigated with varying degrees of success, as reviewed by multiple authors (Noy and Sklan, 1999; Noy and Uni, 2010; Willemsen et al., 2010). Commercially, the ability to provide early nutrition to chicks is dictated by the particular hatching system being utilized, and both hatcher-feeding and on-farm hatching with immediate feed and water access may enhance broiler performance (van de Ven et al., 2011; Souza da Silva et al., 2021). One method of early feeding is providing nutrients immediately posthatch in the hatching baskets or during transportation from the hatchery to the farm. It has been shown that immediate access to feed improves growth and development during the first week posthatch, though compensatory growth of fasted and early hatching chicks often diminishes these early benefits (Kidd et al., 2007; Lamot et al., 2014; Deines et al., 2021). Recently, Souza da Silva et al. (2021) demonstrated potential for sustained benefits in BW, but not FCR, to 39 d posthatch when chicks were fed in the hatcher or hatched on farm, highlighting the need for additional research to better understand broiler responses to hatcher feeding.

A previous experiment in our laboratory demonstrated that hatcher feeding can reduce weight loss in the hatcher for early hatching chicks (Deines et al., 2021). However, compensatory growth of early hatching chicks, independent of feed and water access in the hatcher, diminished this initial benefit of hatchery feeding when chicks of different HWP were comingled during rearing, as would be the case in commercial production. These results agree with previous reports on the ability of early hatching, lighter weight chicks to compensate and achieve equal market-age BW as later hatching chicks in the absence of hatcher feeding (Lamot et al., 2014; Özlü et al., 2018). Therefore, to better understand the relationship between moment of hatch and early feed access, the current experiment was conducted to examine the effects of hatcher feeding on performance and processing yields of chicks reared according to their period of hatch within the hatch window.

MATERIALS AND METHODS

This experiment was conducted at the University of Arkansas Poultry Research Farm (Fayetteville, AR). All animal care and experimental procedures were approved by the University of Arkansas Institutional Animal Care and Use Committee prior to initiation of the experiment.

Egg Source and Incubation

A total of 2,520 hatching eggs from a single, 39-week-old Cobb MV × 500 breeder flock were sourced from a commercial broiler integrator. Eggs were transported to the University of Arkansas Poultry Research Farm hatchery and held overnight in an egg storage room at 18.3°C. All eggs were then set in a single machine (Ps500 Jamesway Incubator Company, Inc. Cambridge, ON, Canada) with a 5,040 egg capacity and incubated using a common broiler profile of 37.6°C at 55% relative humidity (29.4°C wet bulb) from 0 to 18 doi. Eggs were turned every hour.

Nutrient Access and Hatch Window

At 18 doi, eggs were transferred into standard hatch baskets equally divided between 2 hatchers (Ps500 Jamesway Incubator Company, Inc. Cambridge, ON, Canada) set at 36.7°C and 54% relative humidity (27.8°C wet bulb) until time of pull at 504 hoi. The hatchers were equipped with LED lighting to provide approximately 21.5 lux to the interior of the hatching baskets. Twenty hatching baskets without eggs were also placed in each hatcher with equal numbers of baskets designated as control (**CTL**) baskets with no nutrients provided or baskets containing feed and water (**FAW**). The feed provided in the FAW baskets was the same crumbled starter subsequently fed to all chicks at placement (Table 1). Feed and water were provided ad libitum in 50 mL reagent reservoirs (89094-680 VWR International, West Chester, PA). Each basket received 3 reservoirs containing a total of 150 g of water and 3 reservoirs containing a total of 350 g of feed. Recorded amounts of water and feed were added as needed to ensure baskets never ran out. When chicks were removed from the hatcher, remaining feed and water were weighed. Three separate hatching baskets in each hatcher never contained chicks but were configured as FAW baskets to estimate evaporative water loss.

In addition to nutrient access in the hatching basket, a second treatment factor included hatch window period (**HWP**). A previous pilot trial was conducted by hatching eggs from a similar breeder flock to determine the spread of hatch and define a hatch window. Based on these data it was determined that the hatch window be divided into 3 HWP categorized by number of hours until pull (early, 24 to 18 h; middle, 18 to 12 h; late, 12 to 6 h). At the end of each HWP, all hatched chicks were removed from their standard basket, tagged for identification, weighed, and placed into either a CTL or

Table 1. Ingredient and calculated nutrient composition of common diets.

Item	Starter (0 to 14 d)	Grower (14 to 28 d)	Finisher (28 to 42 d)
Ingredient composition, %			
Corn	60.98	64.87	65.03
Soybean meal (46.3%)	34.30	30.08	28.61
Poultry fat	1.16	1.83	3.53
Limestone	1.11	1.07	0.96
Dicalcium phosphate	1.05	0.92	0.77
Sodium chloride	0.44	0.39	0.36
DL-methionine	0.32	0.26	0.24
L-lysine•HCl	0.21	0.17	0.10
L-threonine	0.09	0.07	0.10
Mineral premix[1]	0.10	0.10	0.10
Vitamin premix[2]	0.10	0.10	0.10
Choline chloride (60%)	0.05	0.04	0.04
Selenium premix (0.06%)	0.02	0.02	0.02
Coccidiostat[3]	0.05	0.05	-
Phytase[4]	0.03	0.03	0.03
Calculated nutrient composition, % unless otherwise noted			
AME_n, kcal/kg	3,008	3,086	3,167
Crude protein	21.45	19.59	18.00
Digestible lysine	1.18	1.05	0.95
Digestible TSAA	0.89	0.80	0.74
Digestible threonine	0.77	0.69	0.65
Calcium	0.90	0.84	0.76
Available phosphorus	0.45	0.42	0.38

[1]Supplied the following per kg of diet: vitamin A, 6,350.29 IU; vitamin D_3, 4,535.92 ICU; vitamin E, 45.36 IU; vitamin B_{12}, 0.01 IU; menadione, 1.24 mg; riboflavin, 5.44 mg; d-pantothenic acid, 8.16 mg; niacin, 31.75 mg; folic acid, 0.73 mg; pyridoxine, 2.27 mg; thiamine, 1.27 mg; biotin, 0.07 mg.
[2]Supplied the following per kg of diet: calcium, 55.5 mg; manganese, 100 mg; magnesium, 27 mg; zinc, 100 mg; iron, 50 mg; copper, 10 mg; iodine, 1 mg.
[3]Bio-Cox® 60, Huvepharma, Sofia, Bulgaria (provided 60 g salinomycin sodium per ton).
[4]OptiPhos® 2000 PF, Huvepharma, Sofia, Bulgaria.

FAW experimental basket until the hatch was pulled at 504 hoi. A chick was defined as hatched once fully and independently cleared from the shell. The HWP in which a chick hatched established the amount of time chicks had access to the experimental hatching baskets (CTL or FAW). Chicks in early, middle, and late HWP had 18, 12, or 6 h access to experimental hatching baskets, respectively. The relatively few chicks that hatched more than 24 h before or within 6 h of pull were not used in this experiment. Each hatcher contained 10 CTL and 10 FAW designated baskets resulting in a total of 20 CTL (7 early, 9 middle, and 4 late HWP) and 20 FAW (6 early, 8 middle, and 6 late HWP) experimental baskets, with each basket containing 50 chicks. Unequal representation of HWP replicates reflected the number of chicks that hatched at these time points within the different experimental basket types.

Growout, sampling, and processing

At 21 doi, experimental baskets were removed from the hatchers. Chicks from each experimental basket were weighed and placed into a chick box. Chicks were held at the hatchery in these boxes for 4 h to simulate commercially-relevant processing and holding times and no nutrients were provided for any chicks during this time. At the conclusion of the holding time, chicks were transported to an experimental rearing facility for placement. Of the 40 experimental baskets, 15 CTL (5 early, 6 middle, and 4 late HWP) and 15 FAW (5 early, 5 middle, 5 late) were used for the growout to fully utilize the 30 floor pens available.

All 50 chicks from each experimental basket were placed in a single floor pen to assess live performance in a 42 d experiment. The pens measured 1.52 × 3.05 m and contained used litter that had been top-dressed with fresh pine shavings. Each pen had 2 hanging feeders with commercial feed pans and a single water line with 10 nipples. At 3 d, 3 birds from each pen were randomly selected and euthanized and their yolk sacs and livers were collected and weighed. Bird weights and feed consumption were recorded weekly by pen. Individual bird weights were taken at 21 d and 42 d to assess uniformity. Mortality and associated weights were recorded daily. Common starter (0 to 14 d), grower (14 to 28 d), and finisher (28 to 42 d) feeds (Table 1) and water were provided ad libitum. Feed was removed from the pens 10 h prior to processing on 43 d. Fourteen males from each pen were randomly selected, wing-banded, and processed for determination of carcass and parts weights and yields. Following evisceration, birds were chilled in ice water for 4 h before deboning.

Statistical Analysis

The experiment consisted of 6 treatments in a factorial arrangement of 3 HWP (early, middle, or late) × 2 hatching basket types (CTL or FAW), due to the variation in the number of chicks that hatched in each HWP there were uneven replications of treatment combinations. In total there were 6 replications of the CTL-middle HWP group, 4 replications of the CLT-late HWP group, and 5 replications for all other combinations. Hatcher location was the blocking factor for all hatch data and pen location was the blocking factor for live performance and processing data. All data were analyzed using SAS 9.4 (Cary, NC). The MIXED procedure was utilized for ANOVA, with a Tukey's multiple comparison test used to separate means. Any $P \leq 0.05$ was considered statistically significant.

RESULTS AND DISCUSSION

In the current experiment, the time of hatch was directly correlated with the amount of time chicks had access to nutrients in the hatching basket. As such, we hypothesized that any changes in chick weight that may occur in the hatcher due to dehydration or yolk utilization would be influenced by both HWP and hatching basket nutrient access. At time of hatch, BW was highest ($P = 0.007$) for late hatchers, lowest for early hatchers, and intermediate for middle hatchers (Table 2). This finding is in agreement with the studies of Lamot et al. (2014) and Özlü et al. (2018) who also found that earlier hatching chicks were lighter than later hatchers. By the time of pull at 504 hoi, chicks in early, middle, and late HWP had 18, 12, or 6 h of access to their experimental basket (CTL or FAW). Chicks from CTL baskets had a larger decrease in BW from hatch to pull compared to the chicks from FAW baskets. However, this change in BW varied among HWP groups, leading to a significant ($P < 0.001$) HWP x basket treatment interaction. Chicks from the FAW-early HWP group did not lose any BW ($P = 0.954$) but the FAW-middle and late HWP lost 0.23 and 0.42 g, respectively. These later hatchers likely did not have enough time to consume enough water and feed to counter dehydration and yolk utilization. It is also possible that there is a learning period required for chicks to be able to locate and start consuming nutrients. An inverse pattern of HWP BW change was observed for CTL chicks. Chicks from the CTL-early HWP lost 2.49 g or 5.36% BW which was more ($P < 0.001$) than that of chicks from CTL late HWP (0.93 g or 1.99%). This demonstrates that the longer the CTL chicks were without nutrients in the hatcher after hatching, the more absolute and relative BW they lost. Similarly, Sklan et al. (2000) reported that weights of chicks and poults without nutrients decreased linearly in hatching baskets, losing between 0.14 and 0.17 g per h, and that this weight loss was ameliorated by providing feed access, especially for early hatching chicks and poults.

Interestingly, after removal from the hatcher, chicks from the FAW baskets lost more ($P < 0.001$) BW (0.79 g or 1.68%) during the 4 h hatchery holding period than the CTL chicks (0.50 g or 1.11%; Table 2). A possible explanation for this is that dehydration of CTL chicks had already plateaued in the hatcher, while the FAW chicks consumed water and therefore had more water to lose through respiratory evaporation and excretion during this period. Additionally, the FAW chicks likely decreased in BW as a result of fecal losses from feed consumed in the hatcher. Even though the FAW chicks lost more BW during holding they still had a 1.45 g higher BW at placement compared to CTL chicks, and an interaction ($P = 0.028$) between basket

Table 2. Body weight (BW) and BW change of broiler chicks hatched at different hatch window periods (HWP) within control (CTL) hatching baskets or baskets providing feed and water access (FAW).

					BW change					
		BW (g)			Hatch to pull		Pull to place		Hatch to place	
Item		Hatch	Pull	Placement	Absolute (g)	Relative (%)	Absolute (g)	Relative (%)	Absolute (g)	Relative (%)
Interaction means										
Early − CTL	(n = 7)	46.32	43.98^{c}	43.32^{c}	-2.49^{e}	-5.36^{e}	-0.53	-1.21	-3.01^{d}	-6.49^{d}
Early − FAW	(n = 6)	46.37	46.37^{a}	45.51^{ab}	0.01^{a}	0.01^{a}	-0.86	-1.85	-0.85^{a}	-1.83^{a}
Middle − CTL	(n = 9)	46.75	45.05^{b}	44.66^{b}	-1.69^{d}	-3.62^{d}	-0.40	-0.88	-2.09^{c}	-4.47^{c}
Middle − FAW	(n = 8)	46.78	46.55^{a}	45.89^{a}	-0.23^{ab}	-0.49^{ab}	-0.66	-1.42	-0.89^{a}	-1.90^{a}
Late − CTL	(n = 4)	46.86	45.93^{ab}	45.51^{ab}	-0.93^{c}	-1.99^{c}	-0.57	-1.24	-1.50^{b}	-3.21^{b}
Late − FAW	(n = 6)	47.51	47.09^{a}	46.25^{a}	-0.42^{b}	-0.87^{b}	-0.84	-1.79	-1.26^{ab}	-2.64^{ab}
SEM		0.291	0.302	0.292	0.113	0.233	0.097	0.206	0.155	0.321
Main effect of HWP										
Early	(n = 13)	46.34^{b}	45.17^{c}	44.42^{b}	-1.24^{c}	-2.68^{c}	-0.69	-1.53^{b}	-1.93^{b}	-4.16^{b}
Middle	(n = 17)	46.76^{ab}	45.80^{b}	45.28^{a}	-0.96^{b}	-2.05^{b}	-0.53	-1.15^{a}	-1.49^{a}	-3.18^{a}
Late	(n = 10)	47.18^{a}	46.51^{a}	45.80^{a}	-0.67^{a}	-1.43^{a}	-0.71	-1.51^{ab}	-1.38^{a}	-2.92^{a}
SEM		0.188	0.195	0.189	0.073	0.151	0.062	0.133	0.100	0.207
Main effect of basket										
CTL	(n = 20)	46.64	44.98^{b}	44.44^{b}	-1.70^{b}	-3.66^{b}	-0.50^{a}	-1.11^{a}	-2.20^{b}	-4.72^{b}
FAW	(n = 20)	46.89	46.67^{a}	45.89^{a}	-0.21^{a}	-0.45^{a}	-0.79^{b}	-1.68^{b}	-1.00^{a}	-2.12^{a}
SEM		0.138	0.143	0.138	0.054	0.110	0.046	0.098	0.074	0.152
P-values										
HWP		0.007	<0.001	<0.001	<0.001	<0.001	0.032	0.028	<0.001	<0.001
Basket		0.210	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
HWP x Basket		0.371	0.049	0.028	<0.001	<0.001	0.900	0.937	<0.001	<0.001

$^{a\text{-}d}$Means within a column that do not share a common superscript are significantly different ($P < 0.05$) as determined by a Tukey's multiple comparison test.

Table 3. Body, yolk, and liver weights of 3 d old broiler chicks hatched at different hatch window periods (HWP) within control (CTL) hatching baskets or baskets providing feed and water access (FAW).[1]

		Yolk weights		Liver weights	
Item	Yolk-free BW (g)	Absolute (g)	Relative (%)	Absolute (g)	Relative (%)
Interaction means					
Early − CTL	82.60	1.88	2.22	4.65	5.46
Early − FAW	88.05	1.92	2.13	4.35	4.89
Middle − CTL	80.30	1.71	2.07	4.28	5.22
Middle − FAW	85.53	1.53	1.77	4.37	5.01
Late − CTL	77.14	2.31	2.96	4.25	5.29
Late − FAW	82.70	1.94	2.33	4.27	5.05
SEM	1.883	0.224	0.291	0.285	0.296
Main effect of HWP					
Early	85.33[a]	1.90	2.17[ab]	4.50	5.18
Middle	82.92[ab]	1.62	1.92[b]	4.32	5.11
Late	79.92[b]	2.12	2.65[a]	4.26	5.17
SEM	1.263	0.162	0.196	0.191	0.199
Main effect of basket					
CTL	80.01[b]	1.97	2.42	4.39	5.32
FAW	85.43[a]	1.80	2.08	4.33	4.98
SEM	0.997	0.128	0.154	0.149	0.155
P-values					
HWP	0.012	0.075	0.025	0.620	0.964
Basket	<0.001	0.343	0.119	0.757	0.780
HWP x Basket	0.949	0.664	0.607	0.716	0.758

[a-b]Means within a column that do not share a common superscript are significantly different ($P < 0.05$) as determined by a Tukey's multiple comparison test.

[1]Mean values of 15 birds from each treatment combination. Relative weights are a percentage of yolk-free BW.

type and HWP resulted from an HWP effect on placement weight of CTL chicks that was not observed for FAW chick. The HWP also influenced absolute ($P = 0.032$) and relative ($P = 0.028$) BW change from pull to place and the early HWP lost more relative BW than the middle HWP, with the late HPW being intermediate. Overall weight change from hatch until placement had a significant ($P < 0.001$) interaction between HWP and basket type. The chicks from FAW baskets lost similar amounts of BW among HWP but the CTL-early HWP lost more than the middle and late HWP groups. During this time, chicks from CTL baskets lost more than double the amount of BW as the FAW group. The timing of meconium secretion (i.e., in the hatcher or during 4 h holding period), length of feed and water access, and subsequent opportunity for water and fecal excretion were likely the drivers of these interactions between hatcher nutrient access and HWP on early changes in BW.

An attempt was made to measure consumption of water and feed by chicks from each HWP while in the hatcher. It was evident water and feed disappearance occurred in the FAW hatching baskets and there were trends for more disappearance as access time increased (i.e., greater consumption for early hatchers than late hatchers). Additionally, feed could be visually observed in the crop of chicks from FAW baskets. However, the calculated feed and water consumption (data not shown), even after accounting for evaporation loss, did not correspond with the BW change. As such, the relatively little feed consumed while in the hatcher was not included in the 7 d FI data. In addition to wastage by the chicks, it is likely that the necessity to move hatch baskets during each pull led to more feed and water loss than anticipated. However, the baskets were arranged so that chicks in CTL baskets did not have access to any FAW from any such spillage.

Sampling at 3 d showed that the yolk-free BW (85.43 g) of chicks from FAW baskets was higher ($P < 0.001$) than that of chicks from CTL baskets (80.01 g; Table 3). Absolute and relative residual yolk weights were not different between FAW and CTL indicating that the chicks from FAW baskets were growing more body tissue. Özlü et. al. (2020) also demonstrated that time of access to feed after hatch may not impact yolk utilization. Chicks from the late HWP had lower ($P = 0.012$) yolk-free BW (79.92 g) and higher ($P = 0.025$) relative yolk weight (2.65%) compared to those from the early HWP (85.33 g and 2.17%, respectively), while middle HWP was intermediate. Similar observations were made by Özlü et. al. (2018) at time of hatch. Deines et al. (2021) likewise showed relative yolk weight differences at hatch that may indicate that later hatching chicks have larger yolks that account for a larger proportion of BW at pull, with these differences diminishing by 3 d. This could be due to early hatching chicks using more yolk prior to pull. It is also possible that later hatching chicks result from larger yolk eggs, but further experiments are needed to determine this. This trend in yolk-free BW is inverse to what is expected based on the observed placement BW but may be explained by 7 d BW described later. Absolute yolk weight was not different between HWP ($P = 0.075$). The weight or relative weight of the liver was not different ($P > 0.05$) among any of the groups. These observations indicate that yolk-free BW differences were not due to yolk utilization after pull of hatch or variations in liver growth alone.

At 7 d, chicks from FAW baskets remained heavier than the CTL chicks ($P < 0.001$) but at 14 d they had similar BW ($P = 0.146$) and remained similar ($P >$

Table 4. Live performance (0 to 21 d) of broilers hatched at different hatch window periods (HWP) within control (CTL) hatching baskets or baskets providing feed and water access (FAW) posthatch.[1]

Item	0 to 7 d (g)				0 to 14 d (g)				0 to 21 d (g)			
	7 d BW	BWG	FI	FCR	14 d BW	BWG	FI	FCR	21 d BW	BWG	FI	FCR
Interaction means												
Early – CTL	181	138	168	1.195	476	432	521	1.195	957	914	1,250	1.363
Early – FAW	186	141	173	1.203	476	430	523	1.207	962	917	1,244	1.346
Middle – CTL	176	131	158	1.182	463	418	497	1.183	949	905	1,219	1.341
Middle – FAW	182	136	161	1.163	471	425	499	1.167	961	915	1,220	1.329
Late – CTL	171	125	144	1.131	450	405	485	1.192	954	908	1,225	1.345
Late – FAW	175	129	151	1.149	456	410	480	1.167	940	894	1,192	1.330
SEM	1.2	1.2	2.7	0.0251	4.3	4.3	10.5	0.0229	10.4	10.4	20.7	0.0140
Main effect of HWP												
Early	184[a]	139[a]	170[a]	1.199	476[a]	431[a]	522[a]	1.201	950	915	1,247	1.354
Middle	179[b]	133[b]	159[b]	1.172	467[a]	421[b]	498[b]	1.175	955	910	1,219	1.335
Late	173[c]	127[c]	148[c]	1.140	453[b]	407[c]	483[b]	1.178	947	901	1,209	1.338
SEM	0.8	0.8	1.8	0.0169	2.9	2.9	7.1	0.0154	7.0	7.0	13.9	0.0094
Main effect of basket												
CTL	176[b]	131[b]	156[b]	1.169	463	418	501	1.190	953	909	1,231	1.350
FAW	181[a]	135[a]	162[a]	1.172	468	422	501	1.180	955	909	1,219	1.335
SEM	0.6	0.6	1.4	0.0132	2.3	2.3	5.5	0.0120	5.4	5.4	10.9	0.0073
P-values												
HWP	<0.001	<0.001	<0 .001	0.054	<0.001	<0.001	0.002	0.388	0.413	0.334	0.130	0.268
Basket	<0.001	<0.001	0.015	0.886	0.146	0.305	0.986	0.555	0.873	0.988	0.414	0.176
HWP x Basket	0.620	0.588	0.749	0.701	0.528	0.482	0.926	0.634	0.392	0.397	0.655	0.978

[a-c]Means within a column that do not share a common superscript are significantly different ($P < 0.05$) as determined by a Tukey's multiple comparison test.

[1]Mean values of 6 replications of CTL middle HWP, 4 replications of CLT late HWP, and 5 replications for all other treatment combinations.

0.05) in BW throughout the remainder of the experiment (Tables 4 and 5). No differences in BWG, FI, or FCR were observed beyond 7 d, which is in agreement with the finding of Kidd et al. (2007) who also observed transient improvements in early growth. However, the current findings are in contrast to other studies that reported sustained benefits in performance up to 42 d after providing early feed access (Noy and Sklan, 1999; Henderson et al., 2008). However, each of these studies compared fed chicks to those that were fasted for more than 24 h, and methods of nutrient provision differed from the current experiment. Sklan et al. (2000) provided feed to chicks and poults in the hatching baskets and reported a heavier BW of fed chicks compared to a control to 21 d. The longer hatch window and holding time during that study may have accounted for the sustained depression of BW in control birds and the contrast to

Table 5. Live performance (0 to 42 d) of broilers hatched at different hatch window periods (HWP) within control (CTL) hatching baskets or baskets providing feed and water access (FAW) posthatch.[1]

Item	0 to 28 d (g)				0 to 35 d (g)				0 to 42 d (g)			
	28 d BW	BWG	FI	FCR	35 d BW	BWG	FI	FCR	42 d BW	BWG	FI	FCR
Interaction means												
Early – CTL	1,639	1,595	2,318	1.442	2,317	2,273	3,521	1.540	2,839	2,796	4,746	1.679
Early – FAW	1,624	1,578	2,286	1.442	2,307	2,261	3,507	1.540	2,863	2,818	4,717	1.660
Middle – CTL	1,629	1,583	2,303	1.447	2,334	2,289	3,570	1.545	2,903	2,858	4,849	1.671
Middle – FAW	1,644	1,598	2,292	1.431	2,323	2,277	3,517	1.538	2,916	2,870	4,821	1.650
Late – CTL	1,638	1,592	2,323	1.457	2,363	2,318	3,613	1.557	2,958	2,913	4,834	1.651
Late – FAW	1,623	1,576	2,256	1.428	2,326	2,280	3,506	1.530	2,862	2,816	4,778	1.687
SEM	15.7	15.6	37.0	0.0149	23.3	23.4	51.7	0.0101	42.3	42.3	72.7	0.0164
Main effect of HWP												
Early	1,631	1,587	2,302	1.442	2,312	2,267	3,514	1.540	2,851	2,807	4,732	1.669
Middle	1,636	1,591	2,298	1.439	2,329	2,283	3,543	1.541	2,909	2,864	4,835	1.660
Late	1,630	1,584	2,289	1.443	2,345	2,299	3,559	1.544	2,910	2,864	4,806	1.669
SEM	10.5	10.5	24.8	0.0100	15.7	15.7	34.7	0.0074	28.4	28.4	48.8	0.0110
Main effect of basket												
CTL	1,635	1,590	2,315	1.449	2,338	2,294	3,568	1.547	2,900	2,855	4,810	1.667
FAW	1,630	1,584	2,278	1.434	2,319	2,273	3,510	1.536	2,880	2,834	4,772	1.666
SEM	8.2	8.2	19.4	0.0078	12.2	12.3	27.1	0.0058	22.2	22.1	38.1	0.0086
P-values												
HWP	0.890	0.898	0.935	0.968	0.325	0.346	0.628	0.948	0.226	0.238	0.270	0.787
Basket	0.672	0.590	0.187	0.188	0.273	0.240	0.142	0.168	0.535	0.508	0.490	0.926
HWP x Basket	0.448	0.429	0.706	0.598	0.787	0.793	0.627	0.387	0.257	0.261	0.974	0.127

[1]Mean values of 6 replications of CTL middle HWP, 4 replications of CLT late HWP, and 5 replications for all other treatment combinations.

the current study. Clearly, the amount of time a chick is with or without nutrients after true time of hatch and before placement has a considerable impact on the subsequent performance potential of that chick. Also, the method of feeding and type of nutrients provided may not provide equal benefits. To help clarify such methodological differences, it is recommended that the definition of early feeding be limited to situations in which chicks are provided nutrients posthatch (to differentiate from in ovo feeding) and preplacement on farm (with industry relevant holding times).

No significant ($P > 0.05$) HWP x nutrient access interactions were observed during the growout but both of these factors independently influenced broiler performance. The middle and late HWP chicks were heavier than early HWP chicks at placement ($P < 0.001$; Table 2). Interestingly, the inverse was observed at 7 d whereby chicks from the early HWP were significantly heavier than chicks from middle and late HWP ($P < 0.001$) and they remained heavier at 14 d ($P < 0.001$; Table 4). The switch in BW ranking at 7 d was driven by the higher BWG of chicks from the early HWP ($P < 0.001$) as a result of increased FI ($P < 0.001$; Table 4). The FCR was not a contributor, and in fact, the later hatching chicks tended to have a lower FCR than earlier hatching chicks ($P = 0.054$). Similarly, Lamot et al. (2014) reported that earlier hatching chicks were lighter at placement but became heavier than later hatching counterparts by d 4 through compensatory growth. We observed that 14 d cumulative BWG ($P < 0.001$) and FI ($P = 0.002$) continued to be highest for the early HWP, but BWG was similar ($P > 0.05$) among HWP for the remainder of the experiment (Table 5). After 14 d, chicks from each HWP were also similar ($P > 0.05$) in BW.

It has been shown that sex distribution is skewed more toward females during the early phase of the hatch window, with a bias toward males for later hatching chicks (Williams et al., 1951; Zawalsky, 1962). As such, the fact that chick sex was not accounted for due to logistical limitations is a weakness of the current study that must be considered in the interpretation of performance results beyond 7 d when sex effects become apparent. Nonetheless, similar differences in sex distribution among HWP would be expected under commercial conditions.

Uniformity of BW is a production target that is considered an indicator of overall broiler health and performance (Cobb, 2018). Sklan et al. (2000) reported that feeding in hatching baskets improves growth and uniformity from placement to 21 d. In the current experiment, average BW CV among all treatment groups was 9.4% at 21 d and 10.7% at 42 d, with no effects of treatment observed (Table 6). Mortality, a direct indicator of flock health, was not affected by any of the treatments, with a cumulative average of 2.01% at 42 d (Table 6). The generally low BW CV and mortality indicate that this was a good performing and desirable flock, and treatment effects may have been more apparent in a more challenging environment or with a less desirable flock.

Table 6. Body weight coefficient of variation (CV) and cumulative mortality of broiler hatched at different hatch window periods (HWP) within control (CTL) hatching baskets or baskets providing feed and water access (FAW) posthatch.[1]

	21 d		42 d	
Item	CV (%)	Mortality (%)	CV (%)	Mortality (%)
Interaction means				
Early – CTL	9.4	1.28	11.3	2.55
Early – FAW	11.3	1.70	10.8	2.55
Middle – CTL	9.1	0.34	10.8	2.48
Middle – FAW	9.1	0.00	10.7	1.70
Late – CTL	8.6	1.07	10.0	1.07
Late – FAW	9.1	0.85	10.8	1.70
SEM	0.85	0.58	0.59	1.17
Main effect of HWP				
Early	10.3	1.49	11.1	2.55
Middle	9.1	0.18	10.8	2.09
Late	8.8	0.96	10.4	1.38
SEM	0.57	0.41	0.40	0.79
Main effect of basket				
CTL	9.0	0.90	10.7	2.03
FAW	9.8	0.85	10.8	1.99
SEM	0.45	0.34	0.31	0.61
P-values				
HWP	0.143	0.922	0.508	0.561
Basket	0.194	0.089	0.847	0.957
HWP × Basket	0.432	0.775	0.469	0.798

[1]Mean values of 6 replications of CTL middle HWP, 4 replications of CLT late HWP, and 5 replications for all other treatment combinations.

Previous reports have found that early posthatch fasting decreased satellite cell proliferation and delayed growth, suggesting the importance of immediate postnatal feeding (Halevy et al., 2000). Others have found that there is no compensatory response in the satellite cell populations following early posthatch fasting but also suggested that any improvements in posthatch muscle growth through early feeding were not occurring through a satellite cell mitotic pathway (Mozdziak et al., 2002). Time of hatch has also shown to impact processing weights and muscle morphology (Clark et al., 2017). In the current study, there were no differences between FAW and CTL birds for any of the processing weights or yields (Tables 7 and 8). Similarly, Souza da Silva et al. (2021) found no effects of hatcher feeding on processing yield except for a reduction in wing weight. Other early feeding studies have shown improved breast yield of fed chicks at 5 d posthatch when compared to 48 h delay fed chicks (Wang et al., 2014) and at 36 d posthatch when compared to chicks held in boxes for 34 h (Noy and Sklan, 1999). Although there were no differences in 42 d BW among HWP groups in the current experiment, live weight of birds processed at 43 d from the early and middle HWP groups were heavier ($P = 0.026$) than those from late HWP group. Similar effects of HWP were observed ($P < 0.05$) on hot and chilled carcass and leg quarter weights, but not yields of these or any other parts ($P < 0.05$). Thus, the heavier carcass and leg quarter weights were a function of live weight, and not yield. The HWP response of live weight at 43 d immediately before processing may have been due to the fact that only males were randomly selected for processing to reduce

Table 7. Processing weight and yield of broiler hatched at different hatch window periods (HWP) within control (CTL) hatching baskets or baskets providing feed and water access (FAW) posthatch.[1]

Item	Live	Hot carcass		Hot fat pad		Chilled carcass	
	Weight (g)	Weight (g)	Yield (%)	Weight (g)	Yield (%)	Weight (g)	Yield (%)
Interaction means							
Early − CTL	3,155	2,402	76.09	46.7	1.48	2,441	77.34
Early − FAW	3,156	2,396	75.90	46.5	1.48	2,436	77.19
Middle − CTL	3,157	2,399	75.99	45.7	1.44	2,439	77.26
Middle − FAW	3,153	2,398	76.01	46.2	1.47	2,435	77.20
Late − CTL	3,074	2,332	75.82	46.9	1.52	2,369	77.03
Late − FAW	3,073	2,323	75.58	48.0	1.56	2,358	76.73
SEM	35.0	28.7	0.166	1.60	0.054	29.5	0.191
Main effect of HWP							
Early	3,155[a]	2,399[a]	76.00	46.6	1.48	2,439[a]	77.26
Middle	3,155[a]	2,399[a]	76.00	45.9	1.46	2,437[a]	77.23
Late	3,073[b]	2,328[b]	75.70	47.4	1.54	2,364[b]	76.88
SEM	23.5	19.2	0.111	1.07	0.037	19.8	0.128
Main effect of basket							
CTL	3,128	2,378	75.97	46.4	1.48	2,417	77.21
FAW	3,127	2,372	75.83	46.9	1.50	2,410	77.04
SEM	18.3	15.0	0.087	0.84	0.029	15.4	0.100
P-values							
HWP	0.026	0.018	0.105	0.592	0.205	0.016	0.080
Basket	0.967	0.789	0.280	0.678	0.606	0.759	0.240
HWP × Basket	0.996	0.988	0.655	0.906	0.908	0.989	0.781

[a-b]Means within a column that do not share a common superscript are significantly different ($P < 0.05$) as determined by a Tukey's multiple comparison test.

[1]Mean values of 14 male birds randomly sampled from each of the 6 replicate pens of CTL middle HWP, 4 replicate pens of CLT late HWP, and 5 replicate pens for all other treatment combinations.

variation among the subsample of birds selected for processing, whereas live weighs taken in the house at 42 d included weights of all birds from both sexes when no effect of HWP was observed. Lamot et al. (2014) reported that earlier hatching chicks had a higher breast meat yield at 18 d posthatch compared to middle and late hatching chickens, but additional studies are needed to evaluate these responses at market age following sex-separate rearing

In summary, the findings from this experiment indicate that feed and water access in the hatcher may lead to higher chick weights at placement by minimizing BW loss of early hatching chicks and increase the weight of broilers during the first 7 d of growth. However, nutrient

Table 8. Parts weights and yields of broiler hatched at different hatch window periods (HWP) within control (CTL) hatching baskets or baskets providing feed and water access (FAW) posthatch.[1]

Item	Breast		Tender		Leg quarter		Wing	
	Weight (g)	Yield (%)	Weight (g)	Yield (%)	Weight (g)	Yield (%)	Weight (g)	Yield (%)
Interaction means								
Early − CTL	645.4	20.39	131.1	4.15	729.2	23.13	249.3	7.92
Early − FAW	637.7	20.19	131.2	4.16	740.3	23.44	246.1	7.81
Middle − CTL	629.2	19.94	129.0	4.10	743.1	23.58	248.1	7.89
Middle − FAW	625.0	19.81	128.9	4.09	744.2	23.62	248.8	7.91
Late − CTL	624.3	20.26	126.8	4.12	721.5	23.48	242.7	7.91
Late − FAW	604.9	19.65	126.4	4.11	718.8	23.40	244.3	7.96
SEM	12.86	0.242	2.09	0.043	8.46	0.160	3.23	0.052
Main effect of HWP								
Early	641.6	20.29	131.1	4.16	734.7[ab]	23.28	247.7	7.86
Middle	627.1	19.87	129.0	4.09	743.7[a]	23.60	248.5	7.90
Late	614.6	19.96	126.6	4.12	720.2[b]	23.44	243.5	7.93
SEM	8.62	0.162	1.41	0.029	5.67	0.107	2.17	0.035
Main effect of basket								
CTL	633.0	20.20	129.0	4.12	731.3	23.39	246.7	7.90
FAW	622.6	19.88	128.8	4.12	734.4	23.49	246.4	7.89
SEM	6.73	0.127	1.10	0.023	4.43	0.084	1.69	0.027
P-values								
HWP	0.095	0.139	0.085	0.244	0.018	0.105	0.223	0.361
Basket	0.281	0.089	0.945	0.994	0.617	0.432	0.905	0.764
HWP x Basket	0.797	0.518	0.993	0.975	0.657	0.397	0.687	0.222

[a,b]Means within a column that do not share a common superscript are significantly different ($P < 0.05$) as determined by a Tukey's multiple comparison test.

[1]Mean values of 14 male birds randomly sampled from each of the 6 replicate pens of CTL middle HWP, 4 replicate pens of CLT late HWP, and 5 replicate pens for all other treatment combinations.

access in the hatcher had no influence on final 42 d BW, processing yield, FCR, or mortality. This study also highlighted the differences in early growth rate between chicks hatching at various time periods within the hatch window. In agreement with previous reports, earlier hatching chicks were shown to be lighter at hatch, but had higher FI and BWG to allow them to become heavier than their later hatching counterparts at 7 d. The early BW differences observed among treatment groups were transient and did not impact 42 d BW. Additional research utilizing other genetic strains is needed to determine if the responses are similar. Obviously, differences in holding times have created discrepancies among early feeding studies, and more data are needed to establish the threshold of maximum time without feed that broiler chicks can undergo, both in the hatcher and during per-placement holding, before the potential for compensatory growth is limited.

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DISCLOSURES

The authors declare no conflicts of interest.

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