Research Note: Effect of stocking density on crop fill progression in broilers grown to 14 d

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ABSTRACT Crop fill rates are measured as an indirect means of assessing management during the brooding phase. Primary breeder guidelines indicate that 95% of the chicks assessed should present a crop that is full, soft, and rounded after 24 h, which indicates chicks have successfully located feed and water. Crop fill progression has received little attention in the scientific literature and is primarily discussed in trade literature, and thus, the dynamic nature of crop fill progression has not been previously characterized. This study examined the role of 2 market weight stocking density treatments (29.3 kg/m² and 43.9 kg/m²) on performance and crop fill of broilers grown to 14 d. Crop fill progression was observed at 2, 4, 8, 12, 24, and 48 h after placement and tracked BW of birds that presented empty crops at 24 h; chicks with empty crops were identified to track post-placement BW. Stocking density had no significant effect on bird performance or crop fill. At 24 h, 86% of birds in this study had full, soft, and rounded crops, while only 3% of birds had crops that were devoid of food or water at 24 h. BW for birds with empty crops was significantly lower at 7 d ($P = 0.006$) but not at 14 d ($P = 0.535$). The data herein indicate that crop fill rates of 95% or higher at 24 h may be difficult to achieve in typical commercial broiler settings. In addition, assessing crop fill may be a useful tool to diagnose conspicuous management problems during brooding, but it does not appear to be a direct predictor of early performance.

Key words: crop fill, broiler, stocking density

INTRODUCTION

Crop fill rates are used by some poultry growers and service technicians as indicators of successful management during the brooding phase. Crop fill is typically assessed 24 h after placement to gauge appetite development and that chicks have successfully located feed and water. Primary breeder guidelines (Cobb-Vantress, 2015; Aviagen, 2018) recommend that within 24 h after placement, 95% of chicks should have a full, soft, and rounded crop. Flocks with crop fill rates lower than primary breeder recommendations are a concern for some broiler companies; however, there is nothing published in the scientific literature that systematically assesses crop fill rate progression or validates its usefulness as a predictor of early performance.

The crop serves as a transient storage organ that regulates the passage of food into the gizzard, but the role that is plays in digestion is dependent on multiple factors, such as feeding regimes, feed retention time in the crop, and pH (Bolton, 1964; Abbas Hilmi et al., 2007; Ao et al., 2008). According to Svihus (2014), the crop has not been shown to have any nutritional role in the digestive process, but feed stored in the crop is moistened which may help enzymatic digestion later in the process.

Factors such as feeding regimes and scotoperiod seem to have an impact on the amount of feed that is stored and the time that it is resident in the crop. Shires et al. (1987) found that crop retention times in broilers with ad libitum access to feed and 24 h of light per day was only 7.4 min. Research also indicates that broiler chickens with ad libitum access to feed eat approximately every 30–60 min (Svihus et al., 2013; Czarick et al., 2020) and visit the feeders on average 2.6 times per hour (Li et al., 2020). High-frequency visits to the feeders may diminish the role of the crop to store food

between feedings (Savory, 1985; Chaplin et al., 1992). In contrast, crops of broiler breeders fed every other day did not fully empty for 20 h after feeding (de Beer et al., 2008). Chickens also store food in their crops in response to regular periods of darkness (Savory, 1985), but dark periods of greater than 4 h are needed to elicit anticipatory feeding and subsequent filling of the crop (Duve et al., 2011; Schwean-Lardner et al., 2013).

Stocking density can influence nearly all aspects of live production including economics, production efficiency, well-being, health, and final product quality (McLean et al., 2002; Estevez, 2007). Dozier et al. (2007) reported negative effects on BW, feed to gain ration (**F:G**), litter moisture content, and footpad lesion scores as stocking density were increased incrementally from 30 to 45 kg of BW/m^2. It has also been recognized as a factor affecting feeding and drinking behaviors (McLean et al., 2002; Sanotra et al., 2002; Lolli et al., 2010). Access to feeders and drinkers is restricted at higher stocking densities, especially at later stages in the grow out cycle when birds are larger in size. However, there no scientific literature available that examines the role of stocking density on crop fill, a field measurement performed in the early stages of production to gauge access to feed and water.

Research presented in previous paragraphs suggests that ad libitum feeding and near-continuous lighting during the first week of brooding in commercial production settings may discourage the use of the crop, yet crop fill rates are used, indirectly, to gauge early flock success. No systematic assessment of crop fill rates during the 48-h assessment window recommended by primary breeders has been performed, and the relationship of crop fill with early performance is undefined. The objectives of this study are to 1) determine the effect of stocking density on crop fill rates, 2) determine crop fill rates for broiler chickens up to 48 h after placement, and 3) assess BW at 7 and 14 d for birds that presented an empty crop at 24 h after placement.

MATERIAL AND METHODS

A total of 720 straight-run chicks were obtained from a commercial hatchery on the day of hatch and randomly distributed among 16 pens at 45 birds/pen. Birds were housed at a USDA ARS Poultry Research Unit facility located in Starkville, MS. Each pen measured 3.05 × 1.37 m (10 × 4.5 ft) and was equipped with 1 tube feeder and nipple drinkers. Air temperature was maintained at 32°C (90°F) at placement and reduced to a final temperature of 27°C (80°F) at day 14. Feed and water were provided ad libitum. Chicks were provided a corn–soy diet formulated to meet or exceed NRC recommendations (NRC, 1994); details of the diet formulations were previously published (Dozier et al., 2007). Lighting was provided by 5000K light-emitting diode (LED) bulbs, and birds were fed a standard starter diet provided ad libitum. Mortalities

were assessed daily. All procedures were approved by the USDA ARS Animal Care and Use Committee at the Mississippi State, Mississippi location.

Plastic migration fence (Dandy Light Traps, Statesville, NC) was used to adjust the length of each pen and to set space allowances for 29.3 kg/m^2 and 43.9 kg/m^2 market weight stocking density treatments. Target bird weight was 2.7 kg. Pen length during brooding for the 29.3 and 43.9 kg/m^2 density treatments was 1.59 and 1.08 m, respectively. Pen length was readjusted at day 7 to simulate turn out as occurs in commercial production; final pen length for the 29.3 and 43.9 kg/m^2 density treatments was 3.05 and 2.16 m, respectively. Stocking densities were taken from Global Animal Partnership (GAP, 2017) and National Chicken Council (NCC, 2017) recommendations. Stocking density treatments were represented by eight replicate pens and were alternated to minimize any effects from environmental variations within the test facility.

Crop fill measurements were divided into the following categories: 1) empty, 2) feed only, 3) water only, and 4) full, soft, and rounded. Crop fill was measured in 15 birds/pen at 2, 4, 8, 12, and 48 h after placement as per primary breeder recommendations (Aviagen, 2018). Crop fill was assessed in all birds at 24 h after placement, and all birds with crops that were completely devoid of food or water were tagged with wing bands (890-3 Zip Size 3; National Band and Tag, Newport, KY), weighed, and placed back into their respective pens. Treatments consisted of birds with empty crops at 24 h after placement (EC24) and the total birds in each pen minus the EC24 birds (flock). Birds with EC24 were individually weighed on day 1–7 and day 14 to track growth progress and were culled if weight gain did not occur over a given 48-h period. Pen weight data were taken at placement, 24 h, day 7, and day 14 and used to measure BW and BW gain. Feed was weighed at day 14 and used to calculate feed intake and F:G.

Bird weights at 0, 1, 7, and 14 d and bird performance at 14 d were analyzed using PROC MIXED in SAS (version 9.4.; SAS Institute Inc., Cary, NC), and means were separated using Fisher's Least Significant Difference. PROC MIXED for repeated measures was also used to determine the effect of stocking density on crop fill percentages. A paired t test of BW by pen for the EC24 and flock birds was performed using PROC TTEST in SAS. Pen was considered the experimental unit. A 1-sample t test was performed using PROC TTEST to compare the measured crop fill percent to those recommended by primary breeders. All morality and crop fill percentages were arcsine transformed before analysis. An exponential rise to maximum function was used to model crop fill progression for the full category and for an additional category that combined the full, feed, and water categories (equation 1).

$$C(t) = C_0 * \left(1 - e^{\frac{-t}{\tau}}\right) \qquad (1)$$

Table 1. Live performance response of straight-run broilers grown to 14 d at different market weight stocking densities.

| | Stocking density | | | |
	29.3 kg/m^2	43.9 kg/m^2	SEM	P-values
BW				
0 d	43.1	42.8	0.30	0.398
1 d	51.6	50.9	0.43	0.238
7 d	153.3	153.0	2.72	0.950
14 d	402.1	403.8	6.40	0.860
BWG				
1 d	6.9	5.9	0.52	0.192
7 d	17.3	19.3	1.05	0.199
14 d	332.9	334.4	5.23	0.842
FI				
14 d	474.4	478.0	3.06	0.417
F:G				
14 d	1.3	1.3	0.02	0.776
Mortality	0.5	0.5	1.62	1.000

BWG, BW gain; FI, feed intake.

where $C(t)$ = crop fill percentage at time t after placement (%); C_0 = final crop fill percentage (%); t = time (h); τ = time constant (h).

Exponential decay functions were used to model crop fill progression for the feed-only, water-only, and empty crop categories as shown in equation 2.

$$C(t) = C_0 * e^{\frac{t}{\tau}} \qquad (2)$$

where $C(t)$ = crop fill percentage at time t after placement (%); C_0 = initial crop fill percentage (%); t = time (h); τ = time constant (h).

Exponential rise to maximum and exponential decay analyses were performed using SigmaPlot (v14, Systat Software Inc., 2018). The nonlinear nature of the crop fill distributions necessitated the use of PseudoR^2 (Juneja et al., 2009) to assess goodness of fit the modeled crop fill percentages.

RESULTS AND DISCUSSION

Stocking density had no significant effect on BW or BW gain at 0, 1, 7, or 14 d, nor did it have any significant effect on FI, F:G, or mortality at 14 d (Table 1). Our results differ from those presented by Qaid et al. (2016), which showed that higher stocking densities negatively affect the performance of broiler chicks grown to 14 d. However, stocking densities in their study were much higher than those examined here or commonly used in US broiler production. Stocking density also had no effect on mean crop fill rates for any of the crop fill categories (Table 2).

Measured crop fill was significantly lower than recommended by primary breeders at all time points (Table 3). Primary breeders often cite 95% crop fill at 24 h as an important target and a useful indirect measure of the brooding environment and early flock performance. However, birds in this study were raised in a controlled research facility with stable brooding temperatures and 86% crop fill at 24 h was achieved, which suggests that the primary breeder targets may overestimate what is routinely achievable in commercial production settings. Data to support primary breeder recommendations are unavailable, and no available studies have tracked crop fill progression over time, therefore, direct comparisons are not possible.

A total of 22 birds (3%) in 13 of the 16 pens were classified as EC24 and were tagged with wing bands. Seven pens had 1 EC24 bird, while 6 pens had 2–3. Primary breeders recommend characterizing any bird with a crop that has only food or only water as an empty crop bird. However, in this study, only birds with crops that were completely devoid of food and water at 24 h were classified EC24. Flock mortality rate (excluding EC24 birds) at 14 d was 1.0% (7 of 698), while mortality among the EC24 was 4.5% (1 of 22). The single mortality among the EC24 birds experienced no weight gain by day 3 and was euthanized via cervical dislocation. On necropsy, the bird had a full, soft, and rounded crop but an unabsorbed yolk and exhibited signs of dehydration.

A comparison of pen means showed BW was significantly lower for EC24 birds than the flock birds at 7 d but not at 14 d (Table 4). Although there was no significant difference at 14 d, mean BW was 10.6 g lower for the EC24 birds. Two birds in the EC24 experienced little weight gain during the trial and exhibited low BW at 14 d. One of these birds had a BW of 232.9 g at 14 d, which was outside of the 95% CI of the mean (x ± [s$_x$ × 2.008]; 255.3 g–527.6 g). The other bird had a BW of 264.0 g, more than 63 g lower than the next lowest BW of 327.5 g. Conversely, nine birds in the EC24 group had BW higher than the overall flock mean BW of 403.6 g. In addition, 3 of the EC24 birds were performing very well and had 14 d BW higher than 450 g. Furthermore, if the 2 underperforming birds in the EC24 group are removed from analysis, the mean BW is higher for the EC24 birds (406.5 g) than the overall flock weight (403.6 g). This data suggest crop fill at 24 h is not a good predictor of performance at 14 d.

Table 2. Comparison of GAP and NCC stocking density recommendations on crop fill.

| | Crop fill categories[1] | | | |
Treatment	Mean empty (%)	Mean full (%)	Mean food only (%)	Mean water only (%)
29.3 kg/m^2	2.8	73.2	17.2	1.4
43.9 kg/m^2	3.1	75.3	12.5	2.5
SEM	1.51	2.17	2.02	1.34
P-value	0.838	0.653	0.192	0.250

Abbreviations: GAP, Global Animal Partnership; NCC, National Chicken Council.
[1]Table values represent least square means for crop fill percentages recorded at 2, 4, 8, 12, 24, and 48 h after placement.

Table 3. Measured and primary breeder recommended percentages for full crop birds 24 h after placement.[1]

Primary breeder	Time (h)	Mean crop fill (%)	Recommended (%)	SEM	P-value
1	2	43[b]	>75[a]	0.140	<0.0001
	4	60	-[2]		
	8	73[b]	>80[a]	0.183	0.150
	12	73[b]	>85[a]	0.173	0.004
	24	86[b]	>95[a]	0.084	<0.0001
	48	92[b]	100[a]	0.281	<0.0001
2	8	73[b]	>85[a]	0.183	0.009
	24	86[b]	>95[a]	0.084	<0.0001

[a,b]Means within a row with differing superscripts are significantly different at $P \leq 0.05$.
[1]Table values represent least squares means of crop fill for 16 replicate pens.
[2]Not included in primary breeder recommendations.

Percentage of birds with a full crop increased from 43% at 0 h to 92% at 48 h with the highest rate of growth between 0 and 6 h (Figure 1). Crop fill categories are mutually exclusive, and thus, as the number of birds with full crops increased, the number of birds in the empty and feed-only categories decreased. At 48 h, 99.6% of birds had found feed and water, feed only, or water only. In addition, the number of birds with empty crops decreased from 3.1% at 24 h to 0.4% at 48 h, which indicates 1) that a proportion of birds classified as having empty crops at 24 h found feed, water, or both after the 24 h testing event or 2) some of the birds with empty crops at 24 h had already found feed, water, or both and were simply tested during a resting period when their crops were empty.

Results from the regression analyses indicate that when the full, feed-only, and water-only categories are combined, time to rise to 95% of the final asymptotic crop fill percentage value (97%) was 3 h (Table 5). These regression results indicate that most birds found feed, water, or both within 3 h of being placed in the house. Regression results for the empty crop birds show that time to decay to 95% of the final asymptotic crop fill percentage value (0%) was 11.8 h, which indicates that by approximately 12 h after placement, only 5% of birds had a completely empty crop.

If chicks with completely empty crops were the primary concern to growers and service technicians, crop fill could be assessed as early as 12 h after placement. Less than 5% of birds 12 h after placement should have a completely empty crop. However, primary breeders consider birds that have found only feed or water as

empty crop birds, thus Table 3 and Figure 1 report full crops at only 86% at 24 h. In fact, 24 h after placement 97.4% of birds had found feed, water, or both.

Crop retention times under commercial conditions have not been well defined. Shires et al. (1987) measured crop retention time to be 7.4 min in birds given ad libitum access to feed and continuous lighting, but bird genetics and production settings have changed drastically since these results were published. In addition, research suggests that birds on an ad libitum diet feed about every 30–60 min (Svihus et al., 2013; Czarick et al., 2020). Li et al. (2020) showed that conventionally raised birds visited feeders and drinkers an average of 62 and 46 times per day, respectively. The high frequency of feeding and drinking behaviors may result in short crop residency times (Classen et al., 2019). Data presented here clearly show that feed and water are being stored in the crop, and the percentage of birds with a full crop does increase over the first 48 h after placement. In addition, the data presented here, in light of the frequency at which ad libitum fed birds eat and drink and the potential for short crop residency times, do not seem to support the target crop fills recommended by primary breeders. Crop fill is undoubtedly a useful metric for indirectly assessing the brooding environment and ensuring that nothing has gone drastically wrong during the critical h directly after placement, but the targets set forth by primary
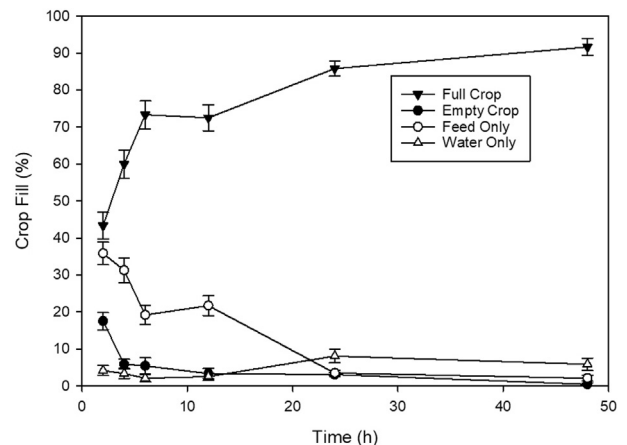
Table 4. Paired t test comparison of BW by pen (n = 6) of empty crop birds at 24 h (EC24) and flock treatments at 7 and 14 d.

Treatment	BW[1]	
	Day 7 (g)	Day 14 (g)
EC24[2]	138.3[b]	396.9
Flock[3]	155.0[a]	407.2
SEM	4.46	15.76
P-value	0.006	0.535

[a,b]Means within a column that have different superscripts are significantly different at $P \leq 0.05$.
[1]Table values represent means for 6 replicate pens. Only 6 pens in the study had multiple EC24 birds and were used in the analysis.
[2]Sample size for EC24 treatment was 2–3 birds per pen (total birds = 14).
[3]Sample size for flock treatment was 41–45 per pen (total birds = 254). Excludes EC24 birds.

Figure 1. Crop fill progression of birds over a 48 h period after placement.

Table 5. Exponential rise to maximum and exponential decay regression coefficients for crop fill percentage distributions and time to 95% of final asymptotic crop fill percentage value.

Crop fill category[1]	C_o[2]	τ[3]	Pseudo R2	Time to 95% of final asymptotic crop fill percentage value (h)
Full + Feed + Water[4]	97.0	1.0	0.40	3.0
Full[4]	83.7	3.2	0.55	9.6
Feed Only[5]	41.9	13.0	0.61	38.4
Empty[5]	26.4	3.9	0.37	11.8

[1]Water-only category not included owing to no discernible trend.
[2]C_o = initial crop fill percentage value (%).
[3]τ = time constant (h).
[4]Exponential rise to max function.
[5]Exponential decay function.

breeder may not be feasible and may be placing undue stress on some growers.

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DISCLOSURES

The authors declare no conflicts of interest.

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