Effects of Feed Withdrawal Time on the Incidence of Fecal Spillage and Contamination of Broiler Carcasses at Processing

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Primary Audience: Poultry Producers, Flock Supervisors, Poultry Processors, Researchers

SUMMARY

Carcass contamination during processing is an expensive problem for poultry processors. Feed withdrawal (FW) is commonly used to reduce the amount of gut contents prior to slaughter, thereby reducing the probability of contamination. The present study used market aged mixed-sex broilers to evaluate the effect of FW time on the incidence of fecal spillage and contamination of broiler carcasses at processing. In order to develop a more simple research protocol for FW, the effects of live haul and holding in stationary crates were compared. Broilers were subjected to 1 of 4 FW times (4, 8, 12, and 16 h) prior to slaughter at a commercial processing plant, in which the incidence of carcass contamination was recorded. Carcass yield and clearance of contents from 8 gut sections were determined. Moisture content of the pooled gut contents was assessed.

Shrink increased from 2.1 to 3.3% of pre-FW BW after 4 and 16 h, respectively. Gut weights decreased significantly with every additional 4 h of FW. The incidence of processing plant inefficiencies decreased with increasing FW time. Gut moisture was not correlated with FW time, although moisture of the gut contents was reduced in birds subjected to live haul. Twelve hours of FW resulted in an optimal combination of gut clearance and carcass yield.

Key words: broiler processing, feed withdrawal, food safety, carcass contamination, gut clearance, live haul

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DESCRIPTION OF PROBLEM

Carcass contamination results in increased processing costs. Broilers that have not been properly conditioned for processing may have too much feed in the fore- or hindgut. The condition of the digesta may also affect the rate of contamination.

To improve product safety, contaminated carcasses must be trimmed, resulting in downgraded carcasses, yield losses, and increased labor costs. In some cases the entire carcass must be discarded because of contamination. As such, there is a great deal of interest on the part of producers and processors in reducing the probability of carcass contamination. Northcutt et al.

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[1] concluded that external carcass contamination affected carcass bacterial counts. Bilgili et al. [2] found no relationship between microbial contamination after chilling and visible contamination of prechill carcasses, but no severely contaminated carcasses were allowed in that study. Some factors that affect gut clearance include feed withdrawal (FW) period length, temperature, light intensity, activity, water availability, live haul time, holding time, stress, and interruption of feed availability [3, 4, 5, 6].

Contamination can occur during processing if digesta or feces leak from the crop or cloaca [7, 8, 9, 10, 11] or if the digestive tract is torn or cut open, allowing the contents to escape onto surrounding tissue. Emptying of the digestive tract reduces the likelihood of contamination during processing. However, withdrawal of feed too early could result in decreased growth and carcass yield. Thus, an effective FW program must allow time for adequate gut clearance while minimizing shrinkage and yield losses [6, 12]. Farhat et al. [13] fed a highly digestible FW supplement and found that carcass contamination could be reduced with shorter FW times, resulting in improved yields. The logistics and economic implications of this approach need to be solved before implementation can occur.

Limited information is available that quantifies the effect of FW times and live haul on gut clearance and BW losses. Summers and Leeson [14] found that birds held in crates demonstrated slowed clearance of the digestive tract, whereas Moran and Bilgili [15] found that a combination of transportation of crated broilers followed by a stationary holding period resulted in lower BW than birds held in stationary crates.

Much of the research in the area of preslaughter FW has quantified gut microflora as a function of FW times [8, 16, 17, 18, 19]. The present study is unique in that it quantifies actual physical contamination of chicken carcasses at the time of slaughter.

The objectives of the present study were to determine the effect of FW time on the clearance of gut contents, gut moisture content, live BW and yield; and to measure the incidence of carcass contamination under commercial conditions. The effect of live haul on gut clearance and carcass contamination was also determined by comparing traits of birds that had been transported on a commercial live haul unit to those of birds held in crates and not transported prior to slaughter.

MATERIALS AND METHODS

Experimental Design

To define the effect of FW time on the incidence of fecal spillage and contamination of broiler carcasses at the time of processing, a 4 $\times$ 2 factorial experimental design with 4 preslaughter FW treatments (4-, 8-, 12-, and 16-h FW) and 2 live haul treatments (transported and not transported) were used. There were 4 replicate pens per FW treatment. Half of the 8 birds from each pen on which detailed data was collected were physically transported in a commercial live-haul unit, and half were held in stationary crates until processing. The dependant variables investigated included the amount of feed remaining in various parts of the gut; digesta moisture content; and contamination at processing (trims and condemns).

Stocks, Housing, and Bird Selection

A total of 2,400 commercial broilers were reared to 42 d of age [20]. Sixteen pens of 150 broilers (mixed-sex) were housed at a stocking density of 13.8 birds/m^2. An increasing light program was used. During the last week of growth, the birds were on constant light. Barn temperature was 18°C during the FW period. The outside temperature during live haul ranged from approximately −5 to 2°C.

At 42 d of age, 8 birds in each pen within ±30 g of the mean 42-d BW were individually weighed, wing-banded, and marked with a livestock paint so that they could be easily identified. These birds are referred to as sentinel birds throughout the current study, as they were monitored very closely throughout the trial. The birds were processed on d 43.

At 16, 12, 8 and 4 h prior to the planned processing time (2000, 1200, 0400, and 0800 h, respectively), feed was removed from each of 4 pens. The BW of the 8 sentinel birds in each pen was recorded at this time to obtain a FW BW. At 0800 h on d 43, the live haul portion of the study was initiated. Half of the sentinel birds from each pen (traceable to pen of origin) were weighed and loaded onto a broiler live haul unit in 16 lots and transported to a commercial processor. Four sentinel birds per pen were weighed and placed in crates to remain at the production unit until slaughter. The holding temperature was approximately 18°C for the birds that were not transported. Just prior to slaughter, all of the sentinel birds at the processing plant and at the production unit were weighed and killed by cervical dislocation. Weight losses were calculated for 2 time periods: in barn and in transit; either on the truck or in the crates. Shrink was calculated according to the following formula:

$$S = (W_{fw} - W_s)/W_{fw} \times 100\%$$

where W_{fw} is the BW at the time of FW, and W_s is the BW at the time of slaughter.

The sentinel birds from the processing plant were returned to the laboratory where all of the sentinel birds were dissected. The weights of the esophagus and crop, proventriculus, gizzard, duodenum, jejunum (end of duodenal loop to Meckel's diverticulum), ileum (Meckel's diverticulum to ileo-cecal junction), ceca, and colon were recorded full and empty. The gut contents were pooled for each bird, weighed, dried overnight at 105°C, and moisture content was calculated.

Processing

Due to processing plant logistics, the birds were killed approximately 1 h behind schedule, such that the treatments were all 1 h longer than reported. Slaughter time of birds that were transported, and those that were held remained synchronized as planned. The birds were unloaded in 16 lots (traceable to pen of origin) and processed. The propensity to contaminate was subjectively scored (Table 1). After scalding and plucking and prior to evisceration, the birds on the processing line were channeled through an abdominal constrictor, which flattened the abdominal area of the bird to approximately 3.0 cm. For each bird the amount of fecal matter that was extruded from the cloaca was subjectively scored by 2 observers on a scale from 0 to 5, with category 0 being no fecal discharge and category 5 being the maximum discharge (Table 1). An average of these observations was used

TABLE 1. Contamination propensity scale

Category	Volume of extruded feces (mL)
0	0
1	0 to 2
2	2 to 4
3	4 to 6
4	6 to 8
5	>8

[A] A linear scale used to quantify extrusion of feces from broilers on the processing line.

to calculate the weighted contamination score (WCS) as follows:

$$WCS = \sum_{i=0}^{5} n_i \times i$$

where WCS = weighted contamination score, n_i = percentage of birds in category i, and i = contamination propensity score value. The number of birds removed from the processing line for trimming or condemnation was also recorded for each lot, traceable to lot.

Statistical Analysis

The data were analyzed using a 2-way analysis of variance using the general linear model procedure of SAS software [21], with FW time and live haul mode (transported or stationary) as the sources of variation. Differences between means were determined using *t*-tests. The pen was considered the experimental unit. The error term for the analysis of variance was pen (live haul × FW). Unless otherwise reported, differences between means were considered significant when $P \leq 0.05$.

RESULTS AND DISCUSSION

BW Loss

There were no significant differences in selection weights of the sentinel birds from the 4 treatments (data not shown). Body weights and BW losses for the period of time between FW and slaughter are reported in Table 2. At the time of FW, birds in the 16-h FW treatment had lower BW (2,494 g) than those in the 12-, 8-, or 4-h FW treatments (2,530, 2,523 and 2,553 g, respectively). Birds in the 4-h FW treatment

TABLE 2. Effect of feed withdrawal (FW) period length on BW, BW loss, and total shrink

	BW (g)				Weight loss (g)			Shrink
FW (h)	FW[A]	Loading[B]	Slaughter[C]	Eviscerated[D]	Barn	In transit	Total	(%)
4	2,553[a]	2,553[a]	2,498[a]	2,096[a]	0.0[c]	54.8[a]	54.8[c]	2.14[c]
8	2,523[b]	2,503[b]	2,467[b]	2,089[a]	19.2[b]	36.0[b]	55.2[c]	2.19[c]
12	2,530[ab]	2,487[b]	2,460[b]	2,089[a]	43.8[a]	27.2[c]	70.9[b]	2.80[b]
16	2,494[c]	2,442[c]	2,412[c]	2,052[b]	52.3[a]	29.7[bc]	81.9[a]	3.29[a]
SEM	8	8	8	9	3.1	2.9	3.7	0.1
P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[a–c]Means within columns with no common superscripts are significantly different ($P < 0.05$).
[A]BW at the time of FW.
[B]BW at the time of loading for live haul.
[C]BW at slaughter.
[D]Eviscerated BW with feet and head removed.

were the heaviest at the FW event (2,553 g). The difference in BW (59 g between the 16- and 4-h FW treatments) resulted from an extra 12 h of access to feed prior to slaughter. Although BW at FW decreased with increasing length of the FW period, there was not a stepwise reduction in FW BW with every additional 4 h of FW. This may have been due to diurnal variability in feed intake, growth patterns, or temperature.

Birds in all treatments were loaded 4 h prior to slaughter. At the time of loading, birds in the 16-h FW treatment had lower BW (2,442 g) than those in the 8- and 12-h FW treatments (2,503 and 2,487 g, respectively). Birds in the 4-h FW treatment were loaded at the time of the FW event. Therefore, their FW and loading BW were the same (2,553 g). This BW was significantly higher than that of birds in all other treatments at the time of loading. The difference in BW between the 16- and the 4-h FW treatment was 111 g at the time of loading.

Birds lost a total of 54.8, 55.2, 70.9, and 81.9 g of live weight in the time between the FW event and slaughter in the 4-, 8-, 12-, and 16-h FW treatments, respectively. Papa [22] found similar weight losses of approximately 42, 64, 80, and 100 g at 4, 8, 12, and 16 h of FW, respectively. At 20 and 24 h, Papa [22] found that broilers lost 109 and 124 g, respectively. In the current study, BW losses during the live haul period ranged from 27.2 to 54.8 g (Table 2). Weight loss during transit in the 16-h FW treatment was not different from that of birds in the 8- and 12-h FW treatments (Table 2). Birds in the 8-h FW treatment lost more BW during transit than birds in the 12-h treatment (36.0 and 27.2 g, respectively). This is likely due to increased excretion by the 8-h FW birds during transit. Early BW losses can be attributed to clearance of the digestive system after intake stops. Using a bent-stick model approximation, the data in the current study suggest that BW loss plateaus approximately 10 h after FW. As the length of the FW period increases, energy requirements are met by catabolism of body energy reserves [15]. Warriss [23] found that once feed is withdrawn, liver glycogen stores are depleted within 6 h. Therefore, BW loss in 12- and 16-h FW treatments could be attributed to catabolism.

At slaughter the greatest BW difference was between the 16- and the 4-h FW treatments (86 g). Body weight of the 8- and 12-h FW treatment birds was intermediate and not significantly different from each other at 2,467 and 2,460 g, respectively.

Eviscerated weights were very uniform in the 4-, 8-, and 12-h FW treatments. Birds in the 16-h FW treatment had reduced eviscerated BW (2.1% less than the 4-h FW birds). Eviscerated BW of the 8- and 12-h FW birds was not significantly (0.3%) less than the 16-h FW treatment. Reduced eviscerated BW resulted from the combination of a shortened growing period and catabolism of muscle protein. This reduction in saleable product is a lost opportunity for the broiler supply chain. Careful management of FW programs is important for maximizing yield.

TABLE 3. Effect of feed withdrawal (FW) period length on inefficiencies at the processing plant

FW (h)	Trimmed[A] (%)	Internal contamination[B] (%)	Reinspected[C] (%)	Total removed from processing line[D] (%)	Weighted contamination score[E]
4	2.3	11.3[a]	0.2	13.8	1.1
8	1.2	8.2[ab]	1.2	10.5	0.6
12	0.8	7.2[b]	1.7	9.7	1.5
16	0.2	5.3[b]	1.7	7.2	1.1
SEM	0.7	1.4	0.8	1.6	0.3
P	0.2525	0.0514	0.5291	0.0643	0.3723

[a,b]Means within columns with no common superscripts are significantly different ($P < 0.05$).
[A]Birds removed from the processing line in order to remove contaminated or damaged parts.
[B]Birds removed from the processing line because of internal (visceral cavity) contamination. Breast meat, legs, and wings salvaged.
[C]Birds removed from the processing line for inspection by veterinarian for any condition of concern.
[D]Total of all birds removed from the processing line; sum of the previous 3 categories.
[E]The weighted contamination score is calculated as follows:

$$WCS = \sum_{i=0}^{5} n_i \times i$$

where WCS = weighted contamination score, n_i = percentage of birds in category i, and i = contamination propensity score value.

Carcass Contamination

Inefficiencies at the time of processing are summarized in Table 3. The total number of birds removed from the processing line almost doubled in the 4 h compared with the 16-h FW treatment ($P = 0.06$). There was a stepwise reduction in the number of birds removed from the processing line with increasing length of the FW period ($P = 0.06$).

A high rate of internal (visceral cavity) contamination occurred. Breast meat, legs, and wings can be salvaged from birds with internal contamination, but they must be processed by hand, creating inefficiency. A total of 11.3% of birds in the 4-h FW treatment were removed from the processing line because of internal contamination. This was not significantly different from the 8-h FW birds (8.2%) but was significantly higher than the 12- and 16-h FW treatments (7.2 and 5.3%, respectively). There was a numerical trend ($P = 0.25$) suggesting that less trimming is required with longer preslaughter FW periods. The weighted contamination score was not significantly affected by FW treatment.

The total weight of the gut (including contents) was reduced with each 4-h increase in the length of the FW period (Table 4). This infers that the probability of contamination will decrease with increased FW times. The distal parts of the digestive tract are of primary concern for external contamination [24, 25, 26]. Compared with the 4-h FW treatment, crop weight was reduced in the 12- and 16-h birds; and colon weight was reduced in the 8-h treatment. Colon weight was not further reduced in the 12- and 16-h FW treatments. Internal contamination likely results from bursting of the duodenum, ileum, and jejunum. Reduction in duodenum and jejunum weights was observed after 12 h of FW; ileum weight was reduced in the 16-h FW treatment. Ceca weight was lower after 8 h of FW and further after 16 h. Similarly, Papa and Dickens [27] found linear relationships between the length of the FW period and lower gut clearance. In the current study, reduction in contents in various parts of the gut continued through the 16 h of FW. Since internal contamination was reduced in the 12-h FW treatment, and yield was unaffected until 16 h of FW, a FW time of 12 h prior to slaughter is recommended.

Gut Moisture

Moisture content of the feces increased with increasing length of the FW period ($P = 0.09$). Moisture content ranged from 80.6 to 82.2% in the 4- and 16-h FW treatments, respectively (Table 4). This can be attributed to increased water intake relative to feed intake in birds subjected to longer FW periods. Similarly, Papa [22] also found a trend to increased moisture in lower gut contents with longer FW times. Birds held on farm until processing had 0.9% higher

TABLE 4. Effect of feed withdrawal (FW) period length on fecal moisture and gut weights[A]

FW time (h)	Fecal moisture (%)	Total gut (g)	Crop (g)	Proventriculus (g)	Gizzard (g)	Duodenum (g)	Jejunum (g)	Ileum (g)	Ceca (g)	Colon (g)
4	80.6	184.4^{a}	16.9^{a}	10.3	37.6^{a}	23.0^{a}	32.4^{a}	27.3^{a}	23.5^{a}	8.3^{a}
8	81.4	167.0^{b}	15.3^{ab}	10.8	31.5^{b}	22.0^{a}	30.8^{ab}	25.1^{a}	19.9^{b}	5.8^{b}
12	82.1	157.1^{c}	14.1^{b}	10.5	33.2^{ab}	20.6^{b}	29.3^{bc}	24.9^{a}	17.5^{bc}	5.1^{b}
16	82.2	149.9^{d}	14.2^{b}	10.5	31.4^{b}	19.5^{b}	27.5^{c}	22.2^{b}	16.5^{c}	4.6^{b}
SEM	0.4	2.1	0.7	0.4	1.6	0.4	0.9	0.8	0.8	0.5
P	0.0870	<0.0001	0.0252	0.8772	0.0486	<0.0001	0.0061	0.0031	<0.0001	0.0002

[a–c]Means within columns with no common superscripts are significantly different ($P < 0.05$).
[A]Gut weights, including contents.

fecal moisture than transported birds (data not shown). Moisture loss from birds during transit stimulates reabsorption of water from the digesta.

Live Haul Simulation

No significant differences were observed in BW or BW loss between birds that were transported and those held in stationary crates. In contrast, Moran and Bilgili [15] found that birds subjected to live haul had greater live BW losses than birds held in stationary crates. In contrast to our 4-h live haul period, which included the time birds were held prior to slaughter in the plant, Moran and Bilgili held birds for 10 h prior to slaughter, which may account for the observed differences. In their trial, the difference in BW loss between the groups was attributed to convective heat loss and behavioral stress associated with live haul, which may have been lower in the current study on account of lower ambient temperature and live haul duration.

Small differences between live haul treatments occurred (data not shown). Proventriculus weight was higher in birds held in crates compared with birds that were transported to the processing plant (11.0 and 10.0 g, respectively). Conversely, duodenum weights were reduced in birds that were not transported compared with birds that were (20.4 g and 22.2 g, respectively). These small differences in gut weights are likely of little consequence to contamination. As already reported, moisture content of the fecal material was reduced by 0.9% in birds that were crated but not transported.

These results indicate that the simulation of a 4-h live haul period by holding birds in crates is an appropriate means of assessing the effects of FW time, and can be used for research purposes.

CONCLUSIONS AND APPLICATIONS

From this study we can conclude the following:

1. In the 12 h prior to FW, broiler BW increased by 60 g. The longer broilers stay on feed, the greater the potential yield of product.
2. In the barn, broilers lost a significant amount of BW in the first 2 4-h periods following FW; there was not a further significant loss in the third 4-h period. A 12-h FW period with 8 h in the barn is adequate for clearing the contents from the digestive tract.
3. A 16-h FW period (12 h in barn) resulted in a 111 g reduction in BW at loading compared with those in the 4-h FW treatment (0 h in barn). Live BW at loading can be increased by approximately 5% by delaying FW by 12 h.
4. Eviscerated BW was 2.1% lower in the 16 h compared with the 4-h FW treatment. There was not a significant reduction in eviscerated yield in the 8- and 12-h FW treatments. Feed withdrawal periods of longer than 12 h will likely result in economic losses due to reduced eviscerated yield.
5. A significant reduction in internal contamination was observed in birds in the 12-h FW treatment. Twelve hours of feed withdrawal is adequate to reduce contamination and prevent carcass shrink.

6. No differences were observed in BW, BW loss, gut weight, or yield between birds that were and birds that were not transported. For research purposes, holding birds in crates is a valid means of simulating the effects of a 4-h live haul period on gut clearance and BW loss.
7. A feed withdrawal period of 12 h is recommended as optimal for reducing contamination and maintaining yield.

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