A Low Residue Nutritive Supplement as an Alternative to Feed Withdrawal in Broilers: Efficacy for Gastrointestinal Tract Emptying and Maintenance of Live Weight Prior to Slaughter

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ABSTRACT
Experiments were conducted to evaluate the production response to a solid phase, nutritive supplement used as an alternative to feed withdrawal in broiler chickens and its effect on gastrointestinal tract (GIT) residue. Three treatments were applied: a conventional 12-h feed withdrawal (control); provision of a highly digestible, carbohydrate-based feed withdrawal supplement (FWS) with no added protein source (FWS0); and provision of FWS containing 16% CP as a highly digestible protein source (FWS16). Both FWS treatments were designed to be highly and rapidly soluble, were formulated to result in nominally lower GIT residues, and were withdrawn for only 3 h prior to slaughter. Visual assessment of segments of the GIT at slaughter indicated no significant differences among treatments in the degree of emptiness of the crop, gizzard, and colon, whereas intestinal contents of both FWS groups were less ($P < 0.05$) than those of the control group. With or without prior acclimation to supplements, live weight losses for both FWS groups were consistently and significantly less than for the control group ($P < 0.05$). In birds acclimated to the supplement, hot eviscerated and chilled carcass weights and deboned breast meat yield were greater for FWS16 than for the control group ($P < 0.05$). Carcass water uptake during chilling was similar or lower for FWS treatments compared to controls so that the effect of supplement on improving product yield was not due to excessive water uptake. These data indicate that the provision of a highly digestible feed withdrawal supplement enhanced lower GIT emptying, reduced live weight loss, and in some instances improved product yield without the need for a prolonged period of feed withdrawal.

(Key words: feed withdrawal, feed withdrawal supplement, live weight shrinkage, yield, carcass contamination)

INTRODUCTION
Preharvest preparation of poultry to empty the gastrointestinal tract (GIT) prior to processing is critical in poultry meat production, because of the potential contribution of feed and fecal residues to carcass contamination (USDA-FSIS, 1996). Individual carcass contamination and associated risk of cross-contamination is a concern to the poultry industry as a potential source of pathogens for consumers. Although the U.S.D.A. recommends the use of postharvest antimicrobial treatments (USDA-FSIS, 1995), research has demonstrated that undesirable effects on processed carcass quality may result (Lillard et al., 1987; Dickens and Whittemore, 1994). Also, current postharvest techniques alone are not consistently or completely effective and do not eliminate the need for online rewashing-reprocessing of carcasses in the event of visible contamination with feed particles or fecal material. Therefore, preharvest measures are considered important toward reducing the risk of bacterial contamination from the GIT (Mulder et al., 1987).

Feed withdrawal prior to processing is intended to reduce contamination from GIT contents. However, feed withdrawal times adopted by the industry vary considerably (Bilgili, 1988), and withdrawal schedules are frequently compromised as a result of unexpected livehaul delays or other production or processing constraints (Cummings and Savage, 1997). Prolonged feed withdrawal has the potential to increase the incidence of bacterial colonization in segments of the GIT (Ramirez et al., 1997; Corrier et al., 1999) and can lead to sloughing and liquefication of the intestinal mucosa with increased fragility of the intestinal wall (Bilgili, 1988; Northcutt et al.,...
1997), all of which may increase the risk of contamination during evisceration. Even optimal withdrawal times result in reduced GIT motility and less gut emptying (Tur et al., 1985). These changes lead to some live weight shrinkage that increases with duration of withdrawal (Benibio and Farr, 1985) and can reach up to 6% of body weight (Buhr et al., 1998). Therefore, it would be beneficial to reduce the time needed to empty the GIT in order to better maintain the normal integrity of the intestinal mucosal lining and potentially improve live weights and carcass yields.

The objective of the present study was to evaluate the production response to a nutritive, solid phase feed withdrawal supplement (FWS) fed to broiler chickens immediately prior to processing as an alternative to conventional feed withdrawal. The effects on GIT residues, live weights, and carcass characteristics were examined.

**MATERIALS AND METHODS**

All birds used in these experiments were a commercial broiler cross (Avian × Avian), reared in floor pens on litter at the Poultry Education and Research Center (PERC). Birds were provided water ad libitum throughout the growout and experimental periods and feed ad libitum throughout growout, except during withdrawal periods as indicated for each experiment. Chicks were fed a commercial broiler starter (#1092-52; 23% CP, 4.5% fat, 3,100 kcal/kg) from hatching until 3 wk of age, at which time they were switched to a commercial grower (18% CP, 4% fat, 3,200 kcal/kg) for the remainder of growout and experiments. All experiments were conducted when birds were 6 wk of age. All animal procedures were approved by the Pennsylvania State University Institutional Animal Care and Use Committee (A3141-01; #99R019-0 through 00R105-00).

Feed withdrawal supplements were formulated based upon a commercial carbohydrate source derived from controlled hydrolysis of corn starch to yield a nonsweet, nutritive D-glucose polymer (maltodextrin) with added salts and with (FWS16) or without (FWS0) a protein source [16% (wt/wt) food-grade, dehydrated egg white]. The maltodextrin selected for inclusion in supplements (Maltrin M150) has an approximate dextrose equivalent of 15 and sugar content of <6%. All ingredients were selected to be highly soluble in the aqueous environment of the avian GIT and to be rapidly and highly digestible so as to contribute nominal lower GIT residue. Supplement formulations are provided in Table 1.

### Experiment 1

In the first experiment, the effects of FWS on live weight changes, carcass measurements, and residual contents of the GIT in comparison to conventional feed withdrawal were assessed in female broilers, using an acclimation period as described below to ensure consumption of supplements. Feed withdrawal supplements were in the form of white pellets approximating the size of broiler feed. Supplement formulations were pelleted by placing the powder in a Teflon mold and allowing it to absorb moisture in a sealed, humidified chamber at approximately 95% relative humidity for 2 h at room temperature. Pellets were then dried in a drying oven at 95°C (200°F).

A total of 150, 1-d-old female broiler chickens were randomly allocated to six pens (25 birds per pen). At 6 wk of age, two pens were randomly allocated to each of three treatment groups (50 birds per group): control, FWS0, and FWS16, for two phases as described in the following protocol.

#### Phase 1 (8 h)—Acclimation Period

To ensure the acceptability of the supplements, there was an 8 h acclimation period in which FWS birds were provided a 50:50 supplement:broiler grower mixture for 4 h followed by a 75:25 mixture for an additional 4 h. During the acclimation period, controls continued to consume commercial broiler grower ad libitum.

#### Phase II (12 h)

At the end of the acclimation period, supplement:broiler grower mixtures were removed, and the respective supplement alone (FWS0 or FWS16) was supplied for 9 h, while broiler feed was removed from the control group. Supplements were removed 3 h prior to processing for all birds, thus allowing for a total of 12 h of feed withdrawal for controls and 9 h of supplement withdrawal supplement (FWS) fed to broiler chickens immediately prior to processing as an alternative to conventional feed withdrawal. The effects on GIT residues, live weights, and carcass characteristics were examined. See Materials and Methods for procedure used to form the pellets.

Experiments 3 and 4: Supplements were provided ad libitum and were in the form of white pellets approximating the size of broiler feed. Supplement formulations were pelleted by placing the powder in a Teflon mold and allowing it to absorb moisture in a sealed, humidified chamber at approximately 95% relative humidity for 2 h at room temperature. Pellets were then dried in a drying oven at 95°C (200°F).

A total of 150, 1-d-old female broiler chickens were randomly allocated to six pens (25 birds per pen). At 6 wk of age, two pens were randomly allocated to each of three treatment groups (50 birds per group): control, FWS0, and FWS16, for two phases as described in the following protocol.

**TABLE 1. Composition of feed withdrawal supplements with (FWS16) and without (FWS0) added protein**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>FWS0</th>
<th>FWS16</th>
</tr>
</thead>
<tbody>
<tr>
<td>M(t)-M150</td>
<td>99.30</td>
<td>83.30</td>
</tr>
<tr>
<td>Dehydrated egg white</td>
<td>0.000</td>
<td>16.00</td>
</tr>
<tr>
<td>NaCl</td>
<td>0.144</td>
<td>0.144</td>
</tr>
<tr>
<td>KCl</td>
<td>0.080</td>
<td>0.080</td>
</tr>
<tr>
<td>Tri-K-Citrate</td>
<td>0.520</td>
<td>0.520</td>
</tr>
<tr>
<td>Thiamine</td>
<td>3.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Niacin</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>6.0</td>
<td>6.0</td>
</tr>
</tbody>
</table>

1Experiments 1 and 2: Supplements were provided ad libitum and were in the form of white pellets approximating the size of broiler feed. See Materials and Methods for procedure used to form the pellets. Experiments 3 and 4: Supplements were provided ad libitum and were in the form of colored, aggregated particles approximating the appearance of broiler crumbs. See Materials and Methods for procedure used to form the crumbs.

2Maltodextrin with an approximate dextrose equivalent of 15. Dextrose equivalent is a relative measure of the degree of starch polymer hydrolysis compared to a standard of 100 for dextrose. Maltrin is a product of Grain Processing Corporation, Muscatine, IA.

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3Longenecker’s Hatchery Inc., Elizabethtown, PA.
4Wenger Feeds, Rheems, PA.
5Grain Processing Corporation (GPC), Muscatine, IA.
6Quaker State Farms, Klingerstown, PA.
consumption followed by 3 h of supplement withdrawal for FWS groups.

Feed and supplement consumption, beginning live weight immediately prior to treatments, as well as final live weight prior to slaughter were obtained at the appropriate intervals. At the end of the treatment period (12 h), all birds were transferred to the slaughter and processing facility at the PERC, killed by exsanguination, then scalded (60 C, 47 s) and defeathered in a rotary drum picker. Birds were manually eviscerated, and hot carcass weights were obtained. Viscera were randomly collected from 15 to 20 birds of each treatment, placed in plastic sample bags on ice in the order they were collected, and stored for subsequent GIT content analysis in the lab immediately following initial carcass processing. Carcasses were chilled for 1 h in ice water, and then hung and allowed to drain for 15 min before a chilled, drained weight was obtained. Carcasses were then individually bagged and stored at 4 C for 24 h. After final chilled weights were obtained, left and right breast muscles were removed from the carcasses by trained personnel and were weighed separately.

Collected GIT were brought to the lab and processed individually as follows. The crop, gizzard, small intestine, right cecum, and colon were clamped proximally and distally and then excised. Each segment was cut open to expose the contents. Trained laboratory personnel evaluated the quantity of content in each segment by a visual scoring system using a threshold model consisting of a three-point scale based on reference segments containing contents of increasing quantity. A visual score was given according to the observed quantity of contents as follows. A score of 1 indicated a completely empty segment, a score of 2 was given for segments that had a moderate quantity of residue, and a score of 3 was given for segments that were filled with feed or supplement particles, digesta, or fecal contents (depending upon the GIT segment examined). In addition, observations were recorded to indicate the gross appearance of the contents (e.g., liquid, undigested feed, or supplement particles).

**Experiment 2**

In a second experiment, the effects of feed withdrawal supplements on live weight changes and carcass measurements in comparison to conventional feed withdrawal were assessed in male broilers, again with supplements in the form of white pellets, and using an acclimation period to ensure supplement consumption.

A total of 72, 1-d-old male broiler chicks (Avian × Avian) were allocated to three pens (15 birds per pen). At 6 wk of age, pens were culled to 10 birds per pen and one pen was allocated to each of three treatment groups (10 birds per treatment): control, FWS0, and FWS16. Feed was withdrawn from the control birds for 12 h prior to slaughter and FWS birds received the respective supplement (FWS0 or FWS16) ad libitum for 9 h, followed by 3 h of supplement withdrawal prior to slaughter.

Feed and supplement consumption, beginning live weight, as well as final live weight immediately prior to slaughter were obtained at the appropriate intervals.

**Experiment 3**

A preliminary (third) experiment was designed to assess whether broilers would consume FWS without an acclimation phase. Powdered supplements were aggregated by mixing the powder in a commercial dough mixer with diluted food coloring to give the mixture a greenish-blue color resembling that of commercial broiler feed. Food coloring was prepared by mixing 45 mL of tap water with 40 drops of yellow, 25 drops of red, 10 drops of blue, and 20 drops of green food coloring. This food color mixture was dripped into 4 cups of the supplement powder slowly to produce amorphous aggregates of the powder. The aggregated, amorphous particles were then dried in a drying oven at 125 C and resembled feed crumbles. No acclimation period was used in conjunction with supplements for this experiment.

A total of 45, 1-d-old male broiler chicks (Avian × Avian) were allocated to three pens (15 birds per pen). At 6 wk of age, pens were culled to 10 birds per pen and one pen was allocated to each of three treatment groups (10 birds per treatment): control, FWS0, and FWS16. Feed was withdrawn from the control birds for 12 h prior to slaughter and FWS birds received the respective supplement (FWS0 or FWS16) ad libitum for 9 h, followed by 3 h of supplement withdrawal prior to slaughter.

Feed and supplement consumption, beginning live weight, as well as final live weight immediately prior to slaughter were obtained at the appropriate intervals.

**Experiment 4**

A final experiment further confirmed live weights and carcass responses of broilers that were provided FWS. FWS treatments were similar in appearance to commercial feed particles and provided without an acclimation period.

Because prior experiments had demonstrated that consumption of FWS0 was typically less than (and live weight losses greater than) that of FWS16, this final experiment was primarily to compare the response of FWS16 versus conventional feed withdrawal with larger groups of birds. A total of 105 male broiler chicks (Avian × Avian) were allocated to seven pens of 15 birds per pen. Three pens (45 birds) were randomly assigned to the control group and three pens (45 birds) to FWS16. An additional single pen of 15 birds was allocated to the FWS0 group as an internal control to previous experiments. Feed was withdrawn from control birds for 12 h prior to slaughter and FWS birds received supplement (FWS16) ad libitum for 9 h followed by 3 h of supplement withdrawal. Feed and supplement consumption, beginning live weight immediately prior to treatments, as well as final live weight prior to slaughter were obtained at the appropriate intervals. Carcass processing, viscera collection, and scoring of GIT contents were performed as described in Experiment 1.

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1 McCormick & Co., Inc., Hunt Valley, MD.
**Statistical Analysis**

Data were analyzed by one-way analysis of variance as a completely randomized design using the general linear models procedure of the Statistical Analysis System (SAS Institute, 1990). Live weight prior to initiation of treatments was used as a covariate in analyses of final live weight and carcass measurements. When significant differences among treatments were found, means were separated by the multicollinearity Scheffe’s test using probabilities generated by the least squares means option of the general linear models procedure of SAS software. Live weight changes for Experiments 1 and 2 involving acclimation periods were calculated for the period from the end of acclimation until slaughter, to assess the effect of FWS treatment not confounded by acclimation. Effects of FWS on carcass measurements independent of acclimation could not be separated; however, comparison with outcomes from experiments not utilizing an acclimation period indicated that any acclimation effects were not significant. Individual birds were the experimental unit for live weight changes and carcass measurements, and pens were the experimental unit for feed and supplement consumption. All values are least squares means, and measures of variance are standard errors of the least squares means. All statements of significance are based on a probability of 5%.

**RESULTS AND DISCUSSION**

**Experiment 1**

Visual assessment scores were obtained to determine the relative efficacy of FWS on GIT clearance. The GIT was examined for any signs of undigested feed and supplement residue, as well as overall GIT integrity (e.g., sloughing of intestinal lining). The objective was to develop a nutritive supplement that would help in emptying the GIT by maintaining lower GIT motility and, at the same time, be completely digested and absorbed. Visual assessment scores indicated no significant differences among treatments in residual contents for the crop, gizzard, and colon (Table 2). However, intestinal scores for both supplement groups were significantly lower than for the control group. Although birds in the control group were without feed for 12 h, feed and fecal material were still observed in lower portions of the intestine. Cecae of the FWS16 group contained less residue ($P < 0.05$) than those of the FWS0 and control groups. The difference in intestinal contents between FWS0 and FWS16 birds was not significant, indicating that both supplements were similarly readily digested and absorbed, despite greater consumption of FWS16.

Passage rate of digesta through the GIT of the chicken depends upon propulsive and inhibitory reflexes induced in the muscles of the proventriculus and in the upper small bowel (Richardson, 1972). In turkeys, passage rate is slowed over 200% by feed withdrawal, and this effect is aggravated with prolonged feed deprivation (Duke et al., 1969). The proportion of broiler chickens evacuating excreta during slaughter increased with increasing duration of feed withdrawal (Papa and Dickens, 1988). The upper GIT of feed-deprived chickens was emptied rapidly, whereas the lower segments required more time for evacuation compared to those of fed birds (Tur et al., 1985). After 16 h of feed withdrawal, broiler chickens still had 25.7 g of intestinal contents (Zuidhof and McGovern, 1999). It is likely that the birds subjected to 12 h of feed withdrawal in the present study had an increased inhibitory reflex that extended the retention time of digesta, resulting in greater ($P < 0.05$) intestinal contents. It is hypothesized that feeding FWS provided normal physiological stimuli that maintained active upper GIT peristalsis, resulting in maintenance rather than loss of lower GIT motility and, consequently, more effective emptying of fecal residues.

A high thyroxine ($T_4$):triiodothyronine ($T_3$) ratio (Tur et al., 1987) was reported to reduce GIT transit time in young chickens. Feed deprivation in chickens induces $T_3$ hypothyroidism (May, 1978), which may contribute to differences in GIT motility and, consequently, evacuation as observed between birds receiving the nutritive supplements and those subjected to conventional feed withdrawal.

Birds on FWS0 and FWS16 treatments consumed 31 and 35 g of supplement/bird, respectively, during the 9 h when supplements were provided exclusively (Experiment 1). Conventional feed withdrawal for 12 h resulted in greater average live weight loss ($67$ g; $P < 0.05$) compared to provision of either supplement, the latter of which did not differ from each other ($29$ and $16$ g for FWS0 and FWS16 treatments, respectively; Table 3). Final live weights of FWS0 ($2,280$ g) and FWS16 ($2,293$ g) birds were greater ($P < 0.05$) than controls ($2,242$ g). Control birds lost $2.84\%$ of their live weights in 12 h, which was significantly greater than for either FWS group, and FWS0 lost more weight (1.23%; $P < 0.05$) than FWS16 birds (0.70%) (Table 3).

When average supplement consumption per bird for FWS groups was expressed per unit (g) reduction in weight loss versus control birds, average values for FWS0 and FWS16 were 0.82 and 0.71, respectively (g of supplement consumed/g of weight loss reduction versus controls). This high efficiency of supplement utilization was probably due to the high digestibility and caloric value of the supplements and the usually greater efficiency of use of dietary nutrients when ME intake was below the requirements for maintenance. Based upon estimates by Scott et al. (1982) and Klasing (1998), average ME for maintenance (basal metabolic rate, heat increment, and minimal activity) of female broilers was calculated to be approximately 140 kcal/12 h. However, control, FWS0, and FWS16 birds consumed 0 kcal ME (0 g), 124 kcal ME (31 g), and 140 kcal ME (35 g), respectively, assuming a calculated physiological fuel value of 4 kcal/g of FWS0 or FWS16 supplements. Although the supplement groups were at approximately zero energy balance, control birds were in negative balance, indicating the possibility of
some protein mobilization that would result in uric acid-N and body water excretion.

Average hot carcass weight of the control group was significantly lower than for FWS0 and FWS16 groups (Table 3), which were not different from each other. Average chilled carcass weights were similar for the three treatment groups, but water uptake by control carcasses was greater (\( P < 0.05 \)) than that for FWS groups (Table 3). Total deboned breast meat yield was similar among treatments in this experiment (Table 3). Smaller, more dehydrated carcasses were reported to absorb proportionately more water during chilling than heavier, more hydrated carcasses (Thomson et al., 1961), and greater water uptake resulted from prolonging feed withdrawal (Benibo and Farr, 1985). Proportionately greater uptake of water during chilling by carcasses of control birds compared to FWS0 and FWS16 accounted for the loss of differences in carcass weight for chilled versus hot carcasses and may partially explain the similarity (\( P > 0.05 \)) in breast muscle yield; however, actual tissue moisture content was not determined. Greater water uptake by birds subjected to conventional feed withdrawal protocols (e.g., control birds in this study) will likely become more problematic in the future, as new federal regulations recently in effect (USDA-FSIS, 2002) require the maximum percentage of retained water in raw product be disclosed on the labeling of meat and poultry products. This percentage will invariably be marketed as a quality issue by competing establishments (e.g., as adulteration with water).

### Experiment 2

Birds on FWS0 and FWS16 treatments consumed 31 and 41 g/bird of each supplement, respectively, during the 9 h when supplements were provided exclusively. Conventional feed withdrawal for 12 h resulted in significantly greater average live weight loss compared to provision of the FWS16 supplement (Table 4). Moreover, FWS0 birds had a final live weight loss intermediate between the control group and FWS16 group. Control birds lost 81 g live weight as compared to 34 and 17 g for birds

### Table 2. Visual assessment scores\(^1\) for emptiness of segments of the gastrointestinal tract (GIT) of female broiler chickens provided feed withdrawal supplements (with acclimation)\(^2\) or subjected to 12 h of conventional feed withdrawal at 6 wk of age (Experiment 1)

<table>
<thead>
<tr>
<th>GIT segment</th>
<th>Treatment</th>
<th>n</th>
<th>Crop</th>
<th>Gizzard</th>
<th>Intestine</th>
<th>Cecum</th>
<th>Colon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>20</td>
<td>1.15</td>
<td>1.60</td>
<td>1.55(^a)</td>
<td>2.73(^a)</td>
<td>1.47</td>
<td></td>
</tr>
<tr>
<td>FWS0</td>
<td>15</td>
<td>1.10</td>
<td>1.60</td>
<td>1.15(^b)</td>
<td>2.45(^b)</td>
<td>1.55</td>
<td></td>
</tr>
<tr>
<td>FWS16</td>
<td>15</td>
<td>1.17</td>
<td>1.57</td>
<td>1.12(^b)</td>
<td>2.02(^b)</td>
<td>1.37</td>
<td></td>
</tr>
<tr>
<td>SEM</td>
<td>0.06</td>
<td>0.20</td>
<td>0.08</td>
<td>0.11</td>
<td>0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEM SEM</td>
<td>0.7340</td>
<td>0.9946</td>
<td>0.0002</td>
<td>0.0002</td>
<td>0.7176</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( ^{a,b} \) Means within a column with no common superscript differ significantly \( (P < 0.05) \).

\( ^{1} \) Subjective visual scores were given as follows: 1 = empty, 2 = partially full, and 3 = full.

\( ^{2} \) Acclimation period consisted of feeding a 50:50 ratio of supplement:feed followed by a 75:25 ratio for 4 h each.

Table 3. Live weight changes and carcass characteristics of female broiler chickens provided feed withdrawal supplements (with acclimation)\(^1\) or subjected to 12 h of conventional feed withdrawal at 6 wk of age (Experiment 1)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>Final live weight(^2) (g)</th>
<th>Live weight loss(^3) (g)</th>
<th>Live weight loss(^3) (%)</th>
<th>Hot eviscerated carcass weight (g)</th>
<th>Chilled carcass weight (g)</th>
<th>Water uptake(^4) (% of carcass)</th>
<th>Total deboned breast yield(^5) (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>50</td>
<td>2.24(^a)</td>
<td>(-)67(^a)</td>
<td>(-)12.84(^a)</td>
<td>1.584(^a)</td>
<td>1.629</td>
<td>2.81(^a)</td>
<td>398</td>
</tr>
<tr>
<td>FWS0</td>
<td>50</td>
<td>2.280(^a)</td>
<td>(-)29(^b)</td>
<td>(-)13.8(^b)</td>
<td>1.614(^a)</td>
<td>1.643</td>
<td>1.77(^a)</td>
<td>404</td>
</tr>
<tr>
<td>FWS16</td>
<td>49</td>
<td>2.293(^a)</td>
<td>(-)16(^b)</td>
<td>(-)10.70(^b)</td>
<td>1.602(^a)</td>
<td>1.627</td>
<td>1.50(^b)</td>
<td>397</td>
</tr>
<tr>
<td>SEM</td>
<td>4.4</td>
<td>8.51</td>
<td>0.34</td>
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<tr>
<td>SEM SEM</td>
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<td>0.0002</td>
<td>0.0001</td>
<td>0.0014</td>
<td>0.2206</td>
<td>0.0001</td>
<td>0.4320</td>
<td></td>
</tr>
</tbody>
</table>

\( ^{a,b} \) Means within a column with no common superscript differ significantly \( (P < 0.05) \).

\( ^{1} \) Acclimation period consisted of feeding a 50:50 ratio of supplement:feed followed by a 75:25 ratio for 4 h each.

\( ^{2} \) Total deboned breast yield = final live weight – live weight after acclimation and prior to initiation of treatments.

\( ^{3} \) Live weight immediately prior to processing.

\( ^{4} \) Final live weight – live weight after acclimation and prior to initiation of treatments.

\( ^{5} \) Water uptake loss as a percentage of live weight prior to initiation of treatments. Live weight after acclimation and immediately prior to feed withdrawal was included as a covariate in the analyses. The 9-h supplement consumption was 0, 31, and 35 g per bird for control, FWS0, and FWS16, respectively.
on FWS0 and FWS16 treatments, respectively. The live weight loss of the FWS0 and FWS16 were also significantly different from each other. Final live weights of FWS0 (2,362 g) and FWS16 (2,378 g) birds were greater ($P < 0.05$) than those of the control group (2,321 g). Control birds lost an average of 3.24% live weight in 12 h, which was greater ($P < 0.05$) than for supplement birds, and weight loss for birds consuming FWS0 (1.46% live weight) exceeded that for FWS16 (0.69%) (Table 4). Average grams consumption of supplement per gram of weight loss reduction (versus controls) for FWS0 and FWS16 were 0.66 and 0.64, respectively.

Average hot carcass weight of the control group was significantly lower than for FWS0 and FWS16 groups (Table 4), which were not different from each other. Average chilled carcass weight for the FWS16 group was 2.5% greater ($P < 0.05$) than for controls. Water uptakes by carcasses of the control and FWS16 groups during chilling were similar to each other but were significantly greater than for the FWS0 group (Table 4). Total deboned breast meat yield of FWS16 birds was over 5% greater ($P < 0.05$) than for control and FWS0 birds (426 vs. 404 and 405 g, respectively) (Table 4).

Hot carcass weight did not mirror live weight loss with regard to the lack of significant difference between FWS0 and FWS16. The birds were subjected to 3 h of supplement deprivation, placing them in a postprandial state. The fundamental difference between FWS0 and FWS16 diets was the replacement of 16% carbohydrate with 16% dehydrated egg white in the latter, with greater ($P < 0.05$) supplement consumption of FWS16. Weight loss after 4 h of feed withdrawal in turkeys is considered a result of the evacuation of fluid and dry gut contents and some tissue water (Duke et al., 1997). Dietary protein is associated with greater water excretion as a function of uric acid-N excretion from catabolism of amino acids. This probable dietary induced difference in water excretion between FWS0 and FWS16 may explain the greater ($P < 0.05$) water uptake during chilling by the FWS16 carcass, which was similar to that of the control group. Such a difference between the two supplement treatments was not observed in Experiment 1, in which FWS16 birds consumed approximately 11% more supplement than FWS0, whereas the difference in consumption reached 24% in Experiment 2. This latter difference equated to greater dietary protein intake and resultant water excretion, presumably leading to reduced tissue hydration preharvest, and greater water uptake during chilling.

Average ME for maintenance (basal metabolic rate, heat increment, and minimal activity) of the male broilers was approximately 150 kcal/12 h. The control, FWS0, and FWS16 birds consumed 0 kcal ME (0 g), 124 kcal ME (31 g), and 164 kcal ME (41 g), respectively, assuming a physiological fuel value of 4 kcal/g of supplement. Control and FWS0 birds were in negative energy balance, whereas the ME consumption by FWS16 birds exceeded that for maintenance, which may support the improvement in breast muscle yield with the provision of FWS16. The lack of improvement in breast muscle yield for females in Experiment 1 may be attributed to the difference in energy balance versus males (supplement consumption by females in Experiment 1 was equal to energy cost for maintenance; supplement consumption by males in Experiment 2 was greater than maintenance).

### Experiment 3

Because of the practical disadvantages of an acclimation period (Experiments 1 and 2), an effort was made to eliminate the need for acclimation by changing the form and color of the supplement to resemble that of conventional broiler feed in later experiments (Table 1).

Birds on FWS0 and FWS16 treatments consumed 29 and 31 g, respectively, during 9 h when supplement was provided ad libitum. Conventional feed withdrawal for 12 h (control) resulted in significantly greater live weight loss as compared to the FWS16 treatment (Table 5). Control birds lost 76 g live weight as compared to 21 g for birds on the FWS16 treatment. Nonsignificant differences in live weight loss were observed between control and

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>Final live weight (g)</th>
<th>Live weight loss (%)</th>
<th>Live weight loss (%)</th>
<th>Hot eviscerated carcass weight (g)</th>
<th>Chilled carcass weight (g)</th>
<th>Water uptake (%)</th>
<th>Total deboned breast yield (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>24</td>
<td>2,321$^b$</td>
<td>($-$38)$^c$</td>
<td>($-$34)$^c$</td>
<td>1,608$^b$</td>
<td>1,653$^b$</td>
<td>2.72$^a$</td>
<td>40$^p$</td>
</tr>
<tr>
<td>FWS0</td>
<td>24</td>
<td>2,362$^a$</td>
<td>($-$34)$^b$</td>
<td>($-$1.46)$^b$</td>
<td>1,637$^a$</td>
<td>1,668$^a$</td>
<td>1.93$^b$</td>
<td>40$^p$</td>
</tr>
<tr>
<td>FWS16</td>
<td>24</td>
<td>2,378$^c$</td>
<td>($-$0.69)$^c$</td>
<td></td>
<td>1,652$^c$</td>
<td>1,694$^c$</td>
<td>2.54$^c$</td>
<td>426$^c$</td>
</tr>
<tr>
<td>SEM</td>
<td>6.5</td>
<td>6.4</td>
<td>0.26</td>
<td>8.2</td>
<td>8.7</td>
<td>0.18</td>
<td>5.3</td>
<td></td>
</tr>
</tbody>
</table>

$^a$Means within a column with no common superscript differ significantly ($P < 0.05$).

$^b$Acclimation period consisted of feeding a 50:50 supplement:feed mix followed by a 75:25 ratio for 4 h each.

$^c$Control = conventional feed withdrawal for 12 h prior to processing; FWS0 = feed withdrawal supplement without a protein source; FWS16 = feed withdrawal supplement with 16% protein. For both treatments, feeding was as follows: 8-h acclimation period, 9 h ad libitum supplement, and 3 h supplement withdrawal prior to processing.

$^d$Live weight immediately prior to processing.

$^e$Final live weight – live weight after acclimation and prior to initiation of treatments.

$^f$Live weight loss as a percentage of live weight prior to initiation of treatments. Live weight after acclimation and immediately prior to feed withdrawal was included as a covariate in the analyses. The 9-h supplement consumption was 0, 31, and 41 g per bird for control, FWS0, and FWS16, respectively.
TABLE 5. Live weight changes of male broiler chickens provided feed withdrawal supplements (without an acclimation period) or subjected to 12-h conventional feed withdrawal at 6 wk of age (Experiment 3)

<table>
<thead>
<tr>
<th>Treatment1</th>
<th>n</th>
<th>Final live weight2 (g)</th>
<th>Live weight loss3 (g)</th>
<th>Live weight loss%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>10</td>
<td>2,435b</td>
<td>(−)76.5b</td>
<td>(−)2.97b</td>
</tr>
<tr>
<td>FWS0</td>
<td>10</td>
<td>2,458b</td>
<td>(−)48.2ab</td>
<td>(−)1.97ab</td>
</tr>
<tr>
<td>FWS16</td>
<td>10</td>
<td>2,488a</td>
<td>(−)21.2c</td>
<td>(−)0.83c</td>
</tr>
<tr>
<td>SEM</td>
<td>11</td>
<td>10</td>
<td>0.43</td>
<td>0.0051</td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>0.0064</td>
<td></td>
<td>0.0065</td>
</tr>
</tbody>
</table>

**a,b**Means within a column with no common superscript differ significantly (P < 0.05).
1Control = conventional feed withdrawal for 12 h prior to processing; FWS0 = feed withdrawal supplement without a protein source; FWS16 = feed withdrawal supplement with 16% protein. For both treatments, feeding was as follows: 9 h ad libitum supplement; 3 h supplement withdrawal prior to processing.
2Live weight immediately prior to processing.
3Final live weight – initial live weight prior to initiation of treatments.
4Live weight loss as a percentage of the live weight prior to initiation of treatments. Initial body weight prior to treatments was used as a covariate for adjustment of final live weight responses. The 9-h supplement consumption was 0, 29, and 31 g per bird for control, FWS0, and FWS16, respectively.

FWS0 groups (76 vs. 48 g, respectively). Final live weights (covariate adjusted for initial weight at initiation of treatments) of FWS16 birds were greater (P < 0.05) than for control birds (2,488 vs. 2,435 g, respectively). On average, control birds lost 2.97% of live weight in 12 h, which was significantly greater than for FWS16 birds (0.83% live weight loss). Birds on FWS0 lost 1.97% live weight, which was intermediate between the control and FWS16 groups (Table 5). The lack of statistical significance for differences in live weight loss between control and FWS0 was likely due to the low number of observations per treatment in this preliminary experiment (n = 10 birds/treatment), combined with the high variability observed due to the meal eating behavior of chickens (Cummings and Savage, 1997). An individual bird not consuming sufficient supplement in the allowed period would not realize the benefits of preservation of live weight.

**Experiment 4**

Birds on FWS0 and FWS16 treatments consumed 32 and 36 g supplement, respectively, during 9 h when supplement was provided ad libitum. Final live weights among treatments were significantly different (P < 0.05; FWS16 > FWS0 > control = 2,527, 2,507 and 2,484 g, respectively). Feed withdrawal for 12 h resulted in significantly greater live body weight loss compared to FWS0 and FWS16 (Table 6). Average live weight loss for the FWS0 group was greater (P < 0.05) than for the FWS16 group. Control birds lost 78 g of live weight compared to 54 and 34 g for FWS0 and FWS16 birds, respectively. On average, control birds lost 3.00% of their live body weights in 12 h, which was greater (P < 0.05) than for the FWS0 birds (2.11% average live weight loss) and FWS16 birds (1.35% average live weight) (Table 6). Supplement consumption per unit weight loss reduction (as explained for Experiment 2) was 1.34 and 0.77 for FWS0 and FWS16, respectively.

Hot carcass weight was not significantly affected by treatments; however, a numerical improvement was observed as a result of feeding the supplements (Table 6). Chilled carcass weight was greater (P < 0.05) for FWS16 birds than for controls. Water uptake by the carcass during chilling was not significantly different among treatments (Table 6). Differences in absolute yield of deboned breast meat were not significant (Table 7).

Overall, differences in live weight loss were observed in all experiments. These experiments were not designed to determine the effect of feed withdrawal time on water loss and shrinkage but, rather, the response to the supplement treatments compared to a conventional 12-h feed withdrawal. The average percentage live weight loss with use of the FWS16 treatment over the four experiments was approximately 0.89%. This percentage of shrinkage is 45 and 63% lower than that reported by Benibo and Farr (1985) and Papa and Dickens (1988), respectively, after 4 h of feed withdrawal following a conventional broiler feeding program. In addition, the FWS16 birds exhibited significantly less GIT residue than control birds, and Papa and Dickens (1988) reported a 74% increase in excreta DM collection from the lower GIT of birds subjected to 4 to 12 h of feed withdrawal.

Chilled, dressed carcass yield of FWS16 birds was equivalent to or greater than controls, with the outcome depending upon the degree of water uptake during chilling relative to control birds. When water uptake for FWS16 was less than controls (Table 3), carcass yields were equivalent. When water uptake for FWS16 was equivalent to control groups (Tables 4 and 6), yield was greater for FWS16 birds than controls. Therefore, the use of FWS16 as a feed withdrawal supplement resulted in increased product yield with no greater water uptake than the conventional practice of feed withdrawal or in equivalent product yield with less water uptake (i.e., adulteration) during processing (see relevant discussion under Experiment 1).

Reprocessing of carcasses as a result of digesta and fecal contamination results in economic losses for integrated companies. Feed withdrawal is the conventional method currently used as part of all programs to comply with Federal regulations directed toward minimizing carcass contamination from GIT contents. However, feed with-
TABLE 6. Live weight changes and carcass characteristics of male broiler chickens provided feed withdrawal supplements (without an acclimation period) or subjected to 12 h conventional feed withdrawal at 6 wk of age (Experiment 4)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>Final live weight (g)</th>
<th>Live weight loss (%)</th>
<th>Live weight loss (g)</th>
<th>Hot eviscerated carcass weight (g)</th>
<th>Chilled carcass weight (g)</th>
<th>Water uptake (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>45</td>
<td>2.484&lt;sup&gt;a&lt;/sup&gt;</td>
<td>(-)78&lt;sup&gt;a&lt;/sup&gt;</td>
<td>(-)3.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1,760</td>
<td>1,795&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.02</td>
</tr>
<tr>
<td>FWS0</td>
<td>15</td>
<td>2.507&lt;sup&gt;b&lt;/sup&gt;</td>
<td>(-)21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1,771</td>
<td>1,806&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.02</td>
<td></td>
</tr>
<tr>
<td>FWS16</td>
<td>45</td>
<td>2.522&lt;sup&gt;c&lt;/sup&gt;</td>
<td>(-)34&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1,777</td>
<td>1,817</td>
<td>2.21</td>
<td></td>
</tr>
<tr>
<td>SEM</td>
<td>4.9</td>
<td>4.9</td>
<td>0.19</td>
<td>8.7</td>
<td>8.5</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.2667</td>
<td>0.0338</td>
<td>0.7308</td>
<td></td>
</tr>
</tbody>
</table>

*Means within a column with no common superscript differ significantly (P < 0.05).

<sup>a</sup>Control = conventional feed withdrawal for 12 h prior to processing; FWS0 = feed withdrawal supplement without a protein source; FWS16 = feed withdrawal supplement with 16% protein. For both treatments, feeding was as follows: 9 h ad libitum supplement; 3 h supplement withdrawal prior to processing.

<sup>b</sup>Live weight immediately prior to processing.

<sup>c</sup>Live weight loss = initial live weight prior to initiation of treatments.

<sup>d</sup>Live weight loss as a percentage of live weight prior to initiation of treatments. Initial body weight prior to initiation of treatments was used as a covariate for adjustment of final live weight responses. The 9-h supplement consumption was 0, 32, and 36 g per bird for control, FWS0, and FWS16, respectively.

drawal results in an undesirable impact on product yield and quality. A method that would aid in evacuating the GIT in a relatively short time, while maintaining the integrity of the GIT and reducing or eliminating live weight shrinkage, would be of economic importance to the poultry and other meat animal industries. The objective of the current studies was to evaluate the efficacy of a nutritive, solid phase feed withdrawal supplement fed to broiler chickens immediately prior to processing as an alternative to conventional feed withdrawal.

Provision of the nutritive supplement resulted in less digesta and fecal material in the GIT, reduced live weight shrinkage normally associated with feed deprivation, and, in some experiments, improved chilled carcass and breast meat yield. The variability in yield across experiments may be correlated to variation in level of supplement consumption, with a threshold likely necessary to realize a significant impact on yield (for example, among Experiments 2, 3, and 4, as consumption of FWS16 increased, yield differences became more prominent and eventually significant at 41 g/bird consumption). The integration of such a nutritive supplement in preharvest management programs would overcome the need for in-house feed withdrawal, prevent liquification of the mucosal lining and deterioration of GIT integrity when duration of feed withdrawal is prolonged (Northcutt et al., 1997), and potentially reduce the fragility of the GIT and risk for rupturing during processing, thus reducing the risk for carcass contamination.

FWS also relieves the birds from stress associated with feed-deprivation. A nutritive supplement formulated with an antimicrobial compound included may also reduce the risk of carcass contamination and cross-contamination, by reducing the total bacterial load in the GIT that might be released in the event of a breakage. The quantity of supplement consumed is critical, and requires amplification through improvement in the physical form or palatability. Use of a further refined supplement could allow more efficient production of wholesome meat products and enable commercial poultry operations to better conform to existing USDA-FSIS regulations.

TABLE 7. Deboned breast meat yield for male broiler chickens provided feed withdrawal supplements (without an acclimation period) or subjected to 12 h conventional feed withdrawal at 6 wk of age (Experiment 4)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>n</th>
<th>Deboned left breast weight (g)</th>
<th>Deboned right breast weight (g)</th>
<th>Total breast weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>45</td>
<td>230</td>
<td>225</td>
<td>455</td>
</tr>
<tr>
<td>FWS0</td>
<td>15</td>
<td>235</td>
<td>229</td>
<td>466</td>
</tr>
<tr>
<td>FWS16</td>
<td>45</td>
<td>233</td>
<td>227</td>
<td>461</td>
</tr>
<tr>
<td>SEM</td>
<td>2.87</td>
<td>2.92</td>
<td>8.53</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td></td>
<td>0.4498</td>
<td>0.5885</td>
<td>0.5061</td>
</tr>
</tbody>
</table>

*Control = conventional feed withdrawal for 12 h prior to processing; FWS0 = feed withdrawal supplement without a protein source; FWS16 = feed withdrawal supplement with 16% protein. For both treatments, feeding was as follows: 9 h ad libitum supplement; 3 h supplement withdrawal prior to processing.

<sup>a</sup>Initial body weight prior to initiation of treatments was used as a covariate for adjustment of final live weight responses.

REFERENCES


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