Original Research Article

Effect of protein sources on performance characteristics of turkeys in the first three weeks of life

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1. Introduction

Turkey poults are severely protein depleted at hatch, as protein is preferentially used as an energy source during the hatching process. This is because gluconeogenesis from protein does not require oxygen, which is limited during the transition from chorionallantois to pulmonary respiration (Uni and Ferket, 2004). Additionally, protein digestion is impaired in young birds because of the transition from yolk sac nutrients, which are predominantly lipids, to a high protein exogenous feed (Noy and Sklan, 1997; Sklan, 2001). The transition from yolk to feed is compromised because of the immature state of the digestive tract in young poults, which leads to a reduced ability to digest and absorb protein. The ability to use dietary protein and amino acids (AA) at a young age is important as these nutrients are required for basic body function, muscle cell proliferation and subsequent meat production (Firman and Boling, 1998; Halevy et al., 2000, 2003; Moore et al., 2005). Due to protein depletion and the decreased ability of poults to digest protein, it is essential to provide birds with adequate levels of high quality dietary protein following hatch.

Abstract

The effect of nutrition during the early life of turkey poults has a long-lasting impact on bird performance. This study assessed the digestibility of 5 high protein feed ingredients (soybean meal [SBM], corn gluten meal [CGM], canola protein concentrate [CPC], fish meal [FM], and porcine meal [PCM]) in broiler chickens, as well as their use in turkey pre-starter diets fed to 21 d of age. The first experiment (5 × 2 factorial arrangement) determined nitrogen corrected apparent metabolizable energy (AMEn) and apparent ileal amino acid digestibility (AIAAD) of each ingredient in broiler chickens at 5 and 21 d of age, using 6 replications of 30 and 8 chicks, respectively. In the second experiment (completely randomized design), 4 replication pens, containing 23 d-old poults, were randomly assigned to one of 5 dietary treatments. The diets were formulated based on the AMEn and AIAAD values derived in the first experiment, and consisted of a high SBM control diet, and 4 additional diets with either CPC, FM, PCM or CGM replacing 25% of the protein supplied by SBM in the control diet. Statistical analysis was completed using Proc Mixed in SAS 9.3. Planned contrasts were used to compare treatments in the second experiment. Trends were identified at P < 0.10 and significant differences identified at P < 0.05. Bird age did not affect CPC, FM, CGM, and SBM AMEn, but the PCM value at d 5 was higher than that at d 21. Apparent ileal amino acid digestibility increased with age for most amino acids (AA), but the response was AA and protein source dependent. The largest average increase in AIAAD between 5 and 21 d of age was observed for CGM. Inclusion of CPC, FM, PCM, or CGM increased body weight up to 14 d, in comparison to poults fed the SBM diet, but feed efficiency and water consumption were not affected. Terminal ileum digesta moisture values were higher for birds fed SBM when compared to those fed PCM. These results demonstrate that combining SBM with CPC, FM, PCM, or CGM improves poult performance during the first 14 d of life in comparison to feeding SBM alone.

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Currently, the most commonly used protein source in poultry diets is soybean meal (SBM) because its nutritional profile (energy, AA level and balance) is complimentary to that of cereal grains and the poults’ requirements. The market for food products from vegetable fed animals has increased the level of SBM used in turkey diets. Despite the favorable nutritional profile of SBM, when used at high levels as the sole protein source in practical pre-starter diets, the effects of anti-nutritional factors (ANF) may be underestimated. These ANF include protease inhibitors, which impair protein digestion (Paliyeyguru et al., 2011), lectins, which affect carbohydrate digestion, as well as disrupting and causing damage to the intestinal wall (Fasina et al., 2003), phytic acid, which interferes with mineral and protein absorption (Cowieson et al., 2004), and non-starch polysaccharides, which cause fluid retention, increased passage rate, and subsequent poor nutrient absorption when in high concentrations within the digestive tract (Stein et al., 2008). Although industrial processing reduces the level of protease inhibitors and lectins (Kumar, 1992), the high inclusion rates of SBM may result in diet levels that have adverse effects. Potassium levels in SBM may also have anti-nutritive effects, as high levels of potassium in SBM have been associated with increased water intake and as a result increased excreta moisture (Youssef et al., 2011). Reducing the SBM levels in pre-starter feeds by including other protein sources could be advantageous because it dilutes the levels of SBM ANF present in the feed. Other protein sources may also provide beneficial effects due to their nutritional properties and potential bioactive compounds. Bioactive compounds provide biological benefits to the bird by improving physiological functions (Muir et al., 2013) and are present in both vegetable and animal protein sources. For example, animal tissue cells contain bioactive compounds called polyamines (Smith et al., 2000), which are synthesized from ornithine and methionine, and are essential for cell growth (Smith et al., 1996). The presence of these compounds in the feed due to the addition of animal protein may benefit the performance of poults.

Combining protein sources in turkey pre-starter diets may improve turkey performance due to a reduction in the effects of SBM ANF and/or positive effects of other high protein ingredients. Further, the age effect on digestibility may vary with diet protein source, which in turn will influence accuracy of feed formulation and the selection of ingredients. To increase the accuracy of diet formulation and provide additional digestibility data on high protein ingredients, their nutritive values (apparent ileal amino acid digestibility [AIAAD] and nitrogen corrected apparent metabolizable energy [AMEn]) were determined using 5 and 21 d-old broiler chicks. Subsequently, performance was compared for poults fed a diet containing SBM as the sole protein source to diets where 25% of the protein provided by SBM was replaced by one of 2 animal-based (rendered) products (fish meal [FM] and porcine meal [PCM]) or one of 2 plant-based protein sources (corn gluten meal [CGM] and canola protein concentrate [CPC]). It was hypothesized that protein source digestibility increases with age on an ingredient specific basis, that reducing SBM in pre-starter diets by including other protein sources improves poults performance, and birds fed PCM and FM diets will outperform those fed CPC and CGM.

2. Materials and methods

The experimental procedures used in this research were approved by the University of Saskatchewan Animal Research Ethics Board. Animals were cared for according to the Canadian Council on Animal Care guidelines On the Care and Use of Farm Animals in Research, Teaching, and Testing (CCAC, 2009).

2.1. Digestibility assay

2.1.1. Birds and housing

Male Ross 308 × 308 broiler chicks were obtained from a commercial hatchery at the day of hatch (Lilydale, Wynyard, Canada) and used to determine AMEn and AIAAD at 5 and 21 d of age. For 5 d AMEn and AIAAD, 1,080 birds were randomly assigned to 72 Jamesway battery brooder cages (50 cm wide × 85 cm long × 25 cm high) at the day of hatch (d 0). Each cage containing 15 birds was randomly assigned to one of 6 treatments, with 12 replication cages per treatment. An additional 288 birds used for d 21 digestibility were placed in a floor pen until random allocation to one of 72 battery cages (4 birds per cage) on d 5. Room temperature was initially set at 32 °C and then gradually decreased by 3 °C every week. Birds were exposed to 20 h of light at light intensity 20 lx and 4 h of dark during the experiment. Feed and water were supplied ad libitum throughout the experiment. Cages were checked daily for mortality.

2.1.2. Dietary treatments

The d-5 digestibility chicks were fed experimental diets from d 0 to 5. The d-21 digestibility chicks were fed a commercial starter diet from d 0 until 15, after which they were given the experimental diets. Six treatment diets were fed in this experiment (Table 1) and all protein concentrations were analyzed for AA and mineral content prior to diet formulations (Table 2). The protein sources used were SBM, CGM, CPC, FM and PCM. The CPC was an experimental ingredient created by solubilizing canola meal protein in water, treating with phytase to remove phytate and then filtering to remove hulls. Protein sources were included at 40% of the diet in exchange for corn, SBM, and canola oil in the basal diet. Diets were fed as a mash with 1.5% celite added as an indigestible marker.

### Table 1

Ingredients and composition of test diets on an as-is basis for apparent ileal amino acid digestibility and AMEn (%).

| Item                        | Basal | SBM | CGM | CPC | FM | PCM |
|-----------------------------|-------|-----|-----|-----|----|-----|
| Ingredients                 |       |     |     |     |    |     |
| Corn                        | 80.41 | 46.41 | 46.41 | 46.41 | 46.41 | 46.41 |
| Soybean meal                | 13.31 | 47.68 | 7.68 | 7.68 | 7.68 |
| CGM                         | 1.63  | 1.63 | 1.63 | 1.63 | 1.63 |
| CPC                         | 1.35  | 1.35 | 1.35 | 1.35 | 1.35 |
| FM                          | 1.50  | 1.50 | 1.50 | 1.50 | 1.50 |
| Sodium chloride             | 0.32  | 0.32 | 0.32 | 0.32 | 0.32 |
| Choline chloride            | 0.10  | 0.10 | 0.10 | 0.10 | 0.10 |
| Calculated nutrient composition | 3.075 | 2.703 | 3.263 | 2.917 | 2.903 | 3.263 |

AMEn = nitrogen-corrected apparent metabolizable energy; SBM = soybean meal; CGM = corn gluten meal; CPC = canola protein concentrate; FM = fish meal; PCM = porcine meal.

Supplied per kilogram of diet: 11,000 IU vitamin A; 2,200 IU vitamin D₃; 300 IU vitamin E; 2.0 mg menadione; 1.5 mg thiamine; 6.0 mg riboflavin; 60.0 mg niacin; 4.0 mg pyridoxine; 0.02 mg vitamin B₁₂; 10 mg pantothenic acid; 0.6 mg folic acid; 0.15 mg biotin; 80 mg iron; 80 mg zinc; 80 mg manganese; 10 mg copper; 0.8 mg iodine; 0.3 mg selenium.
To reduce this in 2.2. Production trial FM feeding 24 h after a 28 d incubation period. Hybrid converter turkey
tribution of poults to treatments based on hatch time, and initial experiment, poult hatch times were recorded to permit equal dis-
2.1.3. Data collection Body weight gain and feed consumption were measured on a cage basis from d 0 to 5 for d-5 digestibility and d 15 to 21 for d-21 digestibility. Excreta was collected 4 times over 48 h on plastic sheets placed under each cage beginning on d 3 for d-5 digestibility birds and on d 19 for d-21 digestibility birds. The samples were dried in a forced air oven at 55 °C, pooled on a cage basis, and ground (1.0-mm screen) using a Retsch grinder (Hann, Germany). Following grinding and prior to chemical analysis, samples from 2 cages were pooled to create a total of 6 replications per treatment for analysis. The samples were analyzed in duplicate for dry matter (AOAC, 2006) using method 930.15. Samples were analyzed for N using a Leco nitrogen analyzer (Model 601, Leco Corporation, St. Joseph, MI, USA) according to the AOAC (2006) combustion method 990.03, and N values were converted to crude protein using 6.25 as the conversion factor. Acid insoluble ash was determined as described previously (Vogtmann et al., 2006) combustion method 990.03, and N values were converted to crude protein using 6.25 as the conversion factor. Acid insoluble

| Item | SBM | CGM | CPC | FM | PCM |
|------|-----|-----|-----|----|-----|
| Crude Protein | 47.30 | 66.00 | 60.30 | 61.20 | 49.40 |
| Alanine | 1.99 | 5.19 | 2.82 | 3.88 | 3.69 |
| Arginine | 3.79 | 2.33 | 4.11 | 4.64 | 3.91 |
| Cysteine | 0.74 | 1.06 | 1.18 | 0.56 | 0.48 |
| Glycine | 1.80 | 1.66 | 3.32 | 4.07 | 6.28 |
| Histidine | 1.51 | 1.18 | 1.17 | 1.71 | 1.42 |
| Isoleucine | 2.21 | 2.45 | 2.91 | 2.84 | 1.79 |
| Leucine | 3.73 | 10.40 | 5.28 | 4.99 | 3.65 |
| Lysine | 2.98 | 1.03 | 3.41 | 5.68 | 3.52 |
| Methionine | 0.63 | 1.47 | 1.27 | 1.64 | 0.90 |
| Phenylalanine | 2.48 | 4.07 | 3.26 | 2.88 | 2.15 |
| Proline | 2.46 | 5.35 | 3.53 | 2.97 | 4.05 |
| Serine | 2.54 | 3.44 | 3.09 | 2.71 | 2.22 |
| Threonine | 1.88 | 2.19 | 2.38 | 2.68 | 1.67 |
| Tyrosine | 2.01 | 3.61 | 2.14 | 2.39 | 1.51 |
| Valine | 2.20 | 2.76 | 3.41 | 3.21 | 2.34 |
| Minerals Calcium | 0.38 | 0.14 | 0.97 | 3.81 | 6.43 |
| Total phosphorus | 0.54 | 0.28 | 1.06 | 2.25 | 3.92 |
| Sodium | 0.19 | 0.07 | 1.08 | 1.50 | 0.47 |
| Potassium | 2.27 | 0.26 | 0.40 | 0.88 | 0.53 |

SBM – soybean meal; CGM – corn gluten meal; CPC – canola protein concentrate; FM – fish meal; PCM – porcine meal.

2.1.4. Analysis

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\text{AIAADC} = \frac{\text{use d } 21 \text{ values for the digestibility values derived from older animals, the 21 d determined digestibility values were used in feed formulation. The decision to use d 21 values for the first 3 wk was made in order to create a practical, commercially applicable diet. The remaining 4 diets were formulated by calculating the percentage of protein being supplied by the SBM in the basal diet and mathematically substituting one of 4 alternative ingredients to replace 25% of the protein SBM was contributing. The alternative ingredients were CGM, CPC, FM and PCM. All diets were analyzed using AOAC International (2006) methods for the following nutrients: moisture (method 930.15), crude protein (method 990.03), and minerals (method 985.01), and analyzed minerals were calcium, phosphorus, potassium, sodium and chloride. All diets were formulated on a digestible AA basis and met the minimum values in the Hybrid requirements (Hybrid Turkeys, 2013).}

2.2. Dietary treatments

Each pen was randomly assigned one of 5 treatment diets (Table 3) for the duration of the trial. A basal wheat-SBM diet was formulated to meet Hybrid requirements (Hybrid, 2013). Because the digestible AA requirements for turkey poults are based on digestibility values derived from older animals, the 21 d determined digestibility values were used in feed formulation. The decision to use d 21 values for the first 3 wk was made in order to create a practical, commercially applicable diet. The remaining 4 diets were formulated by calculating the percentage of protein being supplied by the SBM in the basal diet and mathematically substituting one of 4 alternative ingredients to replace 25% of the protein SBM was contributing. The alternative ingredients were CGM, CPC, FM and PCM. All diets were analyzed using AOAC International (2006) methods for the following nutrients: moisture (method 930.15), crude protein (method 990.03), and minerals (method 985.01), and analyzed minerals were calcium, phosphorus, potassium, sodium and chloride. All diets were formulated on a digestible AA basis and met the minimum values in the Hybrid requirements (Hybrid Turkeys, 2013). Analyzed diet nutrient values approximated calculated values shown in Table 3. An exception was the analyzed sodium value of 0.15% in the CPC diet which was 0.03% below the expected value. Diets were fed as a crumble.

2.2. Data collection

Feed intake (pen basis) was measured weekly for the duration of the trial. All water added to the drinkers was weighed and all drinkers were weighed every 24 h to determine daily water intake. Water consumption was corrected daily for evaporation loss using 4 drinkers placed outside of the pens throughout the barn. The evaporation values were an average of 130 g for wk 1, and 100 g for

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Moisture and osmolarity. Moisture was determined by weighing distal ileum (as described previously) were also taken to determine exclusively for the meat yield calculations to ensure that differ-

sexed body weight and breast meat yield. These data were used birds from 3 replication pens) was used to determine individual and 21. At the end of the trial, a sample of 30 birds per treatment (10 wk 2 and 3. Birds were group weighed on a pen basis on d 0, 7, 14 5.460 IU vitamin D3; 100 IU vitamin E; 3.65 mg menadione; 4.15 mg thiamine; 26.78 mg ribo

lar, Canada). The supernatant was removed and microfuged again for an additional 5 min to ensure no particulates remained in the microfuge tube and centrifuged at 35,217 ¼ FM ¼ 0.30 mg selenium.

120.07 mg zinc; 120.08 mg manganese; 18.76 mg copper; 2.10 mg iodine; and 26.50 mg pantothenic acid; 2.65 mg folic acid; 0.51 mg biotin; 80.05 mg iron; 26.78 mg riboflavin; 124.5 mg niacin; 6.75 mg pyridoxine; 0.04 mg vitamin B12; 26.50 mg pantothenic acid; 2.65 mg folic acid; 0.51 mg biotin; 80.05 mg iron; 120.07 mg zinc; 120.08 mg manganese; 18.76 mg copper; 2.10 mg iodine; and 0.30 mg selenium.

3. Results

3.1. Apparent nutrient digestibility

Except for PCM, age did not affect protein source AMEn; the AMEn of PCM was lower on d 21 than d 5 (Table 4). Overall, there was a significant effect of treatment and age on digestibility of all AA, and interactions of main effects were significant for all AA except cysteine and lysine (Table 5). The ingredient with the highest average digestibility coefficient was SBM (0.82), followed by CGM (0.80) and CPC (0.80), FM (0.77), and PCM (0.70). Overall, AA digestibility increased 7% from d 5 to 21. Digestibility of all AA in SBM, CGM, and FM increased from d 5 to 21 (Table 6), with an average increase of 8.17%, 19.27%, and 7.75%, respectively (Table 7). Except for cysteine and serine, digestibility of all AA increased from d 5 to 21 in CPC with an overall average increase of 4.22%. In PCM, AIAAD increased for all AA except for alanine, arginine, glycine, histidine, and proline, with an overall average increase of 9.14%. The largest increase in average AIAAD from d 5 to 21 was observed for CGM, while the smallest increase was observed for PCM.

Table 3 Ingredients and composition of test diets for the turkey production trial (% as-is basis).

| Item                        | Diets          |
|-----------------------------|----------------|
|                             | SBM | CGM | CPC | FM | PCM |
| Ingredients                 |     |     |     |    |     |
| SBM                         | 46.97 | 35.23 | 35.23 | 34.69 | 35.23 |
| Wheat                       | 40.63 | 44.79 | 45.74 | 48.30 | 47.31 |
| CGM                         | – | 8.74 | – | – | – |
| CPC                         | – | – | – | – | – |
| FM                          | – | – | – | – | – |
| PCM                         | – | – | – | – | 9.59 |
| Canola oil                  | 4.23 | 2.8 | 3.11 | 2.52 | 2.20 |
| Monosodium phosphate dicalcium | 2.74 | 2.77 | 2.35 | 1.66 | 0.98 |
| Limestone                   | 2.13 | 2.18 | 2.19 | 1.57 | 1.36 |
| DL-methionine               | 0.47 | 0.35 | 0.38 | 0.4 | 0.46 |
| Salt                        | 0.39 | 0.38 | 0.16 | 0.11 | 0.28 |
| Threonine                   | 0.06 | 0.05 | 0.06 | 0.05 | 0.1 |
| Lysine HCI                  | 0.02 | 0.35 | 0.15 | 0.01 | 0.13 |
| Celite                      | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| Ameri-Bond 2X1              | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 |
| Vitamin/mineral premix2     | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| Choline chloride            | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 |
| Endofeed W                  | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| Calculated nutrient composition |     |     |     |    |     |
| AME, kcal/kg                | 2.850 | 2.850 | 2.850 | 2.850 | 2.850 |
| Crude protein               | 27.7 | 28.6 | 28.6 | 28.5 | 28.8 |
| Crude fat                   | 5.40 | 4.20 | 4.40 | 4.50 | 4.10 |
| Calcium                     | 1.40 | 1.40 | 1.40 | 1.40 | 1.40 |
| Chloride                    | 0.29 | 0.28 | 0.18 | 0.17 | 0.31 |
| Available phosphorus        | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 |
| Potassium                   | 1.12 | 0.93 | 0.94 | 0.98 | 0.96 |
| Sodium                      | 0.18 | 0.18 | 0.18 | 0.19 | 0.18 |
| Digestible arginine         | 1.85 | 1.68 | 1.79 | 1.81 | 1.81 |
| Digestible lysine           | 1.62 | 1.62 | 1.62 | 1.62 | 1.62 |
| Digestible methionine       | 0.78 | 0.74 | 0.74 | 0.79 | 0.79 |
| Digestible methionine & cysteine | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 |
| Digestible threonine        | 0.96 | 0.96 | 1.17 | 0.96 | 0.96 |
| Dietary electrolyte balance, mEq/kg | 340.3 | 284.3 | 284.3 | 288.9 | 277.2 |

SBM – soybean meal; CGM – corn gluten meal; CPC – canola protein concentrate; FM – fish meal; PCM – porcine meal; AME – apparent metabolizable energy.

Table 4 Effect of age on AMEn of protein sources as determined in broiler chickens (kcal/kg).

| Treatment | Days of age | Pooled SEM | P-value |
|-----------|-------------|------------|---------|
| SBM       | 2.415       | 2.368      | 35.8    | NS      |
| CGM       | 3.745       | 3.726      | 30.3    | NS      |
| CPC       | 2.553       | 2.424      | 43.8    | NS      |
| FM        | 3.069       | 2.951      | 45.5    | NS      |
| PCM       | 2.723a      | 2.550b     | 36.7    | 0.0043  |

AMEn – nitrogen-corrected apparent metabolizable energy; SBM – soybean meal; CGM – corn gluten meal; CPC – canola protein concentrate; FM – fish meal; PCM – porcine meal; NS – not significant.

a, b Means within the same row with no common superscript differ significantly (P < 0.05).

1 Means of 6 replications; pooled excreta of 30 (5 d) or 8 (21 d) birds per replicate.
Table 5
Effect of protein source on amino acid digestibility coefficients in broiler chickens.

| Item          | Meal          | Concentration, \% | Days of age | Pooled ANOVA | P-value |
|---------------|---------------|-------------------|-------------|--------------|---------|
|               | SBM           | CPC               | FM          | PCM          | SEM     |
| 3.2. Production trial

3.2.1. Performance data

Hatch time affected d-21 body weight, with body weight increasing with increasing incubation time (Fig. 1). Analysis of variance suggested there was no effect of diet on production parameters except for mortality corrected gain to feed ratio in wk 2 where poult's fed CGM were more efficient than those fed CPC (Table 8). There were trends for an effect of diet for several aspects of growth. Body weight at 14 d was highest for PCM (P = 0.0645) and similarly weight gain was highest for PCM and lowest for SBM during wk 1 (P = 0.0752) and wk 2 (P = 0.0547), respectively. Feed consumption also tended to be highest for PCM and lowest for SBM during wk 2 (P = 0.0564), as well as feed consumption for the duration of the trial (P = 0.0889). Mortality corrected gain to feed ratio showed a tendency to be improved in CGM as compared to PCM for the duration of the trial (P = 0.0748). There was no effect of treatment on mortality.

A priori contrast #1 (SBM vs. average of CGM, CPC, FM and PCM) showed that poult's fed SBM had lower body weights at d 7 and 14 (1773 and 419.4 g, respectively) and lower gains during wk 1 (1166 g) as compared to the average of birds fed the remaining treatments (183.5, 433.1, and 123.0 g). Poult's fed SBM showed a trend for growing more slowly during wk 2 in comparison to birds in other treatments (P = 0.0972).

Contrast #2 (PCM vs. the average of SBM, CGM, CPC, and FM) showed that birds fed PCM had heavier body weights at d 14 and 21 (443.5 and 843.1 g, respectively) than the average of remaining treatments (427.0 and 810.5 g, respectively), with a trend for increased body weights for poult's fed PCM at d 7 (P = 0.0631). Increased gains were observed for the PCM treatment during wk 1, 2, and 3 (125.8, 257.5 and 399.6 g, respectively) than the average of the other treatments (120.7, 245.7 and 383.5 g, respectively). The PCM treatment also resulted in increased feed consumption during wk 2 (324.6 vs. 310.6 g), with a trend for increased consumption during wk 1 (P = 0.0979).

Table 6
Effect of protein source on amino acid content and apparent ileal amino acid digestibility coefficients in 5- and 21-d-old broiler chickens.

| Item          | SBM          | Concentration, \% | CPC          | Concentration, \% | FM          | Concentration, \% |
|---------------|--------------|-------------------|--------------|-------------------|--------------|-------------------|
|               | 5 d          | 21 d              | 5 d          | 21 d              | 5 d          | 21 d              |
| Crude protein | 47.3         | 66.0              | 60.3         | 61.2              | 49.4         |
| Alanine       | 1.99         | 0.77b 0.86a 5.19  | 0.78b 0.89a 2.82 | 0.77b 0.84a 3.88 | 0.79b 0.84a 3.69 | 0.75 0.79 |
| Arginine      | 3.79         | 0.87a 0.91b 2.33 | 0.82b 0.93b 4.11 | 0.84a 0.87a 4.64 | 0.80a 0.84a 3.91 | 0.76 0.80 |
| Cysteine      | 0.74         | 0.45b 0.52b 1.06 | 0.72b 0.84b 1.18 | 0.76b 0.79b 0.56 | 0.50b 0.61b 0.48 | 0.33b 0.45b |
| Glycine       | 1.80         | 0.77a 0.84a 1.66 | 0.76a 0.85a 3.32 | 0.76a 0.79a 4.07 | 0.75a 0.79a 6.28 | 0.73 0.73 |
| Histidine     | 1.51         | 0.84b 0.90b 1.18 | 0.79b 0.90b 1.17 | 0.84a 0.85a 1.71 | 0.75b 0.80b 1.42 | 0.68 0.72 |
| Isoleucine    | 2.21         | 0.81a 0.88a 2.45 | 0.76b 0.91b 2.91 | 0.77b 0.82b 2.84 | 0.74b 0.80b 1.79 | 0.67b 0.74a |
| Leucine       | 1.73         | 0.78b 0.86b 10.4 | 0.78b 0.94b 5.28 | 0.80b 0.84b 4.99 | 0.76b 0.83b 3.65 | 0.70b 0.77b |
| Lysine        | 2.98         | 0.84a 0.90a 1.03 | 0.83a 0.90a 3.41 | 0.81a 0.84a 5.46 | 0.74b 0.78b 3.52 | 0.70b 0.75a |
| Methionin     | 0.63         | 0.84b 0.92b 1.47 | 0.82b 0.94b 1.27 | 0.86b 0.89b 1.64 | 0.97b 0.98b 0.90 | 0.71b 0.78a |
| Phenylalanine | 2.48         | 0.86b 0.93b 4.07 | 0.78b 0.93b 3.26 | 0.86b 0.85b 2.88 | 0.75b 0.83b 2.15 | 0.70b 0.78a |
| Proline       | 2.46         | 0.78b 0.86b 5.53 | 0.78b 0.91b 3.53 | 0.78b 0.82b 2.97 | 0.72b 0.79b 4.05 | 0.68 0.70 |
| Serine        | 2.54         | -0.80b 3.44      | -0.02b 3.11 3.09 | 0.76b 0.79b 2.71 | 0.67b 0.75b 2.22 | 0.57b 0.67b |
| Threonine     | 1.88         | 0.76b 0.83b 2.19 | 0.75b 0.88b 2.38 | 0.75b 0.79b 2.68 | 0.71b 0.78b 1.67 | 0.61b 0.70b |
| Tyrosine      | 2.01         | 0.84b 0.89b 3.61 | 0.82b 0.93b 2.14 | 0.86b 0.90b 2.39 | 0.76b 0.83b 1.51 | 0.70b 0.78a |
| Valine        | 2.20         | 0.78b 0.86b 2.76 | 0.78b 0.93b 3.41 | 0.86b 0.66b 3.21 | 0.76b 0.83b 2.34 | 0.70b 0.78b |
| Average       | 0.82         | 0.85            | 0.73          | 0.79           | 0.74          | 0.80           |

SBM = soybean meal; CGM = corn gluten meal; CPC = canola protein concentrate; FM = fish meal; PCM = porcine meal; NS = not significant.

Means within the same row and main effect with no common superscript differ significantly (P ≤ 0.05).

Means of 6 replications; pooled ileal samples from 30 (5 d) or 8 (21 d) birds per replicate.

1 Concentration of nutrient in protein source samples.
Digestibility and breast portions. A priori contrasts did not show a significant treatment, but females showed increased yield of total breast meat. Yield as a percentage of live weight was not affected by diet. Means for the other protein treatments (147.3 and 119.1 g) demonstrated that PCM resulted in heavier total breast and breast pectoralis major values (153.4 and 124.5 g) in comparison to the FM treatments. Contrast #2 (PCM vs. the average of SBM, CGM, CPC, and FM) showed that PCM had a lower water to feed ratio during wk 2 compared to all treatments except FM. Further, the water to feed ratio was higher for SBM than the values recorded for CGM and PCM. For wk 3, the CPC treatment resulted in a higher water to feed ratio than SBM and FM, while CGM and PCM values were intermediate. For wk 2, CPC had the highest water to gain ratio, followed by SBM, and CGM, FM, and PCM treatments resulting in the lowest values. For wk 3, the CPC treatment water to gain ratio was higher than the SBM and PCM treatments; the values for CGM and FM were intermediate and not different than the previously mentioned treatments. The distal ileum digesta moisture content at d 21 was higher for SBM poult vs. compared to PCM birds, while CGM, CPC, and FM values were intermediate and not different than SBM and PCM treatments. Terminal ileum digesta osmolarity at d 21 was not affected by treatment.

3.2.2. Water consumption and terminal ileum digesta moisture content and osmolarity

Dietary treatment only affected evaporation corrected water consumption for wk 2, with poult fed CPC drinking more than those fed FM; all other treatments were intermediate and not different from the extreme values (Table 10). Water to feed ratio was affected by treatment for wk 2 with the CPC treatment resulting in a higher ratio compared to all treatments except FM. Further, the water to feed ratio was higher for SBM than the values recorded for CGM and PCM. For wk 3, the CPC treatment resulted in a higher water to feed ratio than SBM and FM, while CGM and PCM values were intermediate. For wk 2, CPC had the highest water to gain ratio, followed by SBM, and CGM, FM, and PCM treatments resulting in the lowest values. For wk 3, the CPC treatment water to gain ratio was higher than the SBM and PCM treatments; the values for CGM and FM were intermediate and not different than the previously mentioned treatments. The distal ileum digesta moisture content at d 21 was higher for SBM poult vs. compared to PCM birds, while CGM, CPC, and FM values were intermediate and not different than SBM and PCM treatments. Terminal ileum digesta osmolarity at d 21 was not affected by treatment.

A priori contrast #1 revealed poult fed SBM had increased ileal digesta moisture at d 21 (81.1%) as compared to the other 4 treatments (79.8%). Identified trends were a decreased water to feed ratio during wk 3 (P = 0.0912) and an increased mortality corrected water to gain ratio during wk 2 (P = 0.0672) for the SBM treatment. No differences were observed between SBM and the remaining treatments for evaporation corrected water consumption, water to feed ratio during wk 1 and 2, mortality corrected water to gain ratio during wk 1 and 3, and terminal ileum digesta osmolarity at d 21. Contrast #2 showed that PCM had a lower water to feed ratio (2.42) during wk 2, mortality corrected water to gain ratio in wk 2 (3.02), and terminal ileum digesta moisture at d 21 (78.8%), than the other 4 treatments (2.61, 3.29, and 80.4%, respectively). No difference was identified between PCM and the remaining treatments for evaporation corrected water consumption, water to feed ratio during wk 1 and 3, mortality corrected water to gain ratio during wk 1 and 3, and terminal ileum digesta osmolarity at d 21.

Contrast #3 revealed no difference between vegetable and animal protein for all water consumption parameters during the first week, as well as in terminal ileum digesta osmolarity at d 21. There was an effect during the second and third week of the trial. Evaporation corrected water consumption was increased during wk 2 and 3 in vegetable protein diets (843.8 and 1,301.7 g, respectively).

Table 7

| Item       | Treatment | SBM | CGM | CPC | FM | PCM |
|------------|-----------|-----|-----|-----|----|-----|
| Alanine    |           | 10.47 | 12.34 | 6.10 | 5.95 | 5.06 |
| Arginine   |           | 4.40 | 11.83 | 3.45 | 4.76 | 5.00 |
| Cysteine   |           | 13.46 | 14.29 | 3.80 | 18.03 | 26.67 |
| Glycine    |           | 8.33 | 10.59 | 3.80 | 5.06 | 0.00 |
| Histidine  |           | 6.67 | 12.22 | 1.18 | 6.25 | 5.56 |
| Isoleucine |           | 7.95 | 16.48 | 6.10 | 7.50 | 9.46 |
| Leucine    |           | 9.30 | 17.02 | 4.76 | 8.43 | 9.09 |
| Lysine     |           | 6.67 | 7.78 | 3.57 | 5.13 | 6.67 |
| Methionine |           | 8.70 | 12.77 | 3.37 | 1.02 | 8.97 |
| Phenylalanine |   | 8.05 | 16.13 | 5.88 | 9.64 | 10.26 |
| Proline    |           | 9.30 | 14.29 | 4.88 | 8.86 | 2.86 |
| Serine     |           | 6.98 | 102.30 | 3.80 | 10.67 | 14.92 |
| Threonine  |           | 8.43 | 14.77 | 5.06 | 8.43 | 10.26 |
| Tyrosine   |           | 5.62 | 11.83 | 4.44 | 8.43 | 10.26 |
| Valine     |           | 8.14 | 14.44 | 3.03 | 10.67 | 14.92 |
| Average    |           | 8.17 | 19.27 | 4.22 | 7.75 | 9.14 |

SBM = soybean meal; CGM = corn gluten meal; CPC = canola protein concentrate; FM = fish meal; PCM = porcine meal.
1 Percentage increase calculated as: (d 21 digestibility – d 5 digestibility)/d 21 digestibility × 100.
2 Means of 6 replications; pooled ileal samples from 30 (5 d) or 8 (21 d) birds per replicate.
3 Average percentage increase of apparent ileal amino acid digestibility coefficients of CGM is 13.34%, when serine is removed from the calculation.

Body weight, body weight gain, feed consumption, mortality corrected gain:feed ratio, and mortality were not affected by feeding a vegetable (CGM and CPC) vs. an animal (FM and PCM) protein source (contrast #3). There was a trend for animal protein treatments to produce increased gain (393.4 vs. 382.1 g) during wk 3 of the trial (P = 0.0868).

Breast meat yields on an absolute weight and a percentage of live weight basis are presented in Table 9. On an absolute basis, males had heavier total breast meat and breast meat portions than females. Contrast #2 (PCM vs. the average of SBM, CGM, CPC, and FM) demonstrated that PCM resulted in heavier total breast and pectoralis major values (153.4 and 124.5 g) in comparison to the means for the other protein treatments (147.3 and 119.1 g). Breast meat yield as a percentage of live weight was not affected by dietary treatment, but females showed increased yield of total breast and breast portions. A priori contrasts did not show a significant effect of dietary treatment on proportional breast meat yield.

Figure 1. Effect of hatch time on body weight of turkey poults at 21 d of age. d n + h = day and hour of incubation at hatch pull.
when compared to animal protein diets (732.3 and 1,190.5 g, respectively). The same effect was observed in water to feed ratio during wk 2 and 3 with 2.46 and 2.22, respectively for animal protein diets. This effect was also seen for mortality corrected water to gain ratio during wk 2 and 3 with 3.34 and 3.47, respectively for vegetable protein diets and 2.46 and 2.22, respectively for animal protein diets. The same effect was observed in water to feed ratio when compared to animal protein diets (732.3 and 1,190.5 g, respectively). The same effect was observed in water to feed ratio during wk 2 and 3 with 3.41 and 3.47, respectively for vegetable protein diets and 2.46 and 2.22, respectively for animal protein diets. This effect was also seen for mortality corrected water to gain ratio during wk 2 and 3 with 3.41 and 3.47, respectively for vegetable protein diets and 3.03 and 3.13 for animal protein diets. Finally, birds consuming vegetable protein diets had higher terminal digesta moisture at d 21 (80.4%) than birds consuming animal protein diets (79.3%).

### 4. Discussion

#### 4.1. Apparent nutrient digestibility

Bird age can impact nutrient digestibility, but the nature and extent of this effect is related to age in combination with the ingredients being assessed (Batal and Parsons, 2002; Adeola et al., 2018). Changes in digestibility due to age (from d 2 to 21) are shown in research on the AMEn of maize, wheat and sorghum-based diets in broiler chicks (Thomas et al., 2008). The AMEn was high following hatch, then decreased to d 6, and subsequently increased to d 21 (Thomas et al., 2008). Similar patterns of energy and amino acid digestibility were shown by Batal and Parsons (2002) for a maize-SBM based diet fed to broilers. These data demonstrate that age comparisons are affected by the specific ages being used and therefore comparisons of the present data with other research must keep this in mind. Lopez and Leeson (2008) reported no effect of age on SBM AMEn, which was confirmed in this study. However, the latter study compared 9- to 12- and 30- to 33-d-old chicks, and it is probable that full digestive capacity required for maximum digestibility had been attained at both ages (Batal and Parsons, 2002). In general terms, AMEn is high from hatch to 5 d, then decreases between d 6 to 8 and then increases until a plateau is reached at 14 d. This may explain why there was no effect of age on SBM AMEn in the current study, as

### Table 9

Effect of protein source on breast meat yield of turkey pouls at 3 wk of age.

| Item          | Meal  | Pooled SEM | ANOVA P-value | Contrast (P-values) |
|---------------|-------|------------|----------------|--------------------|
|               | SBM   | CGM        | CPC            | FM                 | PCM                |               |
|               |       |            |                |                   |                   | #1    | #2    | #3    |
| Body weight, g|       |            |                |                   |                   |       |       |       |
| Week 0        | 60.7  | 60.9       | 60.7           | 60.3              | 60.2              | 0.0002| 0.7064| NS    | NS    | NS    |
| Week 1        | 177.3 | 183.0      | 181.3          | 181.5             | 186.0             | 0.0011| 0.1065| 0.0197| 0.0631| NS    |
| Week 2        | 419.4 | 432.9      | 431.7          | 424.1             | 443.5             | 0.0029| 0.0645| 0.0433| 0.0173| NS    |
| Week 3        | 801.9 | 814.2      | 814.6          | 811.2             | 843.1             | 0.0052| 0.1111| NS    | 0.0125| NS    |
| Average gain, g|       |            |                |                   |                   |       |       |       |
| Week 1        | 116.6 | 122.2      | 122.7          | 121.2             | 125.8             | 0.0011| 0.0752| 0.0141| 0.0396| NS    |
| Week 2        | 242.1 | 249.8      | 248.3          | 242.6             | 257.5             | 0.0019| 0.0547| 0.0972| 0.0112| NS    |
| Week 3        | 382.5 | 381.3      | 382.9          | 387.1             | 399.6             | 0.0029| 0.2494| 0.0328| 0.0868| NS    |
| Week 1 to 3   | 741.3 | 753.3      | 753.9          | 751.0             | 782.9             | 0.0052| 0.1035| NS    | 0.0113| NS    |
| Feed consumption, g|   |            |                |                   |                   |       |       |       |
| Week 1        | 128.7 | 130.0      | 135.7          | 133.7             | 136.7             | 0.0012| 0.1213| NS    | 0.0979| NS    |
| Week 2        | 304.6 | 311.5      | 322.3          | 303.9             | 324.6             | 0.0003| 0.0564| NS    | 0.0421| NS    |
| Week 3        | 532.4 | 530.4      | 556.2          | 540.1             | 551.9             | 0.0042| 0.2055| NS    | NS    | NS    |
| Week 1 to 3   | 965.7 | 971.9      | 1014.2         | 977.7             | 1013.3            | 0.0076| 0.0889| NS    | NS    | NS    |
| Mortality corrected gain to feed ratio |   |            |                |                   |                   |       |       |       |
| Week 1        | 0.0094| 0.0437     | 0.0936         | 0.0929            | 0.0919            | 0.0083| 0.5009| NS    | NS    | NS    |
| Week 2        | 0.7946<sup>a</sup> | 0.8022<sup>b</sup> | 0.7708<sup>b</sup> | 0.7989<sup>ab</sup> | 0.7985<sup>ab</sup> | 0.0037| 0.0270| NS    | NS    | NS    |
| Week 3        | 0.7183| 0.7191     | 0.6889         | 0.7179            | 0.7241            | 0.0055| 0.2657| NS    | NS    | NS    |
| Week 1 to 3   | 0.7670| 0.7757     | 0.7346         | 0.7730            | 0.7745            | 0.0049| 0.0748| NS    | NS    | NS    |
| Mortality, %  |       |            |                |                   |                   |       |       |       |
| Week 1        | 3.3   | 3.3        | 6.5            | 6.5               | 6.5               | 1.0685| 0.7886| NS    | NS    | NS    |
| Week 2        | 0.0   | 0.0        | 0.0            | 0.0               | 2.2               | 0.4348| 0.4380| NS    | NS    | NS    |
| Week 3        | 0.0   | 0.0        | 0.0            | 0.0               | 0.0               | 0.0000| --     | --    | --    | --    |
| Week 1 to 3   | 3.3   | 3.3        | 6.5            | 6.5               | 8.7               | 1.3110| 0.7529| NS    | NS    | NS    |

SBM = soybean meal; CGM = corn gluten meal; CPC = canola protein concentrate; FM = fish meal; PCM = porcine meal; NS = not significant.

<sup>a</sup> Means within the same row with no common superscript differ significantly (P < 0.05) with means of 4 replications of 23 birds per replicate.

<sup>b</sup> Contrast #1: SBM versus the average of CGM, CPC, FM, and PCM; contrast #2: PCM vs. the average of SBM, CGM, CPC, and FM; contrast #3: vegetable (CGM and CPC) vs. animal (FM and PCM) addition to SBM.
AMEn values at d 5 (excreta collection from d 3 to 5) and d 21 (excreta collection from d 19 to 21) may be similar due to the timing of the decrease and subsequent increase of AMEn. Other factors which may contribute to differences in AMEn with age include digestive enzyme secretion and nutrient absorption capacity as the animal ages (Dibner et al., 1996; Sklan and Noy, 2000). Research on the effect of young age on AMEn might also be influenced by factors such as time from actual hatch (not hatch pull) and when feed is offered to the birds. This information is most often not included in publications, making comparisons less precise. The decrease in PCM AMEn value for 21-d-old broilers is likely affected by the nature of raw material rendered and the rendering process itself.

The largest increase in AIAAD from d 5 to 21 was observed in CGM. This is an interesting observation because of the unique nature of CGM proteins. These unique properties, including low solubility in some solutions, are due to the presence of zein protein in corn (Shukla and Cheryan, 2001). Zein is difficult to solubilize in water, likely because it has a high proportion of non-polar AA and is lacking basic and acidic AA (Shukla and Cheryan, 2001). In addition, CGM was found to have a slower digestion rate than a variety of other protein sources in an in vitro digestion model (Bryan et al., 2018). Therefore, it is possible that CGM protein may be difficult to solubilize and digest in the immature digestive tract. Another response of interest in CGM is the negative digestibility value of serine at d 5. This response may be because serine is part of mucin and biliary acids (Cowieson et al., 2004; Horn et al., 2009), however, the same negative digestibility was not seen in other AA that make up mucin and biliary acids (Shukla and Cheryan, 2001). At a young age, the GIT is rapidly growing and its ability to effectively utilize diet nutrients similarly increases (Dibner et al., 1996). The combination of a maturing and functional GIT, and the rise in digestive enzymes works together to increase the ability of the bird to digest protein and therefore contributes to the increase in AA digestibility observed between d 5 and 21.
increase in AA digestibility of 13.3%, remaining the highest increase when the 5 test ingredients are compared.

4.2. Production trial

4.2.1. Performance data

During the first 2 wk, birds fed SBM alone had lower body weights, decreased average gain and a trend for lower feed consumption for wk 1. This suggests that turkey poult growth is most susceptible to the negative effects of feeding high SBM diets during the first 14 d of life. The lack of difference between animal and vegetable protein sources for body weight, average gain, feed consumption, and mortality corrected gain to feed ratio indicates that regardless of the protein source being provided, supplementing a high SBM diet with a second protein source is beneficial to production parameters in turkeys. The results may also reflect the accuracy of amino acid availability data used to formulate experimental diets. The lack of protein source effect agrees with Vieira and Lima (2005) who did not observe a difference in performance between broilers fed all vegetable diets or diets containing meat meal.

The depressed performance observed with feeding high SBM levels could be attributed to the dietary concentration of ANF, such as protease inhibitors, lectins, non-starch polysaccharides, phytate, and potentially allergens. It has been demonstrated that protease inhibitors reduce broiler performance (Hoffmann et al., 2019) by inhibiting protein digestion (Palliyeguru et al., 2011), however, these compounds are heat labile and can be reduced during processing. There is minimal research into the critical level of protease inhibitors that will negatively affect poultry performance. However, a recent study by Hoffmann et al. (2019) suggested that dietary trypsin inhibitors levels above 2 mg/g reduce the performance of broilers fed heat-processed SBM. Lectins have the ability to bind dietary carbohydrates and enterocytes in the GIT (Fasina et al., 2003), potentially leading to an impairment of nutrient digestibility. Although protease inhibitors and lectins are drastically reduced during SBM processing, there are still residual levels present, which are highly dependent on the SBM processing temperature (Fasina et al., 2003). Phytate can also lead to impaired digestion and absorption of minerals (including phosphorus, calcium, magnesium, zinc, and iron), starch and protein by forming complexes that cannot be digested and absorbed (Selle et al., 2000). Phytate is not heat labile and would be present in the diet. The animal protein sources and CPC contain essentially no phytate, while CGM and SBM levels are approximately equal (She et al., 2015). The finding that early growth performance of CGM fed pouls was higher than those fed SBM diet suggested phytate was not the factor responsible for slower growth in the latter treatment.

Performance could also be affected by imbalances in minerals or protein within the diet. All diets were balanced to the same calcium, phosphorus, sodium, and chloride levels. The most notable mineral difference was a higher potassium level for the SBM diet. The SBM diet contained 1.12% potassium, while the remaining diets lacked this mineral difference. The elevated potassium led to the increased dietary electrolyte balance and a reduced feed intake was observed. A second dietary factor that may have affected performance is a protein imbalance; however, all diets were balanced to have similar digestible arginine, lysine, methionine, methionine plus cysteine, and threonine levels (Table 3), so this should not have caused the negative impact on growth that was observed in the SBM diet. Further support for this interpretation is the lack of a diet effect on proportional breast meat yield.

4.2.2. Water consumption and terminal ileum digesta moisture content

The highest weekly and overall water consumption was seen for pouls fed the CPC treatment. This treatment effect is difficult to explain, particularly because all diets were balanced to the same minimum mineral content. Sodium, calcium, phosphorus, and potassium were similar in the CPC, CGM, FM, and PCM treatments, yet water consumption was much higher in the CPC treatment. This indicates another component of the diet that was not assessed causing the birds on the CPC treatment to have a higher water intake.

Water consumption of pouls on the SBM diet was not higher than birds fed PCM, which contradicts the finding that digesta moisture was significantly higher in SBM than PCM. This is also not in agreement with other research showing an increase in water intake and litter moisture for broiler chickens fed a diet containing only SBM in comparison to a diet with animal by-products (Vieira and Lima, 2005; Eichner et al., 2007). No effect on water intake may be partially explained by reduced body weight gain and feed intake for the SBM fed pouls during wk 1 (contrast #1,  P = 0.0141) and 2 (contrast #1,  P = 0.0972). If CPC is excluded from the comparison, SBM had the numerically highest water to gain ratio for wk 1 (contrast #1,  P > 0.10) and 2 (contrast #1,  P = 0.0672), but the numerically lowest value for wk 3 (contrast #1,  P > 0.10). It is possible that a factor or factors in SBM caused increased water consumption in the first 2 wk, but after that time pouls were able to adapt. Despite the change in water to feed ratio, digesta moisture in the SBM treatment remained high at the end of wk 3. Possible reasons for the increased moisture content are higher levels of oligosaccharides (Graham et al., 2002) and potassium in SBM. The diets containing vegetable protein had increased water consumption, water to feed and water to gain ratios, and terminal ileum digesta moisture at d 21 in comparison to diets that included animal protein (contrast #3,  P < 0.05). The elevated water consumption and excreta moisture in the vegetable fed diets was also observed by Vieira and Lima (2005).

Determining digestibility and energy levels for feed ingredients is the first step for their use in young turkey diets. The digestibility data from this study indicate that ingredients such as SBM and CPC provide highly digestible protein to pouls. Choosing ingredients that are highly digestible for young turkey diets should be an advantage, because they should maximize early growth and development, while minimizing negative effects of indigestible protein. Large fractions of indigestible protein have been associated with poorer performance (Bryan et al., 2019) and impaired GIT development (Qaisrani et al., 2014; Apajalahi and Viinola, 2016). The digestibility data contradict the results from the performance trial in this study. Soybean meal inclusion at high levels reduced early poult growth, and increased water to gain ratio and digesta moisture, which can also have negative consequences. Adding a complementary protein source with SBM had a positive impact on performance, however, the best performance was observed when...
PCM was added to SBM. This is an interesting result because PCM was one of the more poorly digestible ingredients tested. This research indicates that there are other factors in protein sources other than their digestibility which might be important when selecting high protein ingredients for young turkey diets.

4.3. Hatch window and early poult growth

This research was not designed to study hatch window effects on production. Rather, hatch window was equalized across treatments to reduce its impact on poult growth and digestive tract development. However, it was possible to see if hatch time affected growth rate. Fig. 1 clearly demonstrates that growth rate was negatively impacted by early hatch. These results are similar to research in meat-type chickens (Wyatt et al., 1985; Bergoug et al., 2013) and indicate that narrower hatch windows benefit early poult performance.

5. Conclusions

The AA digestibility of poultry protein sources (SBM, CGM, FM, and PCM) increased with broiler age in a protein source and specific amino acid manner, with the largest increase occurring for CGM. In contrast, AMEn values were either unaffected by age or showed a slight reduction at 21 d of age. The 21 d digestibility values were used to formulate diets containing only SBM or with 25% of the SBM protein replaced by one of the other protein sources, which were fed to turkey pouls for 21 d after hatch. Growth rate of turkey pouls during the first 2 wk of life was reduced when SBM was the only high protein source. Replacing 25% of the SBM protein improved poult growth, regardless of protein source choice or digestibility.

Conflict of interest

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work, there is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the content of this paper.

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