Research Note: Formulating broiler diets using digestible calcium significantly improved growth performance but reduced apparent ileal digestibility of calcium and phosphorus

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ABSTRACT An experiment was conducted to compare the use of a total and digestible Ca formulation system in broilers from hatch to d 37 post-hatch. Ross 308 (n = 288) male broilers were obtained and allocated to one of 2 dietary treatments in floor pens. There were 18 birds per pen and 8 replicate pens per diet. One diet was formulated using ingredient and nutrient recommendations for total Ca and the second diet was formulated using ingredient and nutrient recommendations for standardized ileal digestible (SID) Ca. All diets were formulated to be nutrient adequate using a 2-phase feeding program and including 0.19% available P (avP) and 0.209% total Ca or 0.073% digestible Ca from 1,000 FYT/kg of phytase. On d 17 and 37, tibias and ileal contents were obtained. From hatch to d 37, birds fed diets formulated using digestible Ca gained (P < 0.05) more and were more efficient (P < 0.05) compared with birds fed diets formulated using total Ca. There was no impact of formulation system on tibia ash or minerals. Litter pH (P < 0.05) was greater and litter dry matter (P < 0.05) was lower in birds fed the diets formulated using digestible Ca compared with those fed diets formulated using total Ca. Apparent ileal digestibility (AID) of Ca (P < 0.05), AID of P (P < 0.05) and digestible P intake (P < 0.05) were lower in birds fed diets formulated using digestible Ca compared with those formulated using total Ca at d 17 or 37. However, apparent ileal digested Ca and digestible Ca intake were not different between the experimental diets on d 17 or 37. In conclusion, formulating diets using digestible Ca improved weight gain and feed conversion ratio, but reduced the AID of Ca and P compared with birds fed diets formulated using total Ca. These findings might be reflective of the higher total Ca concentration in the diets formulated using digestible Ca compared with those formulated using total Ca.

Key words: calcium, digestibility, growth performance, litter, tibia ash

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INTRODUCTION

Formulating broiler diets using digestible compared to total formulation systems has led to improvements in growth performance, efficiency, prudent use of resources, and reductions in nutrient excretion into the environment. This is currently standard practice for essential amino acids and P in some regions. Whereas other nutrients, such as Ca are still formulated using total values. Moving to a digestible Ca formulation system may also have benefits for broilers, such as: improved growth performance and nutrient utilization, enable users to understand and monitor the Ca contribution of their ingredients, and reduce excretion of P into the environment due to close and sometimes antagonistic relationships between dietary Ca and P. The standardized ileal digestible (SID) Ca requirements for broilers from hatch to d 10 (David et al., 2021; Walk et al., 2021b) and d 11 to 24 post-hatch (Walk et al., 2022) were recently published. Therefore, the objective of this work was to compare the use of a total and a digestible Ca formulation system in broilers from hatch to d 37 using growth performance, tibia ash, nutrient digestibility, and markers of welfare such as foot pad and litter scores.

MATERIALS AND METHODS

The animal protocol for this research was approved by the Ethical Committee of DSM Animal Nutrition Research Center and complied with the guidelines in the European Union council directive 2010/63/EU for animal experiments. This experiment was conducted at...
Experimental Diets

Phytase activity recovered in the experimental diets was approximately 25% higher than expected, most likely due to analytical variation and 10% overage included in the calculated amount to add to the diets (Table 1). Xylanase and protease recoveries were variable but indicate the products were included in the diets as expected. Analyzed total Ca and total P were within the expected concentrations formulated in the diets.

Growth Performance and Tibia Ash

Initial BW was 40.5 ± 0.5 g. There was no effect of diet on initial BW ($P = 0.48$). Final BW was 2,833 g
and this was 9% greater than breed expectations, whereas FI was 9% below breed guidelines and this resulted in mortality corrected FCR approx. 86% of the breed guidelines. Average overall (hatch to d 37) mortality was 5.9% and not influenced by diet (Table 2). Birds fed diets formulated using digestible Ca gained \( P < 0.05 \) more \((-5\%)\) and FCR \( P < 0.05 \) was improved compared with birds fed diets formulated using total Ca from d 18 to 37 and overall (Table 2). Walk et al. (2021b, 2022) reported birds fed diets formulated to meet the SID Ca from hatch to d 10 were significantly heavier \((+6\%)\) compared with birds fed diets formulated using total Ca. In the previous studies, the diets formulated using SID Ca also contained 3,000 FYT/kg of phytase, which the authors attributed to some of the improvements in BWG compared with birds fed the total Ca diets. In the current study, both treatments contained 1,000 FYT/kg of phytase and there may be other beneficial factors associated with formulating diets using SID Ca that are unknown or not tested in the current study. Unfortunately, additional data to compare, confirm, or refute the use of SID Ca vs. total Ca formulations are not available in peer-reviewed publications and this limits the inferences that can be made at this time. There was no impact of diet on tibia ash percent, tibia ash weight, or tibia Ca or P (Table 2). The current results suggest formulating broiler diets using SID Ca had no negative impact on skeletal development and significantly improved growth performance.

### Table 1. Calculated and analyzed ingredient and nutrient content of the experimental diets, as fed.

| Ingredients (%) | Total Ca\(^1\) | Digestible Ca\(^2\) | Total Ca\(^1\) | Digestible Ca\(^2\) |
|----------------|---------------|----------------------|---------------|----------------------|
| Corn           | 57.96         | 56.92                | 60.78         | 59.72                |
| Soybean meal   | 36.41         | 36.60                | 32.93         | 33.13                |
| Soy oil        | 2.41          | 2.73                 | 3.51          | 3.83                 |
| Salt           | 0.28          | 0.28                 | 0.29          | 0.29                 |
| Limestone      | 0.74          | 1.29                 | 0.72          | 1.22                 |
| Dicalcium phosphate | 1.02          | 1.00                 | 0.73          | 0.77                 |
| Sodium bicarbonate | 0.20          | 0.20                 | 0.20          | 0.20                 |
| Lysine HCl     | 0.11          | 0.11                 | 0.06          | 0.06                 |
| DL-Methionine  | 0.29          | 0.29                 | 0.24          | 0.24                 |
| Threonine      | 0.06          | 0.06                 | 0.02          | 0.02                 |
| Premix\(^3\)   | 0.40          | 0.40                 | 0.40          | 0.40                 |
| Phytase\(^4\)  | 0.01          | 0.01                 | 0.01          | 0.01                 |
| Titanium       | 0.10          | 0.10                 | 0.10          | 0.10                 |
| Xylanase\(^5\) | 0.005         | 0.005                | 0.005         | 0.005                |
| Protease\(^6\) | 0.0045        | 0.0045               | 0.0045        | 0.0045               |

Calculated nutrient contents:

- Crude protein, %: 23.00
- ME, kcal/kg: 3,000.00
- Formulated total Ca\(^1\), %: 0.69
- Formulated SID Ca\(^2\), %: 0.43
- Total P, %: 0.55
- Non-phytate P, %: 0.48
- Phytate P, %: 0.25
- Digestible Met + Cys, %: 0.95
- Digestible Lys, %: 1.28
- Digestible Thr, %: 0.86
- Digestible P, %: 0.44
- Available P, %: 0.45

Analyzed nutrients and recovered enzyme activities:

- Phytase, FYT/kg: 1,316
- Xylanase, FXU/kg: 219
- Glucanase, IU/kg: 46
- Protease, NFP/kg: 30,090
- Dry matter, %: 87.88
- Crude protein, %: 20.93
- Total Ca, %: 0.69
- Total P, %: 0.58

\(^1\)The phytase matrix applied to the total Ca diets was 0.19% avP and 0.209% total Ca.
\(^2\)The phytase matrix applied to the standardized ileal digestible (SID) Ca diets was 0.19% avP and the estimated digestible Ca coefficient for limestone (0.640%) with phytase (Kim et al., 2019).
\(^3\)Vitamin and mineral premix provided (per kilogram of diet): vitamin A 10,000 IU; vitamin D3 3,000 IU; vitamin E 40 mg; vitamin K3 3 mg; vitamin B1 2.5 mg; vitamin B2 8 mg; vitamin B6 5 mg; vitamin B12 0.025 mg; biotin 0.15 mg; folic acid 1.5 mg; niacinamide 50 mg; D-pantothenic acid 12 mg; Fe (as FeSO4) 60 mg; Cu (as CuSO4) 15 mg; Mn (as MnO) 80 mg; Zn (as ZnO) 54 mg; I (as Ca(IO3)2) 1.2 mg; Se (as Na2SeO3) 0.297 mg; calcium as calcium carbonate (carrier) 26.4 mg.
\(^4\)HiPhorius (DSM Nutritional Products, Kaiseraugst, Switzerland) with an analyzed activity of 10,047 FYT/g.
\(^5\)Ronozyme Multigrain (DSM Nutritional Products, Kaiseraugst, Switzerland) with an analyzed activity of 3,490 U/g was added over the top with no energy contribution considered in the formulation.
\(^6\)ProAct 360 (DSM Nutritional Products, Kaiseraugst, Switzerland) with an analyzed activity of 785,470 NFP/g, contributed 0.04% crude protein, 0.04% digestible methionine + cysteine, 0.05% digestible lysine, and 0.05% digestible threonine.
The greater litter pH and moisture could be linked to the higher total Ca level in the SID Ca diet, which has been reported to significantly increase gastrointestinal pH, reduce crude protein digestibility, and increase pathogenic bacteria (Zanu et al., 2020). In the current study, both treatments resulted in litter dry matter was lower than the recommended 75 to 80%. Many factors, such as litter-type, ventilation, feed and water intake, drinker management, and the external environmental conditions can influence litter moisture and subsequently ammonia emissions (Ritz et al., 2017). Average litter scores were 0.94 and 1.06 and were not different between the total or SID Ca diets, respectively. A score of 1 indicates the litter is dry but not easy to move with your foot (Welfare Quality, 2009). Foot pad lesions were scored by 5 different people on 2 different birds randomly chosen per pen. Only 1 bird fed the total Ca diet had a lesion score of 1, the rest of the birds had a lesion score of 0 (data not shown). It is also worth also noting the birds fed SID Ca diets were heavier and mortality was numerically lower (4 vs. 8%) compared with birds fed diets formulated using total Ca, which resulted in a greater number of birds per pen by the conclusion of the study. These factors, and possibly the higher total Ca, may have contributed to the increase in litter moisture in the absence of any difference in litter scores or foot pad lesions. Further research is warranted to determine if the change in litter moisture is a factor associated with formulating diets using SID Ca.

### Apparent Nutrient Utilization and Calculated Digested Nutrients

The AID of N was not influenced by diet on d 17 ($P = 0.66$) or d 37 ($P = 0.67$; data not shown). Apparent ileal digestibility of Ca ($P < 0.05$) or P ($P < 0.05$) were lower in birds fed diets formulated using SID Ca at d 17 and 37 (Table 2). These results were unexpected. However, the total Ca concentration in the diets formulated using SID Ca was greater than those formulated using total Ca and when calculated on a digested Ca or digestible Ca intake basis, there were no differences between the two formulation systems for Ca.

It is well established that increasing total Ca will result in significant decreases in P digestibility and this most likely contributed to the decrease in AID of P, apparent ileal digested P, and digestible P intake in birds fed the SID Ca diets. Therefore, a balance is needed to ensure optimal growth performance and skeletal development are achieved while minimizing nutrient excretion. The formulated SID Ca concentrations in the current study were greater than those estimated to optimize BM gain or P retention, but less than those estimated to optimize tibia ash (David et al., 2021; Walk et al., 2021b, 2022). The lack of a significant difference in the tibia ash percent, ash weight, or mineral content between the two diets could indicate the SID Ca level in the digestible Ca diets could be reduced to optimize P utilization. However, this may negate the beneficial

### Litter Parameters and Foot Pad Lesions

Litter pH (9.08 vs. 8.89; $P < 0.05$) was greater and litter dry matter (56.3 vs. 67.0%; $P < 0.05$) was lower in birds fed the diets formulated using digestible Ca compared with those fed diets formulated using total Ca.

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Table 2. Growth performance, tibia ash, litter quality and apparent ileal digestibility (AID) of calcium and phosphorus of broilers fed diets formulated using total or digestible calcium from hatch to d 37 post-hatch.

| Formulation system | Total calcium | Digestible calcium | SEM | $P$-value |
|--------------------|--------------|--------------------|-----|-----------|
| Hatch to d 17 post-hatch\(^1\) |              |                    |     |           |
| Feed intake, g     | 8.20         | 7.98               | 9   | 0.1174    |
| Body weight gain, g| 7.06         | 6.83               | 8   | 0.0714    |
| Feed conversion    | 1.163        | 1.169              | 0.098 | 0.631     |
| Mortality, %       | 4.17         | 2.08               | 1.4 | 0.3186    |
| Tibia ash, %       | 50.69        | 51.20              | 0.42 | 0.4073    |
| Tibia ash weight, mg/bone | 725 | 713               | 21  | 0.6966    |
| Tibia Ca, mg/bone  | 254          | 249                | 7.3 | 0.6358    |
| Tibia P, mg/bone   | 130          | 127                | 3.7 | 0.5035    |
| AID P, % DM        | 78.00        | 65.75              | 1.5 | <0.0001   |
| Apparent digested P, % | 0.311 | 0.262              | 0.096 | <0.0001   |
| Digestible P intake, mg/h/d | 150   | 123                | 3.1 | <0.0001   |
| AID Ca, %          | 63.45        | 49.66              | 1.6 | <0.0001   |
| Apparent digested Ca, % | 0.301 | 0.312             | 0.098 | 0.3625    |
| Digestible Ca intake, mg/h/d | 145  | 147                | 4.1 | 0.8488    |
| Apparent digested Ca, % | 0.967 | 1.189            | 0.016 | <0.0001   |
| Digestible P intake, mg/h/d | 1638  | 1670              | 25  | 0.6805    |
| AID P, % DM        | 60.75        | 60.30              | 1.9 | 0.0008    |
| Apparent digested P, % | 0.251 | 0.224             | 0.098 | 0.0291    |
| Digestible P intake, mg/h/d | 347   | 311                | 12  | 0.0511    |
| AID Ca, %          | 46.94        | 34.34              | 2.1 | 0.0009    |
| Apparent digested Ca, % | 0.196 | 0.197             | 0.01 | 0.9601    |
| Digestible Ca intake, mg/h/d | 271  | 273                | 17  | 0.9200    |
| Apparent digested Ca, % | 0.781 | 0.870             | 0.03 | 0.0717    |

1Data are the means of 18 birds per pen and 8 replicate pens per treatment for growth performance. Tibia ash parameters were determined from 2 birds per pen and 8 replicate pens per treatment. Apparent ileal digestibility (AID) of nutrients was determined from 5 birds per pen and 8 replicate pens per treatment.

2Data are the means of 13 birds per pen and 8 replicate pens per treatment for growth performance. Tibia ash parameters were determined from 2 birds per pen and 8 replicate pens per treatment. Apparent ileal digestibility (AID) of nutrients was determined from 5 birds per pen and 8 replicate pens per treatment.

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1Data are the means of 18 birds per pen and 8 replicate pens per treatment for growth performance. Tibia ash parameters were determined from 2 birds per pen and 8 replicate pens per treatment. Apparent ileal digestibility (AID) of calcium and phosphorus of broilers fed diets formulated using total or digestible calcium from hatch to d 37 post-hatch.
effects of formulating diets using SID Ca on BWG and FCR. Repeating this work using different levels of digestible Ca to optimize gain or bone ash and at different feeding phases is required to provide adequate commercial recommendations and advice on formulating diets using SID Ca.

DISCLOSURES

The authors have no conflicts of interest to report.

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