Addition of phytogenic blend in different nutrient density diets of meat-type ducks

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ABSTRACT
A total of 160 1-d-old ducklings (mixed gender) were used to evaluate the effects of dietary phytogenic supplementation on growth performance, carcass characteristics, and nutrient digestibility. Each treatment consisted of eight replications and five birds/replication. Treatments were: (T1) high nutrient diet; (T2) T1+phytobiotics; (T3) low nutrient diet; (T4) T3+phytobiotics. The results indicated that inclusion of phytobiotics and nutrients’ density of diets influenced body weight gain and feed conversion ratio (P < 0.05). Feeding low nutrient diets had a negative effect on drip loss percentage. Cooking loss percentage increased (P < 0.05) by reducing nutrient density. Relative weights of breast muscle, abdominal fat and body organs, pH value, and colour of breast muscle were not affected by treatment diets. Supplementing the diets reduced TBARS value on d 14 post-slaughter (P < 0.05). Density of nutrients and phytogenic blend (P < 0.05) improved the digestibility of dry matter and energy, but the digestibility of calcium and phosphorus were not affected by treatments.

1. Introduction
The use of antibiotics as growth promoters (GPA) was common in the poultry industry for decades. However, the concern about their residues in poultry products and consequently, the transmission and the proliferation of resistant bacteria via the food chain resulted in the ban on GPA use. The negative effects on performance and health status of poultry caused by the removal of GPA from the diet of poultry prompted a search for available alternatives. Phytogenic feed additives are one of the available alternatives that are derived from plants, including a wide range of aromatic plants (e.g. thyme, anise, ginger, turmeric, and cinnamon) and their purified constituents, such as essential oils and oleoresins (Windisch et al. 2007). Previous works reported some beneficial effects of phytoogenic feed additives, such as influence of curcumin, capsaicin, and garlic on lipid metabolism (Srinivasan 2005); ability of curcumin, capsaicin, piperine, ginger, fenugreek and asafoetida to stimulate digestion (Platel and Srinivasan 2000); antimicrobial function (Dorman and Deans 2000; Mourey and Canillac 2002; Rota et al. 2004); antioxidant activity of curcumin, capsaicin, and garlic (Kempiaia and Srinivasan 2002; Bottsgolou et al. 2004; Marzoni et al. 2014); and anti-inflammatory potential (Acamovic and Brooker 2005). Dorman and Deans (2000) suggested that essential oils are variable mixtures of mainly terpenoids (linalool, geraniol, thujanol, borneol, menthol, citronellol, and α-terpineol), and a variety of low-molecular-weight aliphatic hydrocarbons (e.g. phenols as thymol, carvacrol, eugenol, guaiacol, and aromatic aldehydes as cinnamaldehyde, cinnamyl, and phellandral). The majority of published data show reduced feed intake (FI) with an improved growth performance when using phytoogenic feed additives in diets of broiler chickens (Botsoglou et al. 2002; Lee et al. 2003; Hernandez et al. 2004; Shanmugavelu et al. 2004; Jang et al. 2007, Franz et al. 2010) that contain oregano essential oil, thymol, cinnamaldehyde, pepper, garlic powder, and a commercial blend of essential oils containing thymol. However, some other studies indicate that plant extracts (capsaicin and polyphenols) can have beneficial effects on the daily weight gain and feed conversion ratio (FCR) of broiler chickens (Kamel 2001). Some other studies focused on other functions of phytogetic feed additives, such as their antioxidant function (Cervato et al. 2000; Abdalla and Roozen 2001; Damechki et al. 2001; Martinez-Tomé et al. 2001; Vichi et al. 2001; Bendini et al. 2002). It has been reported that carvacrol and thymol, the two main phenols which constitute about 78–82% of the essential oil of oregano, are mainly responsible for this antioxidant function (Yanishlieva and Marinova 1995; Yanishlieva et al. 1999). Furthermore, the other monoterpenic hydrocarbons (γ-terpinine and p-cymene that constitute about 5% and 7% of the total oil, respectively) also contribute to this activity (Adam et al. 1998). Most of the published studies mainly focused on the effects of the phytogetic feed additives on pigs and broiler chickens. Considering the production and proportion of meat-type ducks in the poultry industry, the purpose of this study was to evaluate the effects of phytogenic blend containing capsicum oleoresin, cinnamaldehyde, and carvacrol (Xtract®, Pancosma, Geneva, Switzerland) on nutrient digestibility, growth performance, carcass characteristics, and thiobarbituric acid-reactive substance (TBARS) values in ducks.

2. Materials and methods

2.1. Animals, housing, and diets
The experimental protocols describing the management and care of animals were reviewed and approved by the Animal
Care and Use Committee of Dankook University, South Korea. A total of 160 1-d-old SM3 ducklings (as hatched; Cherry Valley Farms Ltd, Laceby, UK; hatched in a local hatchery) with an average BW of 53 g were used in a 42-day experiment. Ducklings were randomly allotted to four treatments. There were eight pens per treatment with five birds per pen. The birds were housed in three-floor battery cages (1.55 × 0.75 × 0.55 m/cage), in an environmentally controlled room (32 to 24°C and 65% relative humidity). Each cage was equipped with two feeders on each side and two nipple drinkers to provide feed and water ad libitum to birds.

The treatments were: (1) high nutrient density diet; (2) high nutrient density diet + 150 ppm phyogenic blend; (3) low nutrient density diet + 150 ppm phyogenic blend; (4) low nutrient density diet + 150 ppm phytogenic blend used in this study was composed of Capsicum oleoresin, Cinnamaldehyde, and Carvacrol (Xtract®, Pancosma, Geneva, Switzerland). The phyogenic blend was added to the diets by using a low-capacity mixer available in the research facility.

### 2.2. Sampling and measurements

On day 0, 7, 21, and 42, the ducks and their remained feed were weighed to allow calculations of body weight gain (BWG), FI, and FCR. Upon completion of the experimental period, two birds per pen were selected randomly, weighed, and slaughtered. The breast muscle, abdominal fat, gizzard, liver, spleen, and Bursa of Fabricius were removed, and excess moisture from all samples was blotted and then weighed. Hunter L* (lightness), a* (redness), and b* (yellowness) of breast meat were measured using a Minolta CR410 chromameter (Konica Minolta Sensing Inc., Osaka, Japan). Drip loss percentage was determined on d 1, 3, 5, and 7 post-slaughter, the procedure described by Honikel (1998). Meat samples (5 g) from breast meat were homogenized in 15 mL distilled water. Sample homogenate (5 mL) was transferred to a test tube and lipid oxidation was determined as the TBARS value described by Ahn et al. (1999). Lipid oxidation was reported as mg of malondialdehyde per kg of meat (Jang et al. 2007). Duplicate pH values for each sample were measured using a pH meter (Fisher Scientific, Pittsburgh, PA). On d 35 of the experiment, 0.2% chromium oxide, as an inert marker was added to all the diets for determination of apparent total tract digestibility (ATTD) of dry matter (DM), nitrogen (N), gross energy (GE), calcium (Ca), and phosphorous (P). Birds were fed with the diets mixed with chromium oxide during d 35–42. On d 42, faecal samples were collected from each pen and stored in a freezer at −20°C until analysed. Before chemical analysis, the faecal samples were thawed and dried at 60°C for 72 h. They were finely ground at a size lower than 1 mm. All the feed and faecal samples were analysed for DM, N, GE, Ca, and P following the procedures described by the AOAC (2000). Chromium was analysed via UV absorption spectrophotometry (Shimadzu, UV-1201, Shimadzu, Kyoto, Japan) based on the method described by Williams et al. (1962). ATTD of the nutrients was calculated using the following

### Table 1. Ingredients and the chemical composition of the diets (as-fed basis).

| Item                  | Prestarter (d 1–5) | Starter (d 5–21) | Grower (d 21–42) |
|-----------------------|--------------------|------------------|------------------|
|                       | High | Low | High | Low | High | Low |
| Ingredients, %        |      |     |      |     |      |     |
| Corn                  | 50.25 | 49.95 | 52.24 | 52.85 | 53.99 | 53.26 |
| Soybean meal (45% CP) | 30.10 | 31.58 | 26.07 | 30.87 | 25.22 | 21.77 |
| Wheat                 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| Corn gluten meal (60% CP) | 3.03 | 0.00 | 5.00 | 0.00 | 0.00 | 0.00 |
| DDGS                  | 0.00  | 0.00  | 0.00  | 0.00  | 3.00  | 3.00  |
| Wheat bran            | 0.00  | 2.27  | 0.00  | 0.47  | 2.22  | 6.44  |
| Limestone             | 1.55  | 1.54  | 1.57  | 1.54  | 2.19  | 2.22  |
| Dicalcium phosphate   | 1.59  | 1.46  | 1.61  | 1.48  | 0.34  | 0.21  |
| L-Lysine (24%)        | 1.29  | 1.01  | 1.30  | 0.78  | 0.66  | 0.74  |
| Tallow                | 1.00  | 1.00  | 1.20  | 1.00  | 1.50  | 1.50  |
| Sodium chloride       | 0.42  | 0.42  | 0.35  | 0.35  | 0.33  | 0.33  |
| DL-Methionine (99%)   | 0.31  | 0.32  | 0.25  | 0.27  | 0.19  | 0.17  |
| NaHCO₃                | 0.10  | 0.10  | 0.10  | 0.10  | 0.10  | 0.10  |
| L-Threonine (98.5%)   | 0.10  | 0.09  | 0.05  | 0.03  | 0.01  | 0.01  |
| Choline (50%)         | 0.1   | 0.1   | 0.1   | 0.1   | 0.1   | 0.1   |
| V-2000 (vitamin)     | 0.06  | 0.06  | 0.06  | 0.06  | 0.05  | 0.05  |
| M-1100 (mineral)      | 0.10  | 0.10  | 0.10  | 0.10  | 0.10  | 0.10  |
| Total                 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

Calculated chemical composition

| ME, kcal/kg | PRE | STARTER | GROWER |
|-------------|-----|---------|--------|
| 2908        | 2858| 2908    | 2908   | 2970   | 2919   |
| CP, %        | 21  | 20      | 21     | 20     | 18     | 17     |
| Lysine, %    | 1.34| 1.30    | 1.26   | 1.22   | 1.07   | 1.01   |
| Met + Cys, % | 1.01| 0.97    | 0.96   | 0.91   | 0.82   | 0.77   |
| Ca, %        | 1.00| 0.98    | 1.00   | 0.98   | 1.00   | 0.98   |
| Na, %        | 0.22| 0.22    | 0.19   | 0.19   | 0.20   | 0.20   |
| Avail. P, %  | 0.50| 0.48    | 0.50   | 0.48   | 0.35   | 0.33   |

*Provided per kg of diet: 15,000 IU of vitamin A, 3750 IU of vitamin D₃, 37.5 mg of vitamin E, 2.55 mg of vitamin K₂, 3 mg of B₁₂, 7.5 mg of B₆, 4.5 mg of B₉, 24 µg of B₁₂, 51 mg of niacin, 1.5 mg of folic acid, 126 mg of biotin, and 13.5 mg of pantothenic acid.

*Provided per kg of complete diet: 37.5 mg of Zn, 137.5 mg of Mn, 37.5 mg of Fe, 0.83 mg of I, 0.23 mg of Se.
formula: \[
\text{Digestibility} \% = 1 - \frac{\text{Nf} \times \text{Cd}}{\text{Nd} \times \text{Cf}} \times 100,
\]

where Nf is the concentration of nutrient in faeces (%DM), Nd the concentration of nutrient in the diet, Cd the concentration of chromium in the diet, and Cf the concentration of chromium in the faeces (Mohammadi Gheisar et al. 2015).

The relative weights of breast muscle, abdominal fat, and organs were expressed as a percentage of live body weight.

2.3. Statistical analysis

The data were analysed using the GLM procedures of SAS (SAS Inst. 1996) as a completely randomized design, with a 2 × 2 factorial arrangement. The main effects were the dietary nutrient density and the phytogenic blend inclusion, as well as any interaction between the two parameters. The average values and standard errors (SE) were reported. Probability values of less than .05 were considered as significant.

3. Results

3.1. Growth performance

The data presented in Table 2 showed that BWG and FCR were influenced (P < .05) by the nutrient density of the diets on d 1–21. On d 21–42, BWG was affected by the nutrient density of diets and inclusion of phytogenic blend (P < .05), but FCR was not affected during d 21–42. The results indicated that during the entire experimental period reducing nutrient density led to a decrease in BWG, but addition of phytogenic blend alleviated the negative effect and improved BWG. There was no significant effect on FI.

3.2. Carcass characteristics

The results of carcass characteristics (Table 3) indicated that the nutrient density of diets influenced the percentage of drip loss on d 7 post-slaughter (P < .05). Drip loss percentage was not affected on d 1, 3, and 5 post-slaughter. The results demonstrated that the percentage of cooking loss was adversely influenced by the nutrient density of diets (P < .05). The colour of breast meat, pH value, and relative weights of organs were not significantly affected by treatment diets. The results of TBARS assay indicated that lipid oxidation increased by reducing nutrient density (P < .05), but supplementing the diets with the phytogenic blend significantly decreased TBARS value on d 14 post-slaughter.

3.3. Nutrient digestibility

The results of nutrients digestibility presented in Table 4 indicated that digestibility of DM, N, and energy was influenced by the nutrient density of the diets and inclusion of the phytogenic blend. Reducing the density of nutrients resulted to a decrease in digestibility of DM (P = .003), N (P = .02), and energy (P = .001). Addition of the phytogenic blend to the diets significantly improved digestibility of DM and energy (P < .05). Calcium and phosphorous retention was not significantly affected by treatment diets.

4. Discussion

Previously, several studies have focused on the effects of phytogenic feed additives; however, published results are contradictory. In one experiment conducted by Lee et al. (2003), broiler chickens were fed with 200 mg/kg feed carvacrol or thymol, carvacrol lowered the FI, weight gain and feed conversion rate, whereas thymol showed no effect. The results of some other studies revealed that addition of phytogenic feed additives to the diet of broiler chickens and laying hens led to the depression in FI (Maass et al. 2005). In contrast, supplementing the diets with oregano herb (2–20 g/kg feed), or oregano oil (100–1000 mg/kg feed), in all cases, improved the performance of broiler chickens (Halle et al. 2004). Westendarp et al. (2006) reported that the addition of carvacrol (50 mg/kg feed), p-cymene (25 mg/kg feed), and γ-terpinene (25 mg/kg feed) as pure substances showed no significant effects. Bampidis et al. (2005) studied the response of turkeys fed with 1.25–3.75 g/kg dried oregano leaves and showed, in contrast, a clearly improved FCR. Brenes and Roura (2010) suggested that due

### Table 2. Effect of dietary phytogenic blend supplementation on growth performance in ducks.

| Items | High ND | Low ND | P-Value |
|-------|---------|--------|---------|
|       | −PB     | +PB    | SE\(a\) | ND PB ND×PB |
| d 1–21 |         |        |         |           |
| BWG\(b\), g | 1328.2 | 1336.3 | 1315.1 | 1321.4 | 4.67 | .01 | .14 | .85 |
| FI\(c\), g  | 2413.5 | 2411.4 | 2425.6 | 2427.4 | 16.59 | .40 | .99 | .91 |
| FCR\(d\)  | 1.82   | 1.80   | 1.84   | 1.84   | 0.015 | .01 | .99 | .91 |
| d 21–42 |         |        |         |           |
| BWG, g   | 1826.0 | 1863.6 | 1733.1 | 1818.1 | 17.72 | .01 | .03 | .84 |
| FI, g    | 3870.3 | 3845.6 | 3840.6 | 3861.7 | 56.95 | .91 | .98 | .69 |
| FCR\(e\) | 2.12   | 2.06   | 2.17   | 2.12   | 0.032 | .09 | .14 | .89 |
| Overall  |         |        |         |           |
| BWG, g   | 3154.2 | 3199.9 | 3088.2 | 3139.5 | 16.30 | .001 | .01 | .86 |
| FI, g    | 6283.8 | 6257.0 | 6266.2 | 6289.1 | 60.46 | .91 | .97 | .68 |
| FCR\(f\) | 1.99   | 1.96   | 2.03   | 2.00   | 0.019 | .04 | .13 | .75 |

Note: ND, nutrient density; PB, phytogenic blend. Number of observation per mean: 8 pens/treatment

\(a\)Standard error.

\(b\)Body weight gain, g/bird.

\(c\)Feed intake, g/bird.

\(d\)Feed conversion ratio.
Effects of dietary phytogenic blend supplementation on carcass quality in ducks. Table 3.

| Items               | High ND | Low ND | SE*  | P-Value |
|---------------------|---------|--------|------|---------|
| Drip loss, %        | PB−     | PB+    | PB−  | PB+     | ND    | PB    | ND×PB |
| d 1                 | 4.22    | 4.69   | 5.08 | 4.27    | 0.358 | .54   | .62   | .08    |
| d 3                 | 7.42    | 7.28   | 7.74 | 7.74    | 0.394 | .33   | .86   | .87    |
| d 5                 | 11.10   | 10.94  | 11.52| 11.41   | 0.334 | .19   | .69   | .96    |
| d 7                 | 13.99   | 13.71  | 14.57| 14.22   | 0.274 | .05   | .25   | .90    |
| Cooking loss, %     | 30.05   | 28.30  | 32.72| 32.45   | 1.031 | .01   | .16   | .25    |
| Relative organ weight, % |       |        |      |         |       |       |       |        |
| Breast muscle       | 7.28    | 7.35   | 7.17 | 7.21    | 0.223 | .59   | .81   | .94    |
| Abdominal fat       | 0.46    | 0.54   | 0.51 | 0.49    | 0.028 | .89   | .24   | .06    |
| Liver               | 4.52    | 4.66   | 4.53 | 4.49    | 0.123 | .51   | .71   | .46    |
| Bursa of Fabricius  | 2.71    | 2.81   | 2.71 | 2.80    | 0.076 | .99   | .21   | .93    |
| Spleen              | 0.09    | 0.10   | 0.10 | 0.09    | 0.005 | .51   | .43   | .24    |
| TBARSb, g/kg        | 0.06    | 0.06   | 0.06 | 0.06    | 0.003 | .45   | .85   | .26    |
| d 0                 | 0.020   | 0.020  | 0.020| 0.020   | 0.001 | .77   | .77   | .77    |
| d 7                 | 0.047   | 0.044  | 0.046| 0.044   | 0.002 | .89   | .14   | .89    |
| d 14                | 0.069   | 0.061  | 0.075| 0.069   | 0.003 | .05   | .04   | 1.00   |

Note: ND, nutrient density; PB, phytogenic blend. Number of observation per mean: 16 ducks/treatment.

Table 4. Effect of dietary phytogenic blend supplementation on nutrient digestibility in ducks.

| Items, %  | High ND | Low ND | SE*  | P-Value |
|-----------|---------|--------|------|---------|
| Dry matter| 80.3    | 80.6   | 79.4 | 80.2    | .18    | .003  | .01   | .11    |
| Nitrogen  | 75.9    | 76.5   | 75.4 | 75.6    | .28    | .02   | .18   | .56    |
| Energy    | 81.2    | 81.9   | 80.5 | 80.8    | .23    | .001  | .03   | .33    |
| Calcium   | 1.5     | 1.4    | 1.5  | 1.5     | .04    | .68   | .14   | .24    |
| Avail. phosphorous | 1.4 | 1.3    | 1.3  | 1.3     | .04    | .39   | .42   | .21    |

Note: ND, nutrient density; PB, phytogenic blend. Number of observation per mean: eight samples/treatment.

*Standard error.

phosphorous 1.4 1.3 1.3 1.3 0.04 .39 .42 .21
Calcium 1.5 1.4 1.5 1.5 0.04 .68 .14 .24
Energy 81.2 81.9 80.5 80.8 0.23 .001 .03 .33
Nitrogen 75.9 76.5 75.4 75.6 0.28 .02 .18 .56
Dry matter 80.3 80.6 79.4 80.2 0.18 .003 .01 .11

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| Energy    | 81.2    | 81.9   | 80.5 | 80.8    | .23    | .001  | .03   | .33    |
| Calcium   | 1.5     | 1.4    | 1.5  | 1.5     | .04    | .68   | .14   | .24    |
| Avail. phosphorous | 1.4 | 1.3    | 1.3  | 1.3     | .04    | .39   | .42   | .21    |

Note: ND, nutrient density; PB, phytogenic blend. Number of observation per mean: eight samples/treatment.

*Standard error.

percentage, but, Soisuwann and Chauychuwong (2014) reported that addition of phytogenic additives (containing capsaicin, thymol, cinnamaldehyde, and carvacrol) to the diet of ducks reduced the percentage of drip loss of their breast meat. They suggested that improved meat quality is due to the improved gastric and intestinal enzyme activities, which resulted in an improvement in the proteinaceous portion of the cell membrane and water-holding capacity of muscle cell membrane as well. Maraschiello et al. (1998) reported that lipid oxidation is a major concern during meat processing, cooking, and storage, which can influence the quality of the product (due to the loss of desirable colour, odour, and flavour and a shortening of the shelf-life). Farag et al. (1989) suggested that antioxidant function of phytogenic feed additives is due to the presence of phenolic OH groups that can retard the hydroxy peroxide formation. In agreement with the results of the present study, Marcincak et al. (2008) and Young et al. (2003) showed increasing lipid oxidation (determined by TBARS value of minced and cooked meat) with increasing storage time. They reported that the addition of feed additives containing oregano decreased the TBARS value.

It has been reported that supplementing the diet of broiler chickens with phytogenic blends (containing carvacrol, cinnamaldehyde, and capsaicin) led to an improvement in DM and crude protein (CP) digestibility (Jamroz et al. 2003; Hernandez et al. 2004; Li et al. 2012). Amad et al. (2011) reported that addition of a phytogenic blend containing thyme and star anise improved ileal digestibility of nutrients. They suggested improvements in the digestibility of nutrients in the small intestine as the main mode of action of phytogenic feed additives. In another study, Ahmed et al. (2013) showed positive impacts of a phytogenic blend containing oregano, anise, orange peel, and chicory essential oils on protein digestibility in weaned piglets. Jang et al. (2007) suggested that addition of phytogenic feed additives improved pancreatic enzyme activities that resulted in improving digestibility of organic matter, CP, and EE in broiler chickens.
5. Conclusion

Several studies have been conducted on phytogenic feed additives with conflicting results due to varying environmental and genetic factors that affect the chemical composition of these feed additives. In agreement with most of the published results, our findings indicate that the addition of the phytogenic blend containing capsicum oleoresin, cinnamaldehyde, and carvacrol improved performance, carcass characteristics, and nutrient digestibility.

Disclosure statement

No potential conflict of interest was reported by the authors.

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