Effects of the plant extract YGF251 on growth performance, meat quality, relative organ weight, nutrient digestibility and blood profiles in broiler chickens: possible role of insulin-like growth factor 1

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ABSTRACT: This study was aimed at evaluating the effects of different concentrations of the dietary plant extract supplement YGF251 (young growth factor) on growth performance, blood profiles, relative organ weight, nutrient digestibility and meat quality in broiler chickens. A total of 640 one-day-old male Arbor Acres broiler chickens with an average initial body weight of 40.25 ± 0.5 g were randomly allotted to one of four treatments lasting four weeks with 10 replicates per treatment and 16 chicks per replicate pen. Dietary treatments consisted of: CON (basal diet); YGF0.05 (CON + 0.05% YGF251); YGF0.1 (CON + 0.10% YGF251); YGF0.15 (CON + 0.15% YGF251). There were no statistical differences in body weight (BW), feed intake (FI) and feed conversion rate (FCR) throughout the whole experiment. However, broiler chickens fed with YGF0.1 diets had greater body weight gains (BWG) than chickens fed CON diets during eight to 28 days and zero to 28 days although the means of pH value, breast meat colour, WHC, drip loss, the relative organ weights of liver, spleen, bursa of Fabricius and breast muscle were not affected by any dietary supplementation ($P > 0.05$). The relative weight of abdominal fat in the CON treatment group was significantly higher than the YGF0.05 and YGF0.1 treatments, although relative gizzard weight was lower with CON treatment compared to YGF0.1 treatment ($P < 0.05$). Femur length and weight were significantly higher in the YGF251-supplemented chicks than in chicks fed the control diet ($P < 0.05$). Broiler chickens fed the YGF0.1 diet had significantly higher blood IgG counts compared to chicks fed the CON and YGF0.05 diets ($P < 0.05$). Moreover, YGF251-supplemented chicks exhibited increased IGF-I concentrations compared to the CON to YGF0.1 treatment ($P < 0.05$). The results of this study indicate that supplementation with 0.1% YGF251 can increase body weight, IgG and energy digestibility and reduce relative abdominal fat and gizzard weight in broiler chickens, while at all concentrations tested YGF251-supplemented chicks showed higher results for femur length and weight and serum IGF-I concentrations compared to the control treatment in broiler chickens.

Keywords: broiler chickens; blood profile; growth performance; meat quality; plant extract

List of abbreviations
BW = body weight, **BWG** = body weight gain, **FCR** = feed conversion rate, **FI** = feed intake, **YGF251** = young growth factor

Most IGF-1 is produced in hepatocytes stimulated by growth hormone; it is also present in other tissues where it is produced in paracrine or autocrine fashion. IGF is usually present in serum as a 150-kDa complex of an IGF molecule, IGFBP-3 and an acid bile subunit. This form facilitates the transport of IGF from the blood into cells (Yakar et al. 2002). IGF-1, once bound to the IGF receptor-1, stimulates muscle cell proliferation and differentiation in the chicken (Duclos et al. 1991). *In ovo* administration of recombinant human IGF-1 increased growth, feed efficiency and tissue development in post-hatch broilers (Kocamis et al. 1998). Tomas et al. (1998) reported that the exogenous administration of IGF-1 significantly increased growth rate, nitrogen balance and food utilisation efficiency by around 10–15%, while carcass fat was consistently

reduced. Broilers in the early growth period given 200 μg recombinant-derived human IGF-1 (rhIGF-I) per kg body weight intramuscularly daily from 11 to 24 days of age did not exhibit any alterations in the average daily gain (ADG), average daily feed intake (ADFI) and the gain-to-feed ratio, body fat or protein content. A decrease in plasma GH levels following chronic injection of IGF-1was observed due to the negative-feedback role of IGF-1 on pituitary GH secretion (McGuinness and Cogburn 1991). Insulin-like growth factors have apparently no growth-promoting effects in normal growing broiler chickens, but seem to exert marked hypoglycemic effects in contrast to GH (Buyse and Decuypere 1999). IGF-1 was described to promote the incorporation of glucose into glycogen and to stimulate growth by enhancing the differentiation of osteoblasts (Schmid et al. 1984) as well as promoting the proliferation of osteoblastic cells and production of bone matrix proteins (Conover 2000).

YGF251 (young growth factor) is a pharmaceutical extracted from herbs including *Phlomis umbrosa Turez, Cynancum wilfordii Hem, Zingiber officinale Rosc, Platycodi Radix* that specifically promotes the secretion of insulin-like growth factor 1 (Kim et al. 2002). Choi et al. (2002) and Kim et al. (2002) reported that YGF251 is highly effective in promoting the secretion of IGF-1 in both humans and mice. Clinical tests performed to study the effects of YGF251 on humans, reported that YGF251-treated groups showed statistically significant increases in serum IGF-1 concentrations (Kim et al. 2002). To the best of our knowledge, the effects of YGF251 on broiler chickens have not yet been investigated. Therefore, the aim of the current study was to assess the effects of YGF251 supplementation on growth performance, blood profile, relative organ weight and breast meat quality in broiler chickens.

MATERIAL AND METHODS

The experiment received prior approval from the Animal Protocol Review Committee of Dankook University.

Preparation of YGF251. *Phlomis umbrosa Turez, Cynancum wilfordii Hem, Zingiber officinale Rosc* and *Platycodi Radix* extracts (25 : 30 : 15 : 30; 5.2% YGF251) were provided by Doosan Feed Inc. (Bucheon, Korea). YGF251 was selected from a panel of natural herbal extracts for the induction of IGF-I due to its *in vivo* efficacy and safety. YGF251 is processed in hot water (60 °C to 95 °C) as processing below 60 °C results in poorer extraction of active ingredients while temperatures higher than 95 °C reduce the levels of active ingredients. The yield of crude extract is then cooled and subjected to centrifugation or paper filtration to remove precipitate. Thereafter, the resulting extract is separated on the basis of molecular weight to obtain the relatively low molecular weight compound with the desired active ingredients (Kim et al. 2002).

Birds and diets. Six hundred and forty one-day-old male Arbor Acres broiler chicks with an average initial BW of 40.25 ± 0.5 g were randomly allotted to four treatments with 10 replicates each and 16 chicks per replicate pen. The experiment lasted four weeks. Broilers were fed with Phase 1 (one to seven days) and Phase 2 (eight to 28 days) diets in the form of mash. They had free access to the diets and water. All diets were formulated according to requirements recommended by the NRC (1994). The composition of the basal diet is shown in Table 1. Dietary treatments were as follows: (1) CON (basal diet); (2) YGF0.05 (CON + 0.05% YGF251); (3) YGF0.1 (CON + 0.10% YGF251); (4) YGF0.15 (CON + 0.15% YGF251). Broiler chickens were raised in a temperature-controlled room with three floors of stainless steel pens of identical size (1.75 × 1.55 m). Room temperature began at 33 °C from Day 1 to Day 3 and was reduced gradually to 24 °C until the end of the experiment; the relative humidity was around 60%.

Chemical analysis. Feed samples were ground to pass through a 1-mm screen, after which they were analysed for DM (method 934.01; AOAC 2000), N (method 968.06; AOAC 2000), Ca (method 984.01; AOAC 1995), and P (method 965.17; AOAC 1995). Nitrogen was also determined (Kjectec 2300 Nitrogen Analyzer; Foss Tecator AB, Hoeganaes, Sweden) and CP was calculated as N 6.25. Gross energy was analysed using an oxygen bomb calorimeter (Parr 1600 Instrument Co., Moline, IL, USA).

Sampling and measurements. Body weight gain, feed intake and feed conversion ratio were then calculated on Days 0, 7 and 28. Body weight gain (BWG) was calculated individually for each period and cumulatively based on pen weights. For the same period, the feed intake (FI) of each pen as a group was measured as BW (Day 7 and Day 28) with cumulative averages calculated. The feed conversion ratio (FCR) was calculated as (feed intake)/(body weight gain).

At the end of the experiment, the coefficient of apparent total tract digestibility (CATTD) of DM, N

Table 1. Diet composition (as-fed basis)

Ingredients (%)	Phase 1	Phase 2
Corn	55.43	63.18
Soybean meal (CP 48%)	28.24	24.41
Corn gluten meal (CP 60%)	6.50	3.50
Soybean oil	5.50	4.89
Dicalcium phosphate	2.46	2.29
Limestone	0.89	0.75
Salt	0.20	0.20
DL-Methionine (98%)	0.17	0.17
L-lysine-HCl (78%)	0.21	0.21
Vitamin premix[1]	0.20	0.20
Trace mineral premix[2]	0.20	0.20
Calculated composition		
ME (MJ/kg)	12.97	12.76
CP (%)	22.00	19.00
Lysine (%)	1.10	1.00
Ca (%)	1.00	0.90
P (%)	0.80	0.75
Available P (%)	0.45	0.40
Analytical composition		
CP (%)	22.30	20.10
Ca (%)	1.00	0.91
P (%)	0.79	0.75

[1]Provided per kg of diet: 15 000 IU of vitamin A, 3750 IU of vitamin D_3, 37.5 mg of vitamin E, 2.55 mg of vitamin K_3, 3 mg of thiamin, 7.5 mg of riboflavin, 4.5 mg of vitamin B_6, 24 μg of vitamin B_{12}, 51 mg of niacin, 1.5 mg of folic acid, 0.2 mg of biotin and 13.5 mg of pantothenic acid

[2]Provided per kg of diet: 37.5 mg of Zn, 37.5 mg of Mn, 37.5 mg of Fe, 3.75 mg of Cu, 0.83 mg of I, 62.5 mg of S and 0.23 mg of Se

and energy (E) were determined using chromic oxide as an indicator (Fenton and Fenton 1979) and according to the methodology described by Zhao et al. (2013). All broiler chicks were fed diets mixed with 2% Cr_2O_3 for seven days before excreta collection at week 4. All excreta were pooled by pen and mixed, after which a representative sample was stored in a freezer at −20 °C until analysis. Before chemical analysis, the excreta samples were thawed and dried for 72 h at 50 °C in a forced-air oven (model FC-610, Advantec, Toyo Seisakusho Co. Ltd., Tokyo, Japan), after which they were finely ground to a size that could pass through a 1-mm screen. All feed and faecal samples were then analysed for DM, N and E as described above. Chromium was analysed using UV absorption spectrophotometry (UV-1201, Shimadzu, Kyoto, Japan). The CATTD was then calculated using the following formula:

$$\text{digestibility (\%)} = \{1 - [(Nf \times Cd)/(Nd \times Cf)]$$

where:

Nf = nutrient concentration in faeces (% DM)

Nd = nutrient concentration in diet (% DM)

Cd = chromium concentration in diet (% DM)

Cf = chromium concentration in faeces (% DM)

At the end of the experiment, 10 broiler chickens were randomly selected from each treatment (one bird per pen) and blood samples were collected from the wing vein using a sterile syringe. Half of the sample was transferred into either a vacuum (clot activator with gel) or a 5 ml K_3EDTA vacuum tube (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ) and stored at −4 °C. The white blood cell (WBC), red blood cell (RBC) and lymphocyte counts in the whole blood were determined using an automatic blood analyser (ADVIA, Bayer, Tarrytown, NY). Serum was separated from whole blood by centrifugation at 3000 *g* for 15 min. Immunoglobins G (IgG) and IGF-1 were analysed using nephelometry (Dade Behring, Marburg, Germany).

After blood collection, the same broiler chickens were weighed individually and sacrificed by cervical dislocation. The stomach, breast meat, bursa of Fabricius, liver, spleen and abdominal fat were removed by trained personnel and weighed. Organ size was expressed as a percentage of BW. The breast meat Hunter L^* (lightness), a^* (redness), and b^* (yellowness) values were measured using a Minolta CR410 Chroma meter (Konica Minolta Sensing Inc., Osaka, Japan), according to methods described by Yan et al. (2011a). Duplicate pH values for each sample were measured using a pH meter (Fisher Scientific, Pittsburgh, PA). Femur length and weight were measured according to the method described by Applegate and Lilburn (2002).The water holding capacity (WHC) was measured in accordance with the methods described by Kauffman et al. (1986). Briefly, a 0.3 g sample was pressed at 3 000 × g for 3 min on a 125-mm-diameter piece of filter paper. The areas of the pressed sample and the expressed moisture were delineated and then determined using a digitising area-line sensor (MT-10S; M.T. Precision Co. Ltd., Tokyo, Japan). The ratio of water:meat area was then calculated, giving a measure of WHC (a smaller ratio indicates a higher WHC). Drip loss was measured as described by Honikel et al. (1986).

Two (2.5 × 2.5 cm) chops were weighed, placed in a drip loss tube (C. Christensen Laboratory, Hillerod, Denmark), and held at 2 °C for 24 h. Then, meat samples were removed, blotted dry on paper towels, and re-weighed. Differences between sample weights were used to calculate drip loss percentage.

Statistical analysis. Data were statistically analysed using the GLM procedure of SAS (SAS Institute 1996), with the pen being defined as the experimental unit. Differences among all treatments were separated using Duncan's multiple range test (Duncan 1955). Probability values of less than 0.05 were considered significant.

RESULTS

Growth performance

The effects of YGF251 on growth performance in broiler chickens are presented in Table 2. There were no differences ($P > 0.05$) in body weight, feed intake and feed conversion rate (FCR) throughout the whole experiment. However, broiler chickens fed YGF0.1 diets had greater body weight gains ($P < 0.05$) compared with chickens fed CON diets during the periods of eight to 28 days and zero to 28 days. No significance differences were observed in mortality between the treatments throughout the whole experiment.

Meat quality and relative organ weight

The means of pH value, breast meat colour, WHC and drip loss did not differ among treatment groups (Table 3). The relative organ weights, proportion of liver, spleen, bursa of Fabricius and breast muscle were not affected by any dietary supplementations (Table 3). However, the CON treatment group exhibited significantly higher relative abdominal fat but lower relative gizzard weight than the YGF0.1 treatment group. Further, the YGF251-supplemented chicks had significantly higher femur length and weight than the CON diet ($P < 0.05$).

Coefficient of total tract digestibility

Broiler chickens fed with YGF0.1 exhibited higher energy digestibility compared with CON diet chicks ($P < 0.05$; Table 4). However, no significant differences were observed in DM and N digestibility among the treatments ($P > 0.05$).

Table 2. Effect of YGF251 on growth performance in broiler chickens

Items	CON	YGF0.05	YGF0.1	YGF0.15	SE	*P*-value
0 day BW (g)	41	40	40	40	0.19	0.25
7 days BW (g)	417	417	424	420	10	0.54
28 days BW (g)	1460	1508	1541	1469	25	0.87
0–7 days						
BWG (g)	376	377	387	380	11	0.82
FI (g)	557	550	560	561	15	0.71
FCR	1.48	1.45	1.44	1.47	0.05	0.12
Mortality (%)	3.45	2.87	2.90	2.73	0.78	0.61
8–28 days						
BWG (g)	1043^{b}	1092^{ab}	1117^{a}	1049^{ab}	22	0.03
FI (g)	1676	1675	1689	1679	22	0.85
FCR	1.60	1.53	1.51	1.60	0.03	0.16
Mortality (%)	1.58	1.43	1.60	1.22	0.25	0.72
0–28 days						
BWG (g)	1419^{b}	1469^{ab}	1504^{a}	1429^{ab}	24	0.02
FI (g)	2233	2225	2249	2240	33	0.25
FCR	1.57	1.51	1.49	1.56	0.02	0.34
Mortality (%)	5.03	4.30	4.50	3.95	0.67	0.25

CON = basal diet; YGF0.05 = basal diet + 0.05% YGF251; YGF0.1 = basal diet + 0.1% YGF251; YGF0.15 = basal diet + 0.15% YGF251; SE = standard error

^{a,b}means in the same row with different superscripts differ ($P < 0.05$)

Table 3. Effect of YGF251 on meat quality and relative organ weight in broiler chickens

Items	CON	YGF0.05	YGF0.1	YGF0.15	SEM	*P*-value
pH value	5.6	5.7	5.7	5.6	0.10	0.56
Breast muscle colour						
Lightness (L^*)	55.5	55.4	56.0	56.4	1.47	0.85
Redness (a^*)	15.3	15.8	14.7	15.1	0.58	0.14
Yellowness (b^*)	14.5	15.4	14.8	15.0	0.62	0.85
WHC (%)	61.8	62.1	61.3	62.4	1.54	0.54
Drip loss (%)						
1 day	2.7	2.7	2.7	2.8	0.29	0.67
3 days	4.8	5.0	4.7	4.6	0.25	0.25
5 days	8.4	8.4	8.3	8.4	0.42	0.65
7 days	11.3	11.3	11.2	11.4	0.43	0.38
Relative organ weight (%)						
Liver	2.97	3.28	3.50	3.17	0.20	0.82
Spleen	0.17	0.14	0.14	0.14	0.02	0.14
Bursa of Fabricius	0.15	0.15	0.14	0.14	0.02	0.52
Breast muscle	17.39	17.36	17.05	16.23	0.63	0.64
Abdominal fat	1.99^{a}	1.57^{b}	1.44^{b}	1.62^{ab}	0.12	0.04
Gizzard	0.94^{b}	0.99^{ab}	1.15^{a}	1.04^{ab}	0.05	0.01
Femur length (cm)	8.5^{b}	9.2^{a}	9.0^{a}	9.1^{a}	0.15	0.01
Femur weight (g)	12.3^{b}	13.5^{a}	14.4^{a}	14.1^{a}	0.41	0.02

CON = basal diet; YGF0.05 = basal diet + 0.05% YGF251; YGF0.1 = basal diet + 0.1% YGF251; YGF0.15 = basal diet + 0.15% YGF251; SEM = standard error of means

^{a,b}means in the same row with different superscripts differ ($P < 0.05$)

Blood profiles

The results of blood characteristics following YGF251 supplementation in the broiler chickens are presented in Table 5. The YGF0.1 treatment group had a significantly higher IgG count compared with CON and YGF0.05 treatment groups ($P < 0.05$). With respect to IGF-1 concentrations, all YGF251 treatment groups showed significantly different values compared to the CON ($P < 0.05$). Similarly, YGF251-supplemented chicks exhibited an increasing tendency for RBC, WBC and lymphocyte values compared to the CON chicks, but these differences were not significant ($P > 0.05$).

DISCUSSION

In the current study, YGF0.1 supplementation increased BWG during the finishing period and overall over the duration of the entire experiment. Kim (2010) reported that circulating hepatic IGF-1 levels increase rapidly after hatching and arrive at a plateau between three to seven weeks of age before gradually declining to basal levels by puberty. The

Table 4. Effect of YGF251 on coefficient of total tract digestibility in broiler chickens

Items (%)	CON	YGF0.05	YGF0.1	YGF0.15	SEM	*P*-value
Dry matter	0.65	0.66	0.65	0.64	0.005	0.85
Nitrogen	0.64	0.65	0.68	0.67	0.017	0.51
Energy	0.67^{b}	0.68^{ab}	0.69^{a}	0.68^{ab}	0.006	0.02

CON = basal diet; YGF0.05 = basal diet + 0.05% YGF251; YGF0.1 = basal diet + 0.1% YGF251; YGF0.15 = basal diet + 0.15% YGF251; SEM = standard error of means

^{a,b}means in the same row with different superscripts differ ($P < 0.05$)

Table 5. Effect of YGF251 on blood profiles in broiler chickens

Items	CON	YGF0.05	YGF0.1	YGF0.15	SEM	*P*-value
WBC (10^3/μl)	301.4	304.9	307.1	309.0	8.80	0.45
RBC (10^6/μl)	1.94	1.97	2.01	2.03	0.09	0.36
Lymphocyte (%)	79.7	83.5	80.7	81.7	2.35	0.95
IgG (mg/dl)	1.45^b	1.55^b	1.71^a	1.58^{ab}	0.04	0.04
IGF-1 (ng/ml)	31.0^b	34.7^a	37.0^a	35.2^a	0.80	0.04

CON = basal diet; YGF0.05 = basal diet + 0.05% YGF251; YGF0.1 = basal diet + 0.1% YGF251; YGF0.15 = basal diet + 0.15% YGF251; SEM = standard error of means

^{a,b}means in the same row with different superscripts differ ($P < 0.05$)

physiological mechanisms of action of the avian IGFs are slightly different compared to mammals; high amounts of IGFs are present in free form in chickens. Several reports indicate that administration of exogenous IGF exerts negative effects on growth rate and body fat decline (Goodridge et al. 1989; McMurtry 1998). Florini et al. (1991) reported that muscle determination genes may play a pivotal role in controlling myogenesis as IGF-1 stimulates terminal myogenic differentiation in L6A1 cells by inducing a large increase in expression of the myogenin gene (myogenin mRNA is elevated by IGF-1). IGF leads to a rise in ornithine decarboxylase activity, DNA, RNA and protein synthesis and finally to cell replication. IGF has distinct effects on the differentiation of cells of mesodermal origin; thus, erythroid cells in the mouse, precursors of muscle cells in the chick and precursors of osteoblasts in the rat undergo differentiation in the presence of IGF (Froesch et al. 1986). According to some *in vivo* studies, IGF-1 infusion is considered more effective in malnourished animals compared to healthy ones, and IGF-1 administration is not thought to stimulate muscle protein synthesis in well-fed mammals and birds (Kita et al. 2002). In the growing chicken, IGF-I mRNA was detected not only in the liver but also in the spleen, lung, brain, kidney, heart, intestine, thymus and muscle. IGFBP-2 is the major binding protein that makes a complex with IGF-1 in the serum and is expressed differentially in mammals (Kita et al. 2005). Therefore, the beneficial effects on growth performance could be attributed to the aforementioned mechanisms and, taken together, YGF251 supplementation can positively influence growth performance in broiler chickens.

In our experiments, meat quality was not changed by YGF251 supplementation in the diet. However, when selling individual parts of chicken, uniform meat colour within the package is important (Cho et al. 2013). No comparisons with other studies could be made because there have been no other studies conducted to evaluate the effects of YGF251 on meat quality. In the present study, the relative weight of abdominal fat was reduced by supplementation with YGF0.05 and YGF0.1. However, broiler chickens fed with YGF0.01 exhibited increased relative gizzard weight compared with the CON group. Huybrechts et al. (1992) reported that a two-week continuous infusion of recombinant human insulin-like growth factor-1 reduced abdominal fat significantly in the highest dose group. In our study, YGF supplementation resulted in increased femur length and weight compared with the CON diet. Choi et al. (2002) reported that oral supplementation of YGF251 to rats significantly increased the concentration of blood IGF-1 compared to the control treatment and observed that the YGF251 treatment group showed 6% higher femur lengths than the control group (31.2 mm vs. 29.5 mm). Yakar et al. (2002) reported that liver IGF-1-deficient mice and ALS knockout mice (IGF-I transport inhibited) showed a reduction in body length, femur length and the total height of the growth plate. However, bone growth was enhanced together with an increase in bone cell number, cell size and extracellular ground substances. Insulin-like growth factor 1 stimulates osteoblast function and short term administration of recombinant human IGF-1 (rhIGF-1) increases bone turnover (Grinspoon et al. 1996). IGF-1-deficient mice exhibit delayed mineralization of the spinal column, sternum and fore paws and are also characterised by reduced chondrocyte proliferation and increased chondrocyte apoptosis in both the spinal ossification centre and the growth plate of long bones. These observations underline the important role played by IGF-1 in skeletal development by promoting

chondrocyte proliferation and maturation while inhibiting apoptosis to form bones of appropriate size and strength (Wang et al. 2006). Both IGF-1 and GH exert their influences at each stage of differentiation rather than acting specifically upon particular subpopulations of cells at certain phases of chondrocyte differentiation. IGF-1 influences chondrocytes principally during the proliferative phase by stimulating clonal expansion, whereas GH acts selectively upon stem cells in the resting phase as a differentiation factor, the ensuing effect on proliferation being triggered by local production of IGF-1 (Hunziker et al. 1994). Therefore, we hypothesised that the inclusion of YGF251 could augment serum IGF-1 concentrations and the immunity of growing broiler chickens.

The intestine is considered to be one of the target organs that is most responsive to IGF-1 (Read et al. 1991; Ziegler et al. 1996), which is regarded as essential for intestinal repair (Simmons et al. 1995). IGF-1 mediates glucose uptake in hepatocytes thus facilitating glycogen synthesis and the maintenance of blood glucose homeostasis in the liver (Wang et al. 2012). IGFs also promote glucose and amino acid transport, glycogen synthesis and stimulate the synthesis of muscle protein while suppressing the decomposition of protein, similarly to insulin metabolism (Nissley and Rechler 1984; Gluckman et al. 1991; Jones and Clemmons 1995; Lee 2000). In this study, birds fed YGF0.1 showed greater energy digestibility than the CON treatment birds ($P < 0.05$). It is thought that, as mentioned above, IGF-1 acts positively on the intestine and on nutrient metabolism. However, the exact mechanism is not known, and further studies are needed to evaluate whether the nutrient digestibility is increased by YGF251 supplementation in a dose-dependent manner.

As blood profiles are routinely monitored to evaluate the immunological response, we analysed some blood indicators to assess the effect of YGF251 supplementation. Serum IgG and IgF-1 increased in response to YGF0.1 supplementation compared with the CON diets. IGF-1 has numerous immune-related functions. IGF-1, with GH and prolactin stimulates the proliferation of immunocompetent cells and modulates humoral and cellular immune functions (Auernhammer and Strasburger 1995). Erythrocytes (RBC) are very important blood components that transport oxygen and ensure increased oxygen consumption during growth. Erythropoiesis (RBC synthesis) is controlled by erythropoietin from the kidney and erythropoietin in turn is regulated by IGF-1, so that IGF-1 may be a factor governing RBC formation and organ and body growth (Kurtz et al. 1988). Administration of recombinant human insulin-like growth factor 1 (rhIGF-1) to mice elicited a significant increase in bone marrow (BM) haematopoietic progenitor cells and erythroid precursor cells, suggesting that rhIGF-1 acts as a haematopoietic growth factor (Tsarfaty et al. 1994). Plasma immunoglobulin concentrations can be used as a parameter to reflect the humoral immune status of animals because of the important roles of these proteins in immune function. Thus, by increasing serum IGF-1 and IgG levels at early stages of development, YGF251 addition may exert beneficial effects on immunity. However, in our previous study we did not observe any significant effect of herb extract mixture on the IgG count compared with the basal diet (Yan et al. 2011b). Few studies have reported the effects of YGF251on WBC, RBC, lymphocyte, IgG and IGF-1 in broiler chickens. Therefore, further experiments are needed to evaluate the effects of YGF251 on immune function.

In conclusion, the results of this study indicate that a YGF0.1 diet can elicit increases in body weight gain, IgG and energy digestibility while promoting reductions in relative abdominal fat and gizzard weight in broiler chickens. Moreover, YGF251-supplemented chicks exhibited better results with respect to femur length and weight and serum IGF-1 concentrations compared to control chickens.

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