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# Supplementation of dietary nano zinc phytogenic on growth performance and carcass traits of the growing Kampung Unggul Balitbangtan chickens

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## Abstract

The objective of this experiment was to evaluate productive performance during the growing period in Kampung Unggul Balitbangtan (KUB) chickens fed on low- and high-nutrient diets containing different levels of dietary nano zinc phytogenic (NZP). The experiment followed a randomized 2 × 6 factorial design, with nutritional content of the diet (high vs low), and dietary NZP (0, 30, 60, 90, 120, or 150 mg Zn/kg) as factors. Each treatment was repeated six times. The feeding trial was carried out until ten weeks of age. Productive performance (feed consumption, FC; body weight gain, BWG; body weight, BW; mortality, feed conversion ratio, FCR; zinc consumption, ZnC; dressing percentage, carcass cut weight; visceral organ weight; and European production efficiency factor, EPEF) was measured. Up to the age of four weeks, dietary NZF dosage impacted BW, BWG, FC, and ZnC. NZP dosage had no effect on mortality. Combination of a high-nutrient diet with 90 mg Zn/kg NZP resulted in the best FCR and EPEF. Up to six weeks, dietary NZP dosage affected BW, BWG, and EPEF. Up to ten weeks of age, addition of NZP (from 30 mg Zn/kg) improved BW, FC, and EPEF. NZP at 30 mg Zn/kg resulted in the best FCR and EPEF. Dietary NZP increased production performance (BW, FC) and economic index (EPEF) in growing KUB chickens fed low- and high-nutrient diets. The recommended use is a high-nutrient diet and 90 mg Zn/kg of NZP.

**Keywords:** Nano zinc phytogenic, growing phase, KUB chicken, low/high-nutrient diet
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## Introduction

Nanotechnology has been applied to increase the efficient use of nutrients, feed additives, and feed supplements in poultry diets (Gopi *et al.,* 2017). Additives in the form of nanoparticles have been reported to increase the absorption and use of feed additives in animals (Hidayat *et al.,* 2021a). Poultry require zinc because it plays an important role in various processes, including cell proliferation and animal growth, and thus supports various biological functions (Salim *et al.,* 2008; Hidayat *et al.,* 2020). Phytogenic compounds such as phenolic compounds have been reported to stimulate animal growth (Noleto-Mendonça *et al.,* 2021).

Nano zinc phytogenic (NZP) is a nanoparticle size (< 1000 nm) feed additive produced by IRIAP (Indonesian Research Institute for Animal Production) in the form of a complex of zinc and phytogenic compounds drawn from plant extracts, which functions as a growth promoter for chickens (Hidayat *et al.,* 2021a). Hidayat *et al.* (2021a) reported that the addition of up to 90 mg Zn/kg of NZP to broiler diets had positive impacts on production performance, health status, and body resistance. Furthermore, NZP functions as an antibacterial against pathogenic bacteria in the intestine, increases antioxidants, and inhibits tissue lipid peroxidation.

Kampung Unggul Balitbangtan (KUB) chickens are the superior variety of local chickens in Indonesia, producing more eggs than other local varieties. It was originally produced by the Indonesian

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Agricultural Research and Development Agency and has since spread throughout the country (Sartika and Iskandar, 2019). Although it is a laying type, KUB chickens are also used by farmers in Indonesia for meat. Kampung Unggul Balitbangtan (KUB) chickens are only kept until the age of 10 weeks and then slaughtered. This is because KUB chickens have a good growth rate. Hidayat *et al.* (2016) reported that the performance of local chickens differed when fed with low- or high-nutrient diets. High-nutrient diets (21% CP; 12.55 MJ ME/kg) led to markedly better production performance than low-nutrient diets (17% CP; 11.72 MJ ME/kg).

The novelty of this study is that the dietary NZP was applied to local chicken diets for the first time in this study. The objective of this study was to evaluate the productive performance of the growing period of KUB chickens fed different levels of dietary NZP as part of low- and high-nutrient diets.

## Materials and Methods

This research was approved by the Animal Welfare Ethics Commission of the Indonesian Agency for Agricultural Research and Development (IAARD) under registration number Balitbangtan/Balitnak/A/11/2021. The experimental format used was a completely randomized factorial design (2 × 6). The first factor was type of feed (high- or low-nutrient diet), while the second factor was dosage of dietary NZF (0, 30, 60, 90, 120, or 150 mg Zn/kg) (Table 1). Despite the low nutrient diet treatment, the nutritional content met the nutritional needs of KUB chickens, according to the report of Hidayat *et al*. (2016). The feed formulation used in this experiment is presented in Table 2. Each treatment was repeated six times and each 60 cm × 100 cm × 150 cm experimental cage was populated with ten unsexed KUB chicks.

A total of 720 unsexed KUB chickens were used. Kampung Unggul Balitbangtan (KUB) chicken DOC (day-old chicks) were obtained from the Indonesian Research Institute for Animal Production (Bogor, West Java province, Indonesia) with an average body weight of 27.3 ±0.96 g/bird. Ten unsexed DOC were taken randomly and reared in experimental cages. All experimental chickens received a vaccination program in accordance with standard operating procedures for rearing local chickens at the IRIAP. Health programs such as vaccination with proper vaccines and cage sanitation were also applied following the health and sanitations programs for modern broilers up to ten weeks of age. The immunization program consisted of: i) at four days old, the DOC were vaccinated against NDIB (New Castle Disease and Infectious Bronchitis); ii) at seven days old, the chickens were vaccinated against IBD (Gumboro); iii) the IBD vaccine was repeated on day 21; iv) Newcastle disease vaccine was repeated at 28 days. No more vaccinations were administered until the experiment was ended when the chicks were 10 weeks of age. Observations were conducted until 10 weeks of age.

Parameters measured were BW, BWG, FC, mortality, ZnC, FCR, EPEF, dressing percentage, carcass cuts, and visceral organ weight of male chickens. Data collection for BW and FC were carried out in groups (experimental units) routinely every week. Weekly body weight was measured by weighing the birds in a cage, then dividing the number of birds to get the average BW. Feed consumption was calculated by subtracting feed offered from feed given in one week, divided by the number of birds to obtain the average FC. Mortality was recorded daily. Percentage mortality was calculated by calculating the number of birds that died against the number of birds at the beginning of the experiment (10 birds/cage). The EPEF calculation followed that of Mavromati *et al.* (2018). Zinc consumption (ZnC) was calculated by multiplying FC during the observation time with the zinc content of the feed.

Slaughter procedure, carcass traits, and visceral organ measurements followed the procedure reported by Moses *et al*. (2022). At ten weeks of age, one male chicken was taken randomly from each experimental cage (each treatment had six replications) for humane slaughter. Birds were fasted for 12 h to prevent contamination of carcasses with digesta and feces. The birds were slaughtered by cutting the jugular vein and allowed to bleed for 3 min. They were scalded at 65 °C in water for 55 s, then defeathered in a rotary drum picker for 20 s, and manually eviscerated. Data were collected on dressing percentage, carcass cuts, and visceral organ weight. The dressing percentage was calculated as a proportion of carcass weight to slaughter weight and then multiplied by 100. The carcass was cut into several carcass cuts (head and neck, two wings, whole breast, whole back, two upper thighs, two lower thighs, two shanks). The percentage of carcass cuts was calculated by dividing the carcass cut weight by the slaughter weight and multiplying by 100. The percentage of internal organs (liver, heart, ventriculus) and abdominal fat was calculated as the weight of internal organs of slaughter weight, multiplied by 100. The length of the sections of the small intestine (duodenum, jejenum, ileum) (cm/g) were calculated by dividing the length of the small intestine (duodenum, jejenum, ileum) by slaughter weight.

The dietary NZP used in this experiment was the result of our own production carried out at the feed chemistry laboratory, IRIAP (Bogor, West Java province, Indonesia). The NZP production process followed the procedure reported by Hidayat *et al.* (2021b). Dietary NZP contains a phenol proportion of

0.156% of dry matter (DM), zinc proportion of 12.68% DM, and antioxidant activity inhibitory concentration ($IC_{50}$) of 22.12 mg/ml.

All data were analysed using analysis of variance (ANOVA) with general linear models in SAS.9.1 (SAS, 2008). Analysis of growth performance data was done in groups at four, six, and ten-week-old KUB chickens to enable detailed examination of the effect of feed treatments on various ages of KUB chickens. If an interaction was identified between the two main factors (nutrients and NZP dosage), further analysis was carried out by combining these two factors (nutrients and NZP dosage). If the results were significantly different, separation of means was done using Duncan's test. The criterion for determining the significance of the effect for each variable was a *P*-value <0.05.

**Table 1.** Feed formulations used to determine productive performance of growing Kampung Unggul Balitbangtan chickens fed different levels of dietary nano zinc phytogenic as part of low- and high-nutrient diets

| Feedstuff | Nutrient content of diet | |
|---|---|---|
| | High | Low |
| Maize (%) | 62 | 51.15 |
| Rice bran (%) | 0 | 22 |
| Soybean meal (%) | 21.35 | 14 |
| Meat bone meal (%) | 12 | 8 |
| Palm Oil (%) | 2 | 2 |
| $CaCO_3$ (%) | 0.5 | 0.5 |
| NaCl (%) | 0.2 | 0.4 |
| DL-Methionine (%) | 0.4 | 0.4 |
| Lysine (%) | 0.45 | 0.45 |
| Tryptophan (%) | 0.1 | 0.1 |
| Dicalcium Phosphate (%) | 1 | 1 |
| Total | 100 | 100 |
| Nutrient content | | |
| Crude Protein* (%) | 21.52 | 17.27 |
| Metabolizable Energy*** (MJ ME/kg) | 12.63 | 11.73 |
| Crude fibre* (%) | 2.31 | 4.42 |
| Crude fat* (%) | 4.69 | 5.26 |
| Total Lysine** (%) | 1.39 | 1.14 |
| Methionine** (%) | 0.65 | 0.59 |
| Methionine + Cystine** (%) | 0.92 | 0.79 |
| Ca* (%) | 1.6 | 1.2 |
| P* (%) | 0.96 | 0.9 |
| Na* (%) | 0.2 | 0.27 |
| Cl* (%) | 0.23 | 0.35 |
| Zn* (ppm) | 45.11 | 39.35 |

Note: *Analysis was conducted at the Feed Chemistry Laboratory at IRIAP (Indonesian Research Institute for Animal Production). ** Calculation results from the results of laboratory analysis of the amino acid content of feed ingredients. *** Result from calculation of metabolizable energy based on the calculation of ME content of feed ingredients according to Rostagno *et al*. (2017). Ca, Calcium; P, Phosphorous; Na; sodium; Cl, Chloride; Zn, Zinc

## Results and Discussion

Performance of KUB chickens up to four weeks old is presented in Tables 2 and 3. Observations were made at the age of the first 4 weeks because the first 4 weeks of age in KUB chickens are the first stage of growth. Nutritional content of the diet (low vs high) affected BW, BWG and FC (*P* <0.05). Nutritional content did not affect mortality and ZnC (*P* > 0.05). The high-nutrient diet improved BW and BWG but decreased FC (P <0.05). Furthermore, NZP dosage impacted BWG, BW, FC, and ZnC (*P* <0.05). Conversely, NZP dosage did not affect mortality (*P* >0.05). Additional NZP, starting at 30 mg Zn/kg, substantially improved BW, BWG, FC, and ZnC, whereas NZP dosage had no effect on mortality. In all performance parameters observed in the group aged up to four weeks (FC, BWG, BW, FCR, EPEF, mortality, and ZnC), the interaction between nutrient content of the diet and NZP dosage was only significant for FCR and EPEF (*P* <0.05). Thus, we analysed the effect of the factor combinations on FCR and EPEF (Table 3). A combination of high-nutrient diet with 90 mg Zn/kg NZP resulted in the best FCR value and the highest EPEF value.

**Table 2.** Performance (body weight, body weight gain, feed consumption, mortality, and Zn consumption) of Kampung Unggul Balitbangtan chickens at 4 weeks old fed high and low nutrient diets

| Factors | Body weight (g/bird) | Body weight gain (g/bird) | Feed consumption (g/bird) | Mortality (%) | Zn consumption (mg/bird) |
|---|---|---|---|---|---|
| **Nutrient (N)** | | | | | |
| Low | 205[b] | 177[b] | 493[a] | 0.555 | 57.00 |
| High | 234[a] | 207[a] | 477[b] | 0.277 | 57.45 |
| SE | 2.39 | 2.39 | 4.08 | 0.330 | 4.32 |
| *P*-value | <0.0001 | <0.0001 | 0.003 | 0.565 | 0.494 |
| **Dose (D)** | | | | | |
| 0 | 203[b] | 175[b] | 460[b] | 0.833 | 19.44[f] |
| 30 | 226[a] | 198[a] | 496[a] | 0.000 | 35.82[e] |
| 60 | 218[a] | 190[a] | 478[a] | 0.8333 | 48.89[d] |
| 90 | 225[a] | 197[a] | 493[a] | 0.8333 | 65.17[c] |
| 120 | 223[a] | 196[a] | 493[a] | 0.000 | 80.05[b] |
| 150 | 223[a] | 195[a] | 489[a] | 0.000 | 93.98[a] |
| SE | 5.540 | 5.570 | 6.645 | 0.417 | 0.78 |
| *P*-value | <0.0001 | <0.0001 | 0.001 | 0.700 | <0.001 |
| **Interaction** | | | | | |
| NxD | NS | NS | NS | NS | NS |

Note: SE, standard error; NS, non-significant. The same superscript in the same column for each factor (nutrient or dose) showed no significant difference (*P* >0.05); N×D; interaction between nutrient content and dose

**Table 3.** Performance (FCR and EPEF) of Kampung Unggul Balitbangtan chickens at 4-weeks old fed high and low nutrient content diets

| Number of Treatment Diet | Combination Factor | | | |
|---|---|---|---|---|
| | Nutrient | Dose | FCR | EPEF |
| 1 | Low | 0 | 2.85[ab*] | 239[f] |
| 2 | Low | 30 | 2.69[b] | 285[cd] |
| 3 | Low | 60 | 2.84[ab] | 243[ef] |
| 4 | Low | 90 | 2.89[a] | 253[def] |
| 5 | Low | 120 | 2.74[ab] | 276[de] |
| 6 | Low | 150 | 2.71[b] | 280[cd] |
| 7 | High | 0 | 2.43[c] | 313[c] |
| 8 | High | 30 | 2.32[cd] | 367[b] |
| 9 | High | 60 | 2.26[cd] | 378[ab] |
| 10 | High | 90 | 2.18[d] | 403[a] |
| 11 | High | 120 | 2.32[cd] | 362[b] |
| 12 | High | 150 | 2.31[cd] | 361[b] |
| | SEM | | 0.033 | 7.29 |
| | *P*-value | | <0.001 | <0.001 |

*Different superscripts in the same column are significantly different (*P* <0.05); SEM, standard error mean; FCR, feed conversion ratio; EPEF, European production efficiency factor

In the Zn-supplemented groups at four weeks of age, adding NZP improved BW, BWG, and FC (*P* <0,05) (Table 2). For these parameters, the dose effect of NZP worked without interacting with the nutritional content (low vs high) of the diet given (Table 2). However, to achieve the best FCR and EPEF, a combination of high nutritional content and a dosage of 90 mg Zn/kg NZP is required (Table 3). This indicates that until four weeks of age, it is necessary for KUB chickens to consume feed with high nutritional content and NZP at a dose of 90 mg Zn/kg to achieve the best feed and economic efficiencies. This dose is in accordance with zinc recommendation for broiler chickens reported by Hidayat *et al.* (2020). This supports a fast growth rate of KUB chickens during the first four weeks of life, requiring high nutrient and zinc dosages from the diet. Total zinc consumed up to four weeks of age when using NZP at a dose of 90 mg Zn/kg was 65.17 mg (Table 2). The estimated amount of zinc required by KUB chickens to achieve the best feed and economic efficiency up to four weeks is 65.17 mg. Table 2 also shows that up to four weeks, addition of NZP of up to 150 mg Zn/kg was not toxic, as the mortality rate was not affected. Several reports indicate that the use of zinc and phytogenic compounds in high doses has a toxic effect on chickens (Oso *et al.,* 2019; Khanam, 2020). When using a low-nutrient diet, the best FCR and EPEF are achieved by using a dosage of 30 mg Zn/kg NZP (Table 3). This dose can therefore be suggested as an alternative for farmers using low-nutrient diets.

**Performance up to six weeks of age**

Performance of KUB chickens up to six weeks of age fed with treatment diets is presented in Tables 4 and 5. Nutritional content of diet (low vs high) affected EPEF, BW, and BWG ($P$ <0.05). Nutrient content of diet did not affect mortality ($P$ >0.05) (Table 4). The high-nutrient diet improved BW, BWG, and EPEF ($P$ <0.05). Dietary NZP dosage affected BW, EPEF, and BWG ($P$ < 0.05). Dosage of NZP did not affect mortality ($P$ >0.05). Additional NZP (from 30 mg Zn/kg) improved EPEF, BW, and BWG ($P$ <0.05) (Table 4). Dietary NZP dosage had no effect on mortality (Table 4). In all performance parameters observed up to six weeks of age (BW, BWG, FC, FCR, EPEF, mortality, and ZnC), interaction between nutrient content of diet and NZP dosage affected FC, FCR, and ZnC ($P$ <0.05) (Table 4).

Table 5 shows the effect of factor combinations (nutrient level of diet and dosage of NZP) on FC, FCR, and ZnC. The combination of a low-nutrient diet and 90 mg Zn/kg NZP resulted in the highest FC. This indicates that the use of NZF does not decrease the palatability of the ration and may increase the appetite of KUB chickens. The best FCR resulted from combining a high-nutrient diet with 90 mg Zn/kg NZP. NZF works more effectively in increasing the efficiency of feed use when used in a high nutrient diet. The highest ZnC was obtained from the combination of high-nutrient diet and the highest dosage of NZP (150 mg Zn/kg). Results from chickens up to six weeks old suggest that adding NZP improved BWG, EPE, and BW. There was an interaction between nutrient content and NZP dose in FC, FCR, and ZnC. The best feed-use efficiency up to six weeks of age was obtained when combining a high-nutrient diet with 90 mg Zn/kg NZP. Table 5 indicates that when using feed with low nutritional content, the best FCR resulted from 30 mg Zn/kg NZP. Improvements in feed-use efficiency from NZF are strongly related to the nutritional content of the feed.

**Table 4.** Performance (body weight, body weight gain, and mortality) of Kampung Unggul Balitbangtan chicken at 6-weeks fed high and low nutrient content diets

| Factors | Body weight (g/bird) | Body weight gain (g/bird) | EPEF | Mortality (%) |
|---|---|---|---|---|
| **Nutrient (N)** | | | | |
| Low | $362^{b}$ | $334^{b}$ | $284^{b}$ | 1.111 |
| High | $416^{a}$ | $388^{a}$ | $394^{a}$ | 0.277 |
| SE | 4.05 | 4.05 | 6.33 | 0.400 |
| p-value | <0.0001 | <0.0001 | <0.0001 | 0.167 |
| **Dose (D)** | | | | |
| 0 | $361^{b}$ | $334^{b}$ | $297^{b}$ | 0.833 |
| 30 | $405^{a}$ | $377^{a}$ | $363^{a}$ | 0.000 |
| 60 | $387^{a}$ | $359^{a}$ | $340^{a}$ | 0.833 |
| 90 | $393^{a}$ | $365^{a}$ | $343^{a}$ | 1.667 |
| 120 | $396^{a}$ | $368^{a}$ | $346^{a}$ | 0.833 |
| 150 | $391^{a}$ | $364^{a}$ | $346^{a}$ | 0.000 |
| SE | 9.89 | 9.93 | 18.77 | 0.600 |
| p-value | 0.0001 | 0.0002 | 0.0003 | 0.597 |
| **Interaction** | | | | |
| NxD | NS | NS | NS | NS |

Note: SE, standard error; NS, non-significant; EPEF, European production efficiency factor. The same superscript in the same column for each factor (nutrient or dose) showed no significant difference ($P$ >0.05); N×D; interaction between nutrient content and dose

**Table 5.** Performance (feed consumption, FCR, and Zn consumption) of Kampung Unggul Balitbangtan chicken at 6 weeks fed high and low nutrient content diets

| Number of Treatment Diet | Combination Factor | | Feed Consumption (g/bird) | FCR | Zn Consumption (mg/bird) |
|---|---|---|---|---|---|
| | Nutrient | Dose | | | |
| 1 | Low | 0 | 957$^{c}$ | 3.11$^{ab*}$ | 37.68$^{i}$ |
| 2 | Low | 30 | 1030$^{a}$ | 2.90$^{c}$ | 71.45$^{g}$ |
| 3 | Low | 60 | 962$^{c}$ | 2.95$^{c}$ | 95.67$^{f}$ |
| 4 | Low | 90 | 1040$^{a}$ | 3.16$^{a}$ | 134.60$^{d}$ |
| 5 | Low | 120 | 1029$^{a}$ | 2.98$^{bc}$ | 164.02$^{c}$ |
| 6 | Low | 150 | 1025$^{ab}$ | 2.99$^{bc}$ | 194.17$^{a}$ |
| 7 | High | 0 | 965$^{c}$ | 2.68$^{d}$ | 43.57$^{h}$ |
| 8 | High | 30 | 994$^{abc}$ | 2.49$^{e}$ | 74.70$^{g}$ |
| 9 | High | 60 | 981$^{bc}$ | 2.50$^{e}$ | 103.13$^{e}$ |
| 10 | High | 90 | 970$^{c}$ | 2.42$^{e}$ | 131.19$^{d}$ |
| 11 | High | 120 | 982$^{bc}$ | 2.49$^{e}$ | 162.17$^{c}$ |
| 12 | High | 150 | 959$^{c}$ | 2.48$^{e}$ | 187.21$^{b}$ |
| SEM | | | 5.35 | 0.034 | 6.13 |
| *P*-value | | | <0.001 | <0.001 | <0.001 |

*Different superscripts in the same column are significantly different ($P$ <0.05); SEM, Standard Error Mean; FCR, feed conversion ratio

**Performance up to ten weeks of age**

Performance of KUB chickens up to ten weeks of age fed with the treatment diets is presented in Tables 6 and 7. The nutritional content of the diet (low vs high) affected FC, FCR, BW, BWG, FCR, and EPEF ($P$ <0.05) (Table 6). High-nutrient diet resulted in higher BWG, BW, and EPEF ($P$ <0.05) and resulted in better feed conversion (FCR). Addition of NZP had a positive effect on production performance of KUB chickens up to ten weeks of age (Table 6). Additional NZP (from 30 mg Zn/kg) improved BW, EPEF, and FC ($P$ <0.05). Adding dietary NZP at 30 mg Zn/kg resulted in the best FCR and EPEF (Table 6). The use of NZP doses up to 150 mg Zn/kg did not affect mortality ($P$ >0.05).

There was no interaction ($P$ >0.05) for nutritional content and dosage of NZP on BWG, BW, FC, FCR, mortality, and EPEF (Table 6). Interaction between nutrient content of diet and NZP dosage only occurred for ZnC ($P$ <0.05) (Table 7). The highest ZnC up to ten weeks of age was obtained by combining the high-nutrient diet and the highest dosage of NZP (150 mg Zn/kg). In observations of chickens up to ten weeks of age, interactions between nutrient content of diet and NZP dosage did not occur for the main performance parameters (BWG, BW, FC, EPEF, FCR, and mortality). This indicates that in animals at ten weeks of age, the effect of adding various dietary doses of NZP on KUB chicken performance was not affected by nutrient content of the diet. In the group observed up to ten weeks, adding NZP improved BW and FC. The best EPEF was obtained with an addition of 30 mg Zn/kg NZP. Adding NZP up to 150 mg Zn/kg did not have a toxic effect, as seen from the lack of effect on mortality.

Improvements in production performance of growing-period KUB chickens was related to the addition of dietary NZP. This is in line with a previous study (Hidayat *et al.,* 2021a). Adding 55 mg/kg of zinc-methionine nanoparticles to broiler diets improved body weight of broiler chickens (Kumar *et al.,* 2021). Similar results are also reported by Fathi *et al.* (2016), who found that adding 20 mg/kg of zinc nanoparticles markedly increased broiler BW. Zinc is therefore important in supporting the growth of chickens because of its important role in various biological functions (Hidayat *et al.,* 2020). Furthermore, the change in zinc particle size also has positive benefits for chicken growth. This is because zinc in nanoparticle form is more efficiently used in metabolic processes than zinc in conventional forms (Mohammadi *et al.,* 2015). Asheer *et al.* (2018) explained that nano-sized particles can bypass conventional physiological pathways, leading to distribution and transport of nutrients across cell tissue and membranes. Another advantage is that delivery in nano-sized particles can protect zinc from destruction before reaching the target.

Adding 30–150 mg Zn/kg NZP had a positive impact on the production performance of growing KUB chickens. Besides the impacts caused by zinc, positive effects also come from the phytogenic compounds that are contained in NZP. Previous studies have reported that adding phytogenic compounds to the diet improves performance in chickens (Stanacev *et al.,* 2011, Dhama *et al.,* 2015).

Furthermore, phytogenic compounds obtained from guava leaves have been reported as improving BW gain in broiler chickens (Daing *et al*., 2020). The positive impact of phytogenics in improving the growth performance of broiler chickens is related to their beneficial effects on the utilization of nutrients resulting from their ability to stimulate digestive enzymes such as amylase, lipase, protease (Hashemi and Davoodi, 2011; Anderson *et al.,* 2017). Phytogenic compounds have also been found to improve microbiota ecosystems in the digestive tract through controlling pathogenic bacteria (Jamroz *et al.,* 2006).

**Table 6.** Performance (body weight, body weight gain, feed consumption, FCR, EPEF, and mortality) of Kampung Unggul Balitbangtan chickens at 10 weeks old fed high and low nutrient content diets

| Factor | Body weight (g/bird) | Body weight gain (g/bird) | Feed consumption (g/bird) | FCR | EPEF | Mortality (%) |
|---|---|---|---|---|---|---|
| **Nutrient (N)** | | | | | | |
| Low | 827$^{b}$ | 799$^{b}$ | 2505$^{a}$ | 3.13$^{a}$ | 373$^{b}$ | 1.11 |
| High | 890$^{a}$ | 862$^{a}$ | 2369$^{b}$ | 2.74$^{b}$ | 459$^{a}$ | 0.83 |
| SE | 10.89 | 10.88 | 20.88 | 0.026 | 8.69 | 0.70 |
| p-value | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.698 |
| **Dose (D)** | | | | | | |
| 0 | 816$^{b}$ | 789 | 2367$^{b}$ | 3.01 | 387$^{b}$ | 0.83 |
| 30 | 884$^{a}$ | 856 | 2478$^{a}$ | 2.90 | 438$^{a}$ | 0 |
| 60 | 857$^{a}$ | 829 | 2441$^{a}$ | 2.95 | 414$^{ab}$ | 0.83 |
| 90 | 875$^{a}$ | 847 | 2467$^{a}$ | 2.92 | 422$^{a}$ | 2.5 |
| 120 | 858$^{a}$ | 831 | 2440$^{a}$ | 2.94 | 417$^{ab}$ | 0.83 |
| 150 | 859$^{a}$ | 832 | 2429$^{ab}$ | 2.92 | 418$^{a}$ | 0.83 |
| SE | 37.79 | 37.86 | 76.35 | 0.16 | 39.59 | 1.89 |
| P value | 0.0094 | 0.101 | 0.0331 | 0.190 | 0.028 | 0.500 |
| **Interaction** | | | | | | |
| NxD | NS | NS | NS | NS | NS | NS |

Note: SE, standard error; NS, non-significant; EPEF, European production efficiency factor. The same superscript in the same column for each factor (nutrient or dose) showed no significant difference (*P* >0.05); N×D; interaction between nutrient content and dose

**Table 7.** Zinc consumption of Kampung Unggul Balitbangtan chicken at 10 weeks old fed high and low nutrient content diets

| Number of Treatment Diet | Combination Factor | | Zn Consumption (mg/bird) |
|---|---|---|---|
| | Nutrient | Dose | |
| 1 | Low | 0 | 94.44$^{g*}$ |
| 2 | Low | 30 | 178.46$^{f}$ |
| 3 | Low | 60 | 245.40$^{e}$ |
| 4 | Low | 90 | 331.72$^{d}$ |
| 5 | Low | 120 | 397.54$^{c}$ |
| 6 | Low | 150 | 479.02$^{a}$ |
| 7 | High | 0 | 105.34$^{g}$ |
| 8 | High | 30 | 178.96$^{f}$ |
| 9 | High | 60 | 253.61$^{e}$ |
| 10 | High | 90 | 320.35$^{d}$ |
| 11 | High | 120 | 393.85$^{c}$ |
| 12 | High | 150 | 454.35$^{b}$ |
| | SEM | | 14.89 |
| | P-Value | | <0.001 |

*Different superscripts in the same column are significantly different (*P* <0.05); SEM, Standard Error Mean

**Dressing percentage, carcass cuts, and visceral organs**

The effects of the addition of dietary NZP on dressing percentage and carcass cuts of male KUB chickens are presented in Table 8. The influence of dietary NZP on visceral organ percentage is presented in Table 9. The high nutrient diet resulted in a higher dressing percentage (*P* <0.05). Additional NZP dose had no effect on the dressing percentage and external carcass cuts (*P* >0.05). There was no interaction between nutritional content of diet and dosage of NZP in terms of dressing percentage and carcass cut weight (head and neck, two wings, whole back, whole breast, two upper thighs, two lower thighs, two shanks, and abdominal fat) (P >0.05) (Table 8). The high-nutrient diet affected lower gizzard percentage (*P* >0.05), whereas the addition of dietary NZP had no effect on the percentage and length of visceral organs (liver, heart, gizzard, duodenum, jejunum, ileum) (*P* >0.05). There was no interaction between nutritional content of diet and dosage of NZP on the percentage or length of visceral organs (liver, heart, duodenum, jejunum, and ileum) (Table 9).

In this study, the high-nutrient diet produced a higher dressing percentage compared to the low-nutrient diet. Nutritional content of the diet is the main input used by poultry for production, including muscle formation. Reports of the relationship between the nutritional content of the diet and dressing percentage vary. Nunes *et al.* (2012) has found that nutritional content of diet did not determine the dressing percentage, while others have found that nutritional content of diet does determine percentage of dressing (Liu *et al.,* 2017; Hidayat and Iskandar, 2019). In the current study, of all carcass cuts observed, nutritional content of diet only affected the percentage of whole breast; the ventriculus was affected, while the liver, heart, duodenum, jejunum, ileum were not. This indicates that nutritional content of diet has no effect on the acceleration of visceral organ development in growing KUB chickens. Findings in this study are similar to those of Hidayat *et al.* (2016), who found that there was no effect of nutritional content of diet on percentage of carcass cuts and percentage of visceral organs in several types of Indonesian local chickens.

Addition of 30–150 mg Zn/kg dietary NZP did not affect dressing percentage, carcass cuts or visceral organs in the growing period of KUB chickens. Similar results were also reported by Ahmadi *et al.* (2013), who revealed that use of zinc nanoparticles up to a dosage of 120 mg/kg had no effect on the percentage of carcasses and organs in broiler chickens. Adding dietary NZP did not affect the proportion of chicken organs in the way shown by another study using Zn nanoparticles as a treatment.

**Table 8.** Effect of addition dietary nano zinc phytogenic on dressing percentage and external carcass traits (%) of male Kampung Unggul Balitbangtan chickens aged 10 weeks fed high and low nutrient diets (%)

| Factor | Dressing | Head and Neck | Two Wings | Whole Breast | Whole Back | Two Upper thighs | Two Lower thighs | Two Shanks | Abdominal fat |
|---|---|---|---|---|---|---|---|---|---|
| **Nutrient (N)** | | | | | | | | | |
| Low | 74.30$^{b}$ | 8.97 | 8.95 | 16.04$^{b}$ | 14.74 | 10.96 | 10.17 | 4.45 | 0.63 |
| High | 75.56$^{a}$ | 8.76 | 9.2 | 16.83$^{a}$ | 14.89 | 11.2 | 10.27 | 4.37 | 0.68 |
| SE | 0.57 | 0.26 | 0.14 | 0.34 | 0.20 | 0.20 | 0.16 | 0.10 | 0.15 |
| P-value | 0.038 | 0.468 | 0.0531 | 0.016 | 0.458 | 0.225 | 0.580 | 0.530 | 0.788 |
| **Dose (D)** | | | | | | | | | |
| 0 | 74.8 | 8.74 | 8.73 | 17.29 | 14.76 | 10.82 | 10.09 | 4.35 | 0.53 |
| 30 | 74.38 | 8.81 | 9.07 | 15.87 | 15.18 | 10.91 | 10.17 | 4.35 | 0.6 |
| 60 | 75.37 | 8.49 | 9.03 | 16.88 | 14.76 | 11.38 | 10.35 | 4.46 | 0.65 |
| 90 | 75.99 | 9.23 | 9.24 | 16.53 | 15.04 | 11.26 | 10.2 | 4.46 | 0.72 |
| 120 | 74.95 | 8.94 | 9.42 | 16.21 | 14.33 | 11.3 | 10.21 | 4.51 | 0.58 |
| 150 | 74.08 | 8.99 | 8.98 | 15.84 | 14.82 | 10.82 | 10.27 | 4.34 | 0.86 |
| SE | 1.74 | 0.75 | 0.38 | 0.97 | 0.53 | 0.56 | 0.49 | 0.31 | 0.42 |
| P-vaule | 0.459 | 0.772 | 0.072 | 0.075 | 0.273 | 0.340 | 0.974 | 0.939 | 0.862 |
| **Interaction** | | | | | | | | | |
| NxD | NS | NS | NS | NS | NS | NS | NS | NS | NS |

Note: NS, non-significant; SE, standard error. The same superscript in the same column for each factor (nutrient or dose) indicates no significant difference (*P* >0.05). NxD; interaction between nutrient content and dose

**Table 9.** Effect of dietary nano zinc phytogenic on percentage and length of visceral organs in 10-week-old-male Kampung Unggul Balitbangtan chickens fed high and low nutrient diets

| Factors | Liver (%) | Heart (%) | Ventriculus (%) | Duodenum (cm/g) | Jejenum (cm/g) | Ileum (cm/g) |
|---|---|---|---|---|---|---|
| **Nutrient (N)** | | | | | | |
| Low | 1.77 | 0.45 | 2.42[a] | 0.021 | 0.048 | 0.051 |
| High | 1.69 | 0.44 | 2.06[b] | 0.021 | 0.047 | 0.047 |
| SE | 0.1147 | 0.0183 | 0.0978 | 0.0010 | 0.0017 | 0.0021 |
| p-value | 0.588 | 0.851 | 0.0017 | 0.658 | 0.511 | 0.0833 |
| **Dose (D)** | | | | | | |
| 0 | 1.69 | 0.41 | 2.23 | 0.021 | 0.050 | 0.051 |
| 30 | 1.72 | 0.43 | 2.17 | 0.02 | 0.048 | 0.048 |
| 60 | 1.45 | 0.47 | 2.37 | 0.02 | 0.045 | 0.046 |
| 90 | 1.77 | 0.49 | 2.19 | 0.02 | 0.043 | 0.048 |
| 120 | 1.89 | 0.44 | 2.14 | 0.023 | 0.051 | 0.051 |
| 150 | 1.86 | 0.42 | 2.35 | 0.02 | 0.048 | 0.048 |
| SE | 0.3256 | 0.0481 | 0.3442 | 0.0027 | 0.0048 | 0.0057 |
| p-value | 0.500 | 0.104 | 0.689 | 0.357 | 0.075 | 0.700 |
| **Interaction** | | | | | | |
| NxD | NS | NS | NS | NS | NS | NS |

Note: NS, non-significant; SE, standard error. The same superscript in the same column for each factor (nutrient or dose) indicates no significant difference ($P > 0.05$). NxD; interaction between nutrient content and dose

## Conclusion

Adding dietary NZP increased productive performance and economic index in the growing period of KUB chickens fed on low- and high-nutrition diets. To achieve the best performance in the growing period of KUB chickens, this study recommends a combination of a high-nutrient diet and 90 mg Zn/kg of NZP.

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## Authors' Contributions

CH was responsible for creating the research design, collecting data, analysing data, and writing the scientific article. EW was responsible for NZP production, and supervising the writing of the scientific article. RK, KK, YAH, SAA were responsible for collecting data and supervising the writing of the scientific article. ABLI, HZ were responsible for providing KUB chickens and supervising the writing of the scientific article. TWC was responsible for the chicken veterinary program during the feeding trial and supervising the writing of the scientific article.

## Conflicts of Interest Declaration

All authors declare no conflicts of interest in the publication of this manuscript.

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