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*Full Length Research*

# Effect of raw and heat-treated rock phosphate as replacements for bone meal on growth performance, carcass traits and bone characteristics of weanling rabbits

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**ABSTRACT:** Calcium and phosphorus play fundamental roles in regulating metabolic activities and skeletal development in livestock. Rock Phosphate (RP), a naturally occurring calcium-phosphorus rich resource containing high fluoride content, holds promise as an alternative to bone meal. Fifty-four crossbred weanling rabbits, aged seven weeks old with an average initial weight of 599.65 ± 2.70 g, were randomly assigned to nine dietary treatments in a completely randomised design. Raw Rock Phosphate (RRP) or Heat-Treated Rock Phosphate (HTRP) replaced bone meal at 0, 25, 50, 75, or 100% for RRP and HTRP diets, respectively. Feed and water were provided *ad libitum*. Growth performance was monitored for 70 days, after which three rabbits per treatment were euthanised for carcass evaluation and bone analysis following standard procedures. Data were analysed using orthogonal contrasts and polynomial regression in SAS version 9.4 (2023). No significant differences ($p>0.05$) were observed in most growth performance indices, except for the feed conversion ratio between the control and the HTRP group. Carcass characteristics were generally similar across treatments, with the exception of dressed percentage and forelimb weights ($p<0.05$). Bone parameters did not differ significantly ($P > 0.05$) among treatments, except for humeral diameter. It was therefore concluded that rock phosphate was a viable alternative to bone meal and the threat of nutrient loss to complexes was reduced through the adopted processing method of heat treatment, which tends to deflourinate rock phosphate, thereby improving calcium and phosphorus bioavailability for growth performance, carcass quality and bone mineralisation.

**Keywords:** Bone meal, bone mineralisation, carcass, growth performance, rock phosphate.

## INTRODUCTION

Recently, attempts have been made to evaluate alternative sources of feed ingredients for livestock feeding as the most challenging factor facing researchers and farmers in providing adequate nutrition and safe feed for domesticated animals like rabbits. Calcium and phosphorus play fundamental roles in regulating metabolic activities and skeletal development in livestock, which are the two key minerals accounted for in animal diet formulations. Primary dietary calcium sources such as oyster shell, periwinkle shell, limestone, di-calcium phosphate and bone meal have been identified. However, there aren't as many efforts focused on finding local substitutes for the important mineral nutrients, such as phosphorus and calcium (Tumova *et al*., 2004).

Animal bones are also utilised for a variety of purposes, most notably the production of goods like glue, gelatin, ossein, dinner's foot, dicalcium phosphate, fertiliser, and pottery (Agbu *et al*., 2017). The use of bone meal (BM) as a calcium-phosphorus source for livestock diets has declined due to contaminants and the spread of zoonotic diseases, particularly mad cow disease (Tion *et al*., 2012). Rock Phosphate (RP), a naturally occurring calcium-phosphorus rich resource with high fluoride content, holds promise as an alternative for BM. Rock phosphate deposit is abundant in various West African nations, particularly in Togo, Senegal, the Benin Republic, and Nigeria, with commercial quantities of the mineral present in Imo, Ogun and Sokoto states (Agedeson *et al*., 2021). However, its use is restricted due to its high fluorine content. Heat treatment is a method for lowering the fluoride content in raw rock phosphate. Heat-treated rock phosphate, also known as defluorinated or soft rock phosphate, has fluorine contents that are significantly lower than those of raw rock phosphate (RRP) (Agbu *et al*., 2017). Therefore, the volatility of fluoride at high temperature informed the evaluation of Heat-Treated RP (HTRP) as a replacement for BM in rabbit diets (Thomas *et al*., 2007).

Raw Phosphate rock and heat-treated rock phosphate contain approximately the same amounts of calcium and phosphorus as bone meal, of about 17% phosphorus and 34% calcium (Ramteke *et al*., 2018). Therefore, to achieve maximum productivity, low production costs, and a sufficient return on investment, it is essential to evaluate substitutes that have high nutritional value of calcium and phosphorus that is bioavailable in rabbits as a viable alternative to bone meal.

## MATERIALS AND METHODS

### Experimental site

The study was carried out at the University of Ibadan Teaching and Research Farm's Rabbitry Unit, which is situated at a latitude of 7.27 °N and longitude 3.54 °E.

### Ethical approval

University of Ibadan Animal Care and Use Research Ethics Committee approved experimental procedures before the commencement of the study (Approval ID: UI-ACUREC/049-0623/09).

### Rock phosphate processing

Rock phosphate ore was obtained between Latitude 6.82 ºN and Longitude 3.23 ºE of Ifo in Ogun State, Nigeria. The slurry of the extracted ore was sent to a flotation plant, where its particles were washed and dried, then milled (Agbu *et al*., 2017). The rock phosphate used in this study was further ground and sieved through a 200 µm sieve. 1000 g of the raw rock phosphate samples were heated for five hours at varying temperature rates of 10 °C/min up to 600 °C and until the colour changed from brownish grey to reddish brown (Mgaidi *et al*., 2004; Fayiga and Obigbesan, 2017). Using inorganic geochemical X-ray fluorescence spectrophotometry, calcium and phosphorus were analysed. Other feed ingredients were obtained from a reputable feed mill in Ibadan, Oyo State, Nigeria.

### Housing and management of rabbits

Fifty-four (54) cross-bred mongrel weanling rabbits were utilised with an initial average weight of 599.65 ± 2.7 g. Six rabbits were used in each of the nine feeding treatments, and each treatment was replicated three times in pairs in different hutches of approximately 90 x 60 x 60 cm in a Completely Randomised Design CRD, and kept in an open-sided building for effective ventilation. The rabbits were fed *ad libitum.* They were screened for parasites and treated. During the experimental trial period, a temperature range of 25 - 38°C was recorded, and the average relative humidity was 65%. Every morning, leftover feeds were weighed and the difference calculated. The rabbits were weighed once a week over a period of 70 days.

### Statistical analysis

The data obtained were subjected to orthogonal contrast and polynomial regression using SAS 9.4 (2023).

## RESULTS AND DISCUSSION

### Chemical composition of bone meal, raw rock phosphate and heat-treated rock phosphate

Chemical analysis of the BM, RRP and HTRP used in this study revealed calcium contents of 34.45%, 17.16% and 17.11% and proportions of phosphorus as 16.88%, 30.95% and 31.62%, respectively. The fluoride content of BM was 0.34% while RRP and HTRP had 6.30% and 0.09%, respectively. Results of calcium, phosphorus and fluoride content of bone meal from this trial were similar to reports of Agbu *et al.* (2017) and Ramteke *et al*. (2018. However, calcium in RRP and HTRP in this study was lower than the figures reported by the same authors. Nevertheless, phosphorus and fluoride contents were significantly ($p<0.05$) higher compared to values reported by Agbu *et al.* (2017) and Ramteke *et al*. (2018). This could be attributed to differences in ore contents from the different geographical locations. Nevertheless, the calcium and phosphorus analyses from this study agreed with the report of Fayiga and Obigbesan (2017).

### Effect of raw rock phosphate and heat-treated rock phosphate inclusion levels in rabbits' diets on growth performance

The effect of raw rock phosphate and heat-treated rock phosphate inclusion levels on the growth performance of rabbits is presented in Tables 2a and 2b. There were no significant differences ($p>0.05$) in the parameters measured except FCR for A VS B (control verses heat treated rock phosphate). The significant impact could be linked to the

**Table 1.** Compositions of diets containing raw rock phosphate and heat treated rock phosphate for weanling rabbits.

| Ingredients | Percentage replacement of bone meal | | | | |
|---|---|---|---|---|---|
| | **0%** | **25%** | **50%** | **75%** | **100%** |
| Maize | 22.00 | 22.00 | 22.00 | 22.00 | 22.00 |
| Soybean Meal | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 |
| Corn bran | 25.00 | 25.00 | 25.00 | 25.00 | 25.00 |
| PKC | 16.10 | 16.10 | 16.10 | 16.10 | 16.10 |
| Rice Offal | 13.00 | 13.00 | 13.00 | 13.00 | 13.00 |
| Heated Phosphate Rock | 0.00 | 0.75 | 1.50 | 2.25 | 3.00 |
| Bone Meal | 3.00 | 2.25 | 1.50 | 0.75 | 0.00 |
| Methionine | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| Micro Grower mix | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| Industrial Salt | 0.30 | 0.30 | 0.30 | 0.30 | 0.30 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| **Calculated Nutrients** | | | | | |
| M.E (kcal/kg) | 2412.17 | 2412.17 | 2412.17 | 2412.17 | 2412.17 |
| Crude Protein | 16.92 | 16.92 | 16.92 | 16.92 | 16.92 |
| Crude fibre | 11.25 | 11.25 | 11.25 | 11.25 | 11.25 |
| Fat | 6.60 | 6.60 | 6.60 | 6.60 | 6.60 |
| Calcium | 1.03 | 0.05 | 0.15 | 0.23 | 0.30 |
| Phosphorus | 0.51 | 0.08 | 0.46 | 0.70 | 0.93 |

Micro-Mix Growers, Vitamin and Trace Minerals Supplied the following additional Micro and Macro nutrient Premix: Niacin 45,000.00 mg, Vitamin A, 10,000,000.00 I.U, Iron 120,000.00 mg, Cobalt 300,00 mg, D3 2,000,000.00 I.U, E, 20,000.00 mg, Vitamin B1 3,000.00 mg, B2 5,000.00 mg, Anti-oxidant 120,000.00 mg, Vitamin B6 4,000.00 mg, Vitamin B12 20.00 mg, Folic acid I,000.00 mg, Biotin 50.00 mg, Manganese 300,000.00 mg, Vitamin K3 mg, Copper 8,500.00 mg, Iodine 1,500.00 mg, Selenium 120.00 mg, Zinc 80,000.00 mg, Chlorine chloride 300,000.00 mg Calcium Pantothenate 10,000.00 mg and M.E – Metabolisable Energy.

**Table 2a.** Effect of raw rock phosphate and heat-treated rock phosphate inclusion levels in diets on growth performance of rabbits.

| Parameters | BM (0%) | HTRP (25%) | HTRP (50%) | HTRP (75%) | HTRP (100%) | RRP (25%) | RRP (50%) | RRP (75%) | RRP (100%) | SEM |
|---|---|---|---|---|---|---|---|---|---|---|
| Initial Wt (g) | 599.67 | 600.33 | 602.17 | 599.50 | 596.83 | 599.33 | 599.17 | 599.83 | 600.50 | 63.59 |
| Final Wt (g) | 1648.95 | 1730.47 | 1568.37 | 1511.38 | 1492.90 | 1707.63 | 1739.02 | 1779.17 | 1406.17 | 99.24 |
| ADFI (g/day) | 40.74 | 56.72 | 53.08 | 52.57 | 42.86 | 46.80 | 50.88 | 46.54 | 47.74 | 3.81 |
| ADWG (g/day) | 14.99 | 16.15 | 13.81 | 13.03 | 12.80 | 15.83 | 16.28 | 16.85 | 11.51 | 1.52 |
| FCR | 2.73 | 4.10 | 4.04 | 4.50 | 3.45 | 2.98 | 3.32 | 2.87 | 4.53 | 0.56 |

BM= Bone Meal; RRP= Raw Rock Phosphate; HTRP=Heat Treated Rock Phosphate.

**Table 2b.** Effect of raw rock phosphate and heat-treated rock phosphate inclusion levels in diets on growth performance of rabbits.

| Parameters | Orthogonal Contrast | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **A vs (B+C)** | **P>F** | **B vs C** | **P>F** | **A vs B** | **P>F** | **A vs C** | **P>F** |
| Initial Wt (g) | 0.01 | 1.000 | 0.0000 | 1.000 | 0.01 | 1.000 | 0.01 | 1.000 |
| Final Wt (g) | 5482.69 | 0.762 | 81114.96 | 0.248 | 25699.06 | 0.513 | 392.77 | 0.935 |
| ADG (g/day) | 1.12 | 0.777 | 16.54 | 0.279 | 5.25 | 0.540 | 0.08 | 0.940 |
| ADFI (g/day) | 422.97 | 0.777 | 16.54 | 0.279 | 5.25 | 0.540 | 0.08 | 0.940 |
| FCR | 5.32 | 0.097 | 4.27 | 0.137 | 8.07 | 0.043 | 2.35 | 0.267 |

A = Control; B = Heat-treated rock phosphate; C = Raw rock phosphate; VS = verses; ADFI = Average Daily Feed Intake; ADWG = Average Daily Weight Gain; FCR = Feed Conversion Ratio; Wt= weight.

**Table 3a.** Carcass characteristics of rabbits fed diets with varied inclusion levels of raw rock phosphate and heat-treated rock phosphate.

| Parameters | BM (0%) | HTRP (25%) | HTRP (50%) | HTRP (75%) | HTRP (100%) | RRP (25%) | RRP (50%) | RRP (75%) | RRP (100%) | SEM |
|---|---|---|---|---|---|---|---|---|---|---|
| Final Body wt (g) | 1634.43 | 1993.97 | 1451.17 | 1780.80 | 1593.40 | 1755.93 | 1925.83 | 1795.20 | 1393.97 | 90.45 |
| Bled wt (kg) | 1.58 | 1.95 | 1.39 | 1.65 | 1.62 | 1.60 | 1.83 | 1.71 | 1.30 | 0.09 |
| Skinned wt (kg) | 1.44 | 1.79 | 1.27 | 1.53 | 1.46 | 1.48 | 1.69 | 1.56 | 1.21 | 0.08 |
| Dressed (%) | 56.73 | 50.68 | 48.12 | 39.67 | 56.76 | 50.38 | 49.16 | 49.07 | 49.70 | 2.68 |
| Forelimb (%) | 15.47 | 8.30 | 8.25 | 6.87 | 9.87 | 7.80 | 7.49 | 7.86 | 8.06 | 0.79 |
| Hindlimb (%) | 16.14 | 15.09 | 14.26 | 11.81 | 16.18 | 14.49 | 13.94 | 19.05 | 16.12 | 0.97 |
| Loin (%) | 13.50 | 15.62 | 12.33 | 9.53 | 13.94 | 13.66 | 14.66 | 10.54 | 10.63 | 0.83 |

BM = Bone Meal; RRP = Raw Rock Phosphate; HTRP = Heat Treated Rock Phosphate

**Table 3b.** Carcass characteristics of rabbits fed diets with varied inclusion levels of raw rock phosphate and heat treated rock phosphate.

| Parameters | Orthogonal Contrast | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A vs (B+C) | P>F | B vs C | P>F | A vs B | P>F | A vs C | P>F |
| Final Body wt (g) | 13766.46 | 0.464 | 3146.46 | 0.724 | 8755.58 | 0.558 | 16653.34 | 0.421 |
| Bled wt (g) | 0.01 | 0.549 | 0.02 | 0.415 | 0.02 | 0.410 | 0.00 | 0.756 |
| Skinned wt (g) | 0.00 | 0.5016 | 0.00 | 0.623 | 0.01 | 0.429 | 0.00 | 0.628 |
| Dressed (%) | 151.637 | 0.016 | 3.57 | 0.689 | 150.80 | 0.017 | 122.87 | 0.028 |
| Forelimb (%) | 35815.68 | 0.000 | 214.80 | 0.708 | 30591.38 | 0.000 | 33919.79 | 0.000 |
| Hindlimb (%) | 82.63 | 0.800 | 4833.68 | 0.065 | 936.94 | 0.398 | 178.54 | 0.710 |
| Loin (%) | 21.47 | 0.870 | 184.26 | 0.632 | 0.01 | 0.997 | 75.49 | 0.759 |

A = Control; B = Heat treated rock phosphate; C = Raw rock phosphate and VS = verses and Wt = weight.

presence of aluminium and magnesium oxide at varying inclusion levels of rock phosphate, which might have interfered with feed intake and body weight gain, which affected the FCR. The FCR optimal level of HTRP was observed to linearly increase up to 75.69% and RRP decreased to 40.13% as shown in Figure 1. However, the significant differences (p>0.05) of the result could be due to the presence of fluoride, aluminium, and magnesium oxides at the varying rock phosphate inclusion levels. The reports of Tahir *et al*. (2011) and Agbu *et al*. (2017) supported the findings of this study. The authors reported that substituting Hazara and Sokoto rock phosphate (HRP and SRP) for DCP in the diets at varying inclusion levels had a significant difference (p<0.05) among groups for growth performance, which was due to the presence of fluoride at different inclusion levels.

### Carcass characteristics of rabbits fed varied inclusion levels of raw rock phosphate and heat treated rock phosphate

The carcass characteristics of rabbits fed varied inclusion levels of raw rock phosphate and heat-treated rock phosphate diets are shown in Tables 3a and 3b. The component of an animal that is left over after it has been slaughtered and its internal and exterior byproducts removed is called a carcass (Olaleru and Abu, 2021). The statistical analyses of the dressed weight percentage showed that rabbits fed a control diet and HTRP or RRP at different inclusion levels differed significantly (P < 0.05). This could be attributed to varying calcium/phosphorus ratio imbalances as reported by Clarence *et al*. (1995), who stated that calcium-phosphorus ratio imbalances could affect animal metabolic activities, thereby altering its physiological state. The orthogonal contrast of the forelimbs of rabbits had a significant (p<0.05) impact across treatments except control against RRP diets. The impact was similar to the report of Clarence *et al*. (1995).

### Assessment of raw rock phosphate and heat-treated rock phosphate inclusion levels in rabbit diets on visceral organs

The results of the effect of varied inclusion levels of raw rock phosphate and heat-treated rock phosphate in rabbit diets on visceral organs are presented in Table 4a and 4b. The kidney, large intestine, small intestine and stomach weights differed significantly (p<0.05). Diets fed to rabbits with HTRP or RRP at varying inclusion levels showed that B VS C did not differ significantly (p>0.05) for kidneys, but differed significantly (p<0.05) from other groups when compared to BM. The significant influence of parameters

**Table 4a.** Effect of varied inclusion levels of raw rock phosphate and heat-treated rock phosphate in rabbit diets on visceral organs.

| Parameters | BM (0%) | HTRP (25%) | HTRP (50%) | HTRP (75%) | HTRP (100%) | RRP (25%) | RRP (50%) | RRP (75%) | RRP (100%) | SEM |
|---|---|---|---|---|---|---|---|---|---|---|
| Liver (%) | 2.44 | 3.15 | 2.61 | 2.08 | 2.86 | 2.50 | 2.64 | 2.22 | 2.67 | 0.37 |
| Kidney (%) | 0.39 | 0.53 | 0.62 | 0.48 | 0.59 | 0.46 | 0.52 | 0.55 | 0.68 | 0.06 |
| Large intestine (%) | 13.06 | 7.89 | 13.22 | 8.02 | 12.97 | 8.77 | 10.63 | 9.94 | 10.84 | 0.69 |
| Small intestine (%) | 2.35 | 4.07 | 4.85 | 2.96 | 4.54 | 3.88 | 4.11 | 3.31 | 4.04 | 0.45 |
| Lungs (%) | 0.81 | 0.59 | 0.89 | 0.74 | 0.78 | 0.58 | 0.63 | 0.75 | 0.70 | 0.06 |
| Large intestine (cm) | 159.50 | 150.00 | 139.50 | 147.00 | 178.00 | 156.00 | 202.50 | 156.50 | 127.50 | 7.23 |
| Small intestine (cm) | 284.00 | 345.00 | 573.00 | 222.50 | 285.00 | 264.50 | 292.50 | 261.50 | 253.50 | 34.30 |
| Stomach (%) | 7.19 | 4.39 | 5.81 | 3.71 | 6.79 | 4.67 | 6.69 | 4.72 | 4.56 | 0.48 |
| Heart (%) | 0.26 | 0.33 | 0.28 | 0.19 | 0.34 | 0.25 | 0.30 | 0.32 | 0.29 | 0.02 |

BM = Bone Meal; RRP = Raw Rock Phosphate; HTRP = Heat Treated Rock Phosphate.

**Table 4b.** Effect of varied inclusion levels of raw rock phosphate and heat-treated rock phosphate in rabbit diets on visceral organs.

| Parameters | Orthogonal Contrast | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A vs (B+C) | P>F | B vs C | P>F | A vs B | P>F | A vs C | P>F |
| Liver (%) | 0.06 | 0.700 | 0.17 | 0.528 | 0.14 | 0.53 | 0.14 | 0.573 |
| Kidney (%) | 0.07 | 0.024 | 0.00 | 1.000 | 0.07 | 0.03 | 0.07 | 0.03 |
| Large intestine (%) | 20.52 | <.000 | 1.38 | 0.137 | 15.41 | <.000 | 21.80 | <.000 |
| Small intestine (%) | 6.81 | 0.004 | 0.29 | 0.505 | 6.99 | 0.004 | 5.32 | 0.009 |
| Large intestine (cm) | 4.73 | 0.407 | 0.22 | 0.856 | 3.67 | 0.464 | 4.90 | 0.399 |
| Small intestine (cm) | 1.90 | 0.774 | 163.65 | 0.015 | 28.65 | 0.273 | 7.50 | 0.570 |
| Lungs (%) | 0.03 | 0.138 | 0.04 | 0.065 | 0.01 | 0.407 | 0.05 | 0.051 |
| Stomach (%) | 10.899 | 0.001 | 0.00 | 0.966 | 9.74 | 0.002 | 9.88 | 0.002 |
| Heart (%) | 0.00 | 0.211 | 0.00 | 0.908 | 0.00 | 0.249 | 0.00 | 0.221 |

A = Control; B = Heat treated rock phosphate; C = Raw rock phosphate; VS = verses.

**Table 5a.** Effect of rock phosphate inclusion levels on femoral mineralisation of rabbits.

| Parameters | BM (0%) | HTRP (25%) | HTRP (50%) | HTRP (75%) | HTRP (100%) | RRP (25%) | RRP (50%) | RRP (75%) | RRP (100%) | SEM |
|---|---|---|---|---|---|---|---|---|---|---|
| Relative femoral weight (%) | 0.36 | 0.42 | 0.46 | 0.47 | 0.39 | 0.33 | 0.39 | 0.43 | 0.54 | 0.04 |
| Final femur (%) | 0.22 | 0.19 | 0.35 | 0.29 | 0.24 | 0.21 | 0.25 | 0.26 | 0.31 | 0.03 |
| Femur ash (%) | 35.02 | 31.57 | 46.26 | 47.80 | 38.16 | 42.38 | 43.71 | 39.90 | 33.19 | 3.23 |
| Femur calcium (%) | 26.56 | 24.22 | 35.08 | 36.24 | 28.94 | 32.14 | 33.15 | 30 25 | 25.16 | 2.43 |
| Femur phosphorus (%) | 13.09 | 11.79 | 17.30 | 17.85 | 14.32 | 15.84 | 16.35 | 14.91 | 12.40 | 1.21 |
| Femur diameter (cm) | 0.53 | 0.53 | 0.70 | 0.63 | 0.67 | 0.63 | 0.63 | 0.60 | 0.57 | 0.04 |
| Femur length (cm) | 8.07 | 7.83 | 8.57 | 8.27 | 8.00 | 8.33 | 8.10 | 8.20 | 7.27 | 0.21 |
| Femur density g/cm$^3$ | 4.33 | 4.00 | 5.67 | 5.17 | 4.33 | 4.67 | 4.67 | 4.83 | 4.17 | 0.22 |
| Femur bone strength (kgf) | 38.46 | 34.47 | 50.81 | 51.92 | 41.91 | 46.54 | 48.01 | 43.82 | 36.43 | 3.49 |

BM = Bone Meal; RRP = Raw Rock Phosphate; HTRP = Heat Treated Rock Phosphate.

in the orthogonal contrast could be attributed to the presence of fluoride in the diets at varying inclusion levels. The report of Tahir *et al*. (2011) and Agbu *et al*. (2017) supported finding of this study. They found that substituting Hazara and Sokoto rock phosphate for DCP in the diets at varying inclusion levels had a significant impact ($p<0.05$) among groups for visceral organs measured.

**Effect of rock phosphate inclusion levels on femoral mineralisation in rabbits**

The effects of rock phosphate inclusion levels on femoral mineralisation in rabbits are shown in Table 5a and 5b. The physicochemical characteristics of bones suggest that bone parameters may be a more sensitive index than

**Table 5b.** Effect of rock phosphate inclusion levels on femoral mineralisation of rabbits.

| Parameters | Orthogonal Contrast | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A vs (B+C) | P>F | B vs C | P>F | A vs B | P>F | A vs C | P>F |
| Relative femoral weight (%) | 0.01 | 0.111 | 0.00 | 0.711 | 0.01 | 0.104 | 0.01 | 0.158 |
| Femur ash (%) | 76.47 | 0.135 | 7.94 | 0.62 | 84.4 | .0.118 | 54.84 | 0.202 |
| Femur calcium (%) | 44.49 | 0.131 | 5.35 | 0.59 | 49.83 | 0.111 | 31.32 | 0.200 |
| Femur phosphorus (%) | 10.72 | 0.135 | 1.18 | 0.61 | 11.9 | 0.116 | 7.63 | 0.203 |
| Femur diameter (cm) | 0.02 | 0.054 | 0.00 | 0.389 | 0.02 | 0.039 | 0.01 | 0.111 |
| Femur length (cm) | 0.00 | 0.985 | 0.22 | 0.207 | 0.02 | 0.671 | 0.02 | 0.697 |
| Femur density g/cm3 | 0.33 | 0.476 | 0.26 | 0.528 | 0.50 | 0.383 | 0.15 | 0.631 |
| Femur bone strength (kgf) | 89.94 | 0.134 | 7.62 | 0.653 | 97.41 | 6.60 | 66.00 | 0.195 |

A = Control; B = Heat treated rock phosphate; C = Raw rock phosphate; VS = verses.

**Table 6a.** Effect of rock phosphate inclusion levels on humeral mineralisation of rabbits.

| Parameters | BM (0%) | HTRP (25%) | HTRP (50%) | HTRP (75%) | HTRP (100%) | RRP (25%) | RRP (50%) | RRP (75%) | RRP (100%) | SEM |
|---|---|---|---|---|---|---|---|---|---|---|
| Relative humeral weight (%) | 0.19 | 0.20 | 0.24 | 0.22 | 0.19 | 0.17 | 0.19 | 0.21 | 0.26 | 0.02 |
| Humerus density g/cm$^3$ | 2.67 | 2.00 | 3.33 | 2.67 | 2.67 | 2.00 | 2.33 | 3.00 | 2.00 | 0.13 |
| Humerus ash (%) | 34.99 | 31.54 | 46.23 | 47.77 | 38.13 | 42.36 | 43.69 | 39.88 | 33.15 | 3.23 |
| Humerus calcium (%) | 26.53 | 24.20 | 35.05 | 36.22 | 28.91 | 32.12 | 33.12 | 30.23 | 25.13 | 2.43 |
| Humerus phosphorus (%) | 13.06 | 11.77 | 17.27 | 17.83 | 14.23 | 15.81 | 16.31 | 14.88 | 12.37 | 0.62 |
| Humerus length (cm) | 6.27 | 5.53 | 6.24 | 5.85 | 6.03 | 6.20 | 6.07 | 5.97 | 5.67 | 0.14 |
| Humerus diameter (cm) | 0.40 | 0.43 | 0.60 | 0.53 | 0.53 | 0.47 | 0.43 | 0.50 | 0.47 | 0.04 |
| Humerus bone strength (kgf) | 38.09 | 34.64 | 50.76 | 52.46 | 41.87 | 46.51 | 47.97 | 43.79 | 36.40 | 3.54 |

BM = Bone Meal; RRP = Raw Rock Phosphate; HTRP = Heat Treated Rock Phosphate

**Table 6b.** Effect of rock phosphate inclusion levels on humeral mineralisation of rabbits.

| Parameters | Orthogonal Contrast (Mean Square) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A vs (B+C) | P>F | B vs C | P>F | A vs B | P>F | A vs C | P>F |
| Relative humeral weight (%) | 0.00 | 0.381 | 0.00 | 0.753 | 0.00 | 0.354 | 0.00 | 0.463 |
| Humerus density g/cm$^3$ | 0.07 | 0.502 | 0.67 | 0.054 | 0.00 | 1.000 | 0.27 | 0.202 |
| Humerus ash (%) | 76.46 | 0.135 | 7.97 | 0.620 | 84.42 | 0.117 | 54.80 | 0.202 |
| Humerus calcium (%) | 44.58 | 0.130 | 5.35 | 0.590 | 49.92 | 0.111 | 31.39 | 0.200 |
| Humerus phosphorus (%) | 10.71 | 0.132 | 1.14 | 0.614 | 11.85 | 0.116 | 7.65 | 0.201 |
| Humerus length (cm) | 0.28 | 0.049 | 0.02 | 0.558 | 0.30 | 0.042 | 0.20 | 0.087 |
| Humerus diameter (cm) | 0.02 | 0.031 | 0.02 | 0.046 | 0.04 | 0.009 | 0.01 | 0.139 |
| Humerus bone strength (kgf) | 102.84 | 0.116 | 9.60 | 0.620 | 112.37 | 0.101 | 74.66 | 0.176 |

A = Control; B = Heat treated rock phosphate; C = Raw rock phosphate; VS = verses.

swine growth indices for determining the ideal amounts of calcium and phosphorus in diets, according to Kaankuka (1990). The author evaluated the effects of sodium phosphate, dicalcium phosphate, and defluorinated rock phosphate on several bone properties and found similar levels for bone meal, calcium, and phosphorus. The effects of dietary calcium and phosphorus levels on various bone properties have been the subject of numerous studies. The outcomes of this type of research vary according to the parameters and dietary interventions that are used. Longitudinal, internal, and exterior shaft diameters, breaking strength, weight, specific gravity, and cortical index are among the routinely measured physiochemical properties of bones; additional metrics include bone meal and the calcium and phosphorus content of different bones (Kaankuka, 1990). There were no significant differences (p>0.05) in all parameters measured for relative femur weight, femur ash, femur

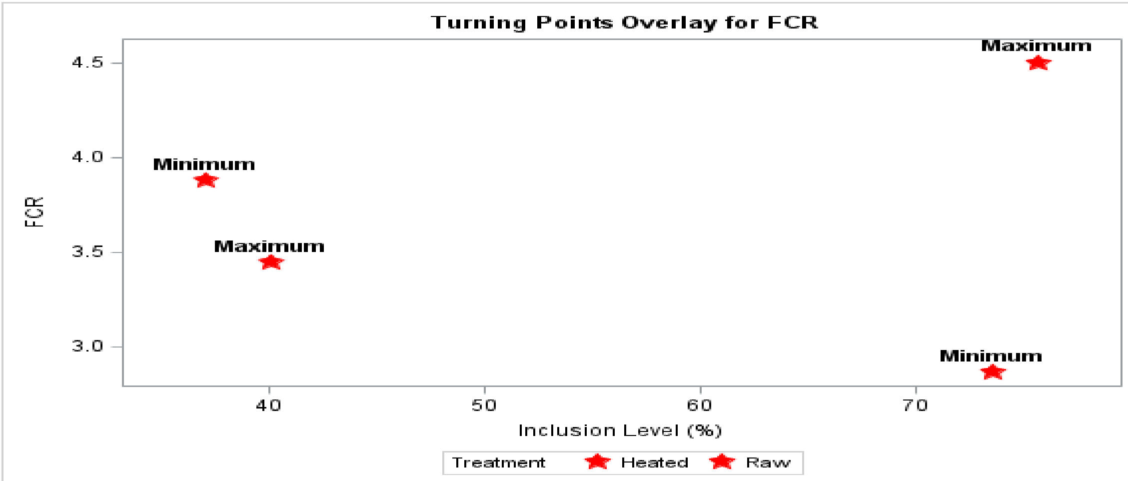


**Figure 1.** Polynomial regression of feed conversion ratio for the effect of raw rock phosphate and heat-treated rock phosphate diets' inclusion levels on growth performance of rabbits.

calcium, femur phosphorus, femur diameter, femur length and femur bone strength.

### Effect of rock phosphate inclusion levels on humeral mineralisation in rabbits

The effects of rock phosphate inclusion levels on humeral mineralisation in rabbits are shown in Table 6a and 6b. Humeral mineralisation in rabbits had no significant difference (p>0.05) as observed for relative humerus weight, humerus density, humerus ash, humerus calcium, humerus phosphorus, humerus length, humeral diameter and humeral bone strength. This followed the same trend as observed in femoral statistical analyses (Kaankuka, 1990).

## Conclusion

The findings from this study on the general performance of rabbits revealed that rock phosphate was a viable alternative to bone meal. The threat of nutrient loss to complexes was reduced through the adopted processing method of heat treatment, which tends to deflourinate rock phosphate, thereby improving growth performance, carcass quality and bone mineralisation.

## CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest that have influenced the content of this publication.

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