

# Evaluation of Mineral Composition, Physical Properties, and Nutritional Value of Local Rock Flours as Feed Supplements for Laying Quails

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**Abstract.** The province of West Sumatra is rich in natural rock deposits that could serve as alternative mineral sources in poultry diets. This study evaluated the mineral composition, physical properties, and nutritional value of rock flour from four areas: Padang Panjang (PP), Palupuh (PH), Halaban (HB), and Kamang (KG). Rock flour samples (50 kg each) were analyzed for macro- and trace minerals, particle size distribution, bulk density, and angle of repose. Their nutritional potential was tested by supplementing 2.5–9.0% rock flour in iso-nitrogenous, iso-caloric, and iso-calcium diets for 200 laying quails (*Coturnix coturnix japonica*), allocated into five dietary treatments: basal diet + 2.5% oyster shell (control, P0), + 9% PP (P1), + 7% PH (P2), + 6% HB (P3), and + 2.5% KG (P4), with 4 replicates of 10 birds each. Calcium content varied widely (5.08–39.74%), with KG containing the highest level ( $p < 0.01$ ). Rock flours were also rich in Fe (643–3611 ppm), Mn (29.6–320.3 ppm), and Zn (2.50–14.02 ppm). Bulk density ranged from 1.12–1.58 g/mL, and fine particles ( $< 250 \mu\text{m}$ ) dominated (52–88%). Dietary treatments had positive effects on egg production, feed conversion ratio (FCR), and eggshell quality. Kamang rock flour (P4) achieved the highest egg production ( $333.5 \pm 8.6 \text{ g/bird/day}$ ), heaviest eggshells ( $0.78 \pm 0.03 \text{ g}$ ), and the lowest FCR ( $3.42 \pm 0.11$ ), while maintaining tibia bone weight ( $0.84 \pm 0.02 \text{ g}$ ) comparable to the control. These results indicate that locally sourced Kamang rock flour is a viable alternative to oyster shells for improving production performance and bone mineralization in laying quails.

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## 1 Introduction

The domestic quail is an excellent layer, with hens starting to lay at 6–10 weeks of age and producing 200–300 eggs per year. Due to their small digestive systems and limited feed intake, laying quails require precise nutrition, including adequate mineral supplements such as grit and calcium to maintain egg production and shell integrity. During the laying period, quail needs 3–4% Ca in the diet, far exceeding the phosphorus requirement of 0.5–0.8%, to ensure robust eggshell formation.. Calcium deficiency often results in fragile and thin eggshells, increasing the risk of egg breakage and economic loss..

Traditionally, calcium supplementation in poultry has relied on limestone and crushed seashell sources, such as oyster shells. These materials provide grit that helps retain calcium in the gizzard, but high inclusion levels (e.g., >3% limestone powder) can reduce feed intake [6]. Moreover, inherent variability in the mineral composition, particle size, and solubility of limestone can influence calcium and phosphorus digestibility and bird performance.. Bivalve shells are less effective as sources of minerals and grit due to their soft texture.. In recent years, researchers have also explored the use of mineral nanomaterials to enhance bioavailability, feed efficiency, and animal growth; however, these approaches involve greater complexity and regulatory considerations .

Alternatively, rock flour (also known as rock dust or mineral fines) is gaining traction for its role in agriculture as a soil amendment. Rich in macronutrients (e.g., calcium, magnesium, potassium) and trace elements (e.g., iron, phosphorus, micronutrients), rock flour provides a broad nutrient profile with slow-release properties. These characteristics suggest potential as a poultry feed supplement that supports both calcium nutrition and grit functionality, particularly in areas such as West Sumatra, which are rich in natural rock deposits.

Given this background, evaluating rock flour from local deposits as a feed supplement for laying quails is both novel and warranted. This study aimed to assess the mineral composition, particle size distribution, bulk density, and angle of repose of rock flour sourced from four distinct areas (Padang Panjang, Palupuh, Halaban, and Kamang) and to test its nutritive value when incorporated into diets at levels of 2.5–9%, compared to conventional oyster shell supplementation. Parameters including feed intake, egg production, feed conversion ratio, eggshell quality, and tibial weight in laying quails were evaluated to assess the potential of rock flour as an effective and safer alternative mineral source

## 2 Materials and Method

### 2.1 Collection and analysis of rock flour samples

Samples of rock flour (each 50 kg) were collected from four local mining companies located in four concession areas in West Sumatra: Padang Panjang (PP), Palupuh (PH), Halaban (HB), and Kamang (KG). The mining companies process natural rock deposits into calcite, dolomite, or magnetite flour by crushing, grinding, and sieving. Each sample was tested for mineral content, particle size, and physical properties. The minerals measured included calcium (Ca), magnesium (Mg), phosphorus (P), potassium (K), sodium (Na), manganese (Mn), cobalt (Co), zinc (Zn), iron (Fe), copper (Cu), and selenium (Se).

Particle size was measured with a Retsch VS 1000 sieve shaker. About 300 g of each sample was dried in an oven for 24 hours, then sieved for 10 minutes into four size groups:

- Coarse: > 600  $\mu\text{m}$
- Medium: 501–600  $\mu\text{m}$
- Small: 250–500  $\mu\text{m}$

- Fine: <250  $\mu\text{m}$

The amount of material in each size group was weighed and expressed as a percentage of the total sample.

Physical properties measured were bulk density and angle of repose. Bulk density was calculated by filling a 100-mm graduated cylinder with the sample, weighing it, and dividing the weight by the volume it filled.

The angle of repose ( $^\circ$ ) was measured by letting the sample flow from a cylinder onto a flat surface to form a cone-shaped pile. We measured the pile's height (h) and base diameter (d) and calculated the angle using the formula:

$$\alpha = \cot^{-1} \left( \frac{2h}{d} \right)$$

## 2.2 Feeding trial

The nutritive values of rock flour were evaluated by mixing 2.5-9% of rock flour with a basal diet. Freshwater oyster shell meal was used as a control. There were five dietary treatments: a basal diet supplemented with 2.5% oyster shell (control diet) (P0) and basal diets supplemented with 9% PP (P1), 7% PH, 6% HB, and 2.5% KG, respectively. Basal diets were prepared using three main components: yellow corn, rice bran, and commercial layer concentrate, with mean levels of 41.2%, 6.5%, and 41.0 %, respectively. All diets were formulated to be iso-nitrogenous and iso-caloric. Table 1 presents the formulation of the experimental diets, including their nutrient and energy content. The nutrient and energy compositions, calculated based on the chemical analysis of feed components, met the standard requirements of laying quail during the production period recommended by the NRC [1].

The experimental diets were offered for 6 weeks to 200 laying quails, aged 8 weeks and averaging  $127.29 \pm 10.44$  g per bird. The quails were grouped into 20 experimental units, each containing 10 birds, with 4 replications per treatment. The birds were randomly housed in battery cages fitted with feed and water troughs. The feeding trial commenced with approximately 20% of quail-day egg production. The birds were maintained and cared for by following animal ethics regulations concerning their holding, rearing, slaughtering, and proper handling, as outlined in Indonesia's Law No. 18 of 2009 (section 66). The following performance parameters were assessed: feed intake, egg production, feed conversion ratio (FCR), egg weight, eggshell quality, tibia bone mineralization, and weights of the gizzard and liver.

**Table 1.** Feed composition and crude nutrient and energy content of experimental diets supplemented with oyster shell and different sources of rock flour.

Feed ingredients (%)	Control (Oyster shell)	Sources of local rock flour:			
		Padang Panjang	Palupuh	Halaban	Kamang
	P0	P1	P2	P3	P4
Yellow corn	43.0	37.5	39.5	43.0	43.0
Rice bran	10.0	2.5	4.0	6.0	10.0
Commercial concentrate	40.0	43.0	42.0	40.0	40.0
Coconut oil	2.0	4.5	4.0	2.5	2.0
Steam bone meal	2.0	3.0	3.0	2.0	2.0
Freshwater oyster shell	2.5				
Kitchen salt	0.5	0.5	0.5	0.5	0.5
Padang Panjang rock flour		9.0			

Feed ingredients (%)	Control (Oyster shell)	Sources of local rock flour:			
		Padang Panjang	Palupuh	Halaban	Kamang
	P0	P1	P2	P3	P4
Palupuh rock flour			7.0		
Halaban rock flour				6.0	
Kamang rock flour					2.5
Total	100.0	100.0	100.0	100.0	100.0
Crude nutrient and energy content					
Crude Protein (%)	17.67	17.26	17.29	17.19	17.67
Crude fat (%)	6.02	7.52	7.22	6.00	6.02
Crude fiber (%)	6.44	5.52	5.72	5.96	6.44
Ca (%)	3.01	3.05	3.02	3.05	3.07
P (%)	0.92	1.08	1.05	0.90	0.91
Metabolizable energy (kcal/kg)	2727.98	2706.17	2731.43	2705.78	2727.98

### 2.3 Statistical analysis

Data on particle size and physical properties were analysed using a completely randomised design consisting of  $4 \times 3$ . Four sources of rock flour and three measurements served as replications. Data from the feeding trial were analysed using a completely randomised design with five diet treatments and four laying quail groups as replicates. Additionally, standard deviations and 95% confidence levels were assessed. Duncan's Multiple Range Test (DMRT) was employed to separate means. Differences were considered statistically significant at  $p < 0.05$ .

### 2.4 Statistical analysis

The survey result data is calculated as an average and a percentage. Data on forage biomass production and mineral content of soils and forage were statistically analysed using a one-way analysis of variance (ANOVA) with SPSS software version 18. The variance analysis was followed by Duncan post hoc multiple comparisons to estimate significant differences between means at  $p < 0.05$ . The results were expressed as mean  $\pm$  SD. The mean concentrations of the determined forage minerals were compared with the standard mineral requirements of grazing cattle.

## 3 Results and Discussion

### 3.1 Mineral composition of rock flour

Table 2 shows the macro- and trace-mineral content of rock flours from four deposits in West Sumatra: Padang Panjang, Palupuh, Halaban, and Kamang. The samples differed noticeably in their mineral composition, which influenced their potential as poultry feed supplements.

Kamang rock flour had the highest calcium content (36.9%), far exceeding the laying quail's requirement of 2.5–3.0% [2]. This makes it a strong candidate for supporting eggshell formation and skeletal health. It also contained the highest levels of phosphorus (88.18 ppm) and potassium (40.00 ppm), minerals essential for energy metabolism, bone strength, egg production, and neuromuscular function [3]. While its trace mineral content was lower than Halaban and Palupuh, the combination of abundant calcium, phosphorus, and potassium

provides a balanced macro-mineral profile that can improve both shell quality and metabolic efficiency.

Halaban had the second-highest calcium content (15.5%) and a notable cobalt content (1.59 ppm), which is essential for vitamin B<sub>12</sub> synthesis and metabolic activity [4]. Palupuh showed the highest magnesium content (12%) and a diverse trace mineral profile (iron, manganese, copper), which can support reproductive performance and antioxidant defenses [5,6,7]. Padang Panjang contained relatively low macro-minerals but had the highest zinc concentration (14.02 ppm), which is important for immunity and tissue repair [8].

The present results indicate that Kamang and Halaban are best suited for calcium supplementation, Palupuh for broad-spectrum mineral enrichment, and Padang Panjang for targeted zinc fortification. Blending these sources could offer a balanced, cost-effective mineral supplement for laying quails.

**Table 2.** Mineral composition of rock flour derived from different local deposit areas in West Sumatra (ppm).

Minerals	Deposit areas:			
	Padang Panjang	Palupuh	Halaban	Kamang
Macro minerals				
Calcium (Ca)	5,845.94	75,681.03	151,550.08	368,890.00
Magnesium (Mg)	4,672.90	12,1840.08	8,315.58	1,813.00
Phosphorus (P)	24.71	32.86	13.76	88.18
Potassium (K)	13.32	19.70	19.04	40.00
Sodium (Na)	81.54	35.37	43.73	50.00
Micro minerals				
Manganese (Mn)	81.54	320.3	43.23	29.59
Cobalt (Co)	nd*	nd*	1.59	0.91
Zinc (Zn)	14.02	7.51	2.46	3.98
Iron (Fe)	1,662.76	3,611.48	360.96	643.1
Copper (Cu)	2.10	2.88	0.78	0.76

\*)Not detected by <0.004; Se: not detected by <0.02

### 3.2 Particle size and physical properties

Table 3 compares particle size, bulk density, and angle of repose. These factors affect feed mixing, flowability, and mineral bioavailability. Kamang contained the highest proportion of medium and coarse-sized particles (>500  $\mu\text{m}$ , 33.1%), which may reduce dust and improve handling. Its lower bulk density (1.10 g/mL) allows for blending well with lighter feed ingredients, minimising segregation. However, its higher angle of repose (51.79°) indicates reduced flowability, which may necessitate adjustments to the processing during automated feed production.

Halaban had the highest proportion of fine particles (<250  $\mu\text{m}$ , 83.3%), which increases surface area and potentially improves mineral absorption [9], but also raises dust concerns [10]. Palupuh and Padang Panjang had intermediate particle sizes and good flowability, with Palupuh showing the lowest angle of repose (47.28°).

From a supplementation standpoint, Kamang's coarser structure may slow mineral release, supporting sustained availability in the digestive tract, while its low bulk density reduces the risk of feed stratification. This physical profile, combined with its high calcium-

phosphorus-potassium content, likely contributed to its superior performance in the feeding trial.

**Table 3.** The mean particle size, bulk density, and angle of repose of rock flour derived from different local deposit areas in West Sumatra.

Minerals	Deposit areas:			
	Padang Panjang	Palupuh	Halaban	Kamang
Particle size (%)				
Fine (<250 $\mu\text{m}$ )	69.31b $\pm$ 0.62	66.26b $\pm$ 1.22	83.32a $\pm$ 0.72	50.84c $\pm$ 0.64
Small (250-500 $\mu\text{m}$ )	22.72a $\pm$ 0.49	22.92a $\pm$ 0.58	15.27b $\pm$ 0.58	16.05b $\pm$ 0.38
Medium (501-600 $\mu\text{m}$ )	5.83c $\pm$ 0.12	8.64b $\pm$ 0.82	0.33d $\pm$ 0.02	25.32a $\pm$ 0.27
Coarse (> 600 $\mu\text{m}$ )	2.12b $\pm$ 0.10	2.16b $\pm$ 0.15	1.08c $\pm$ 0.13	7.80a $\pm$ 0.12
Physical properties				
Bulk density (g/ml)	1.62 $\pm$ 0.40	1.18 $\pm$ 0.42	1.54 $\pm$ 0.54	1.10 $\pm$ 0.39
Angle of repose ( $^{\circ}$ )	48.88 $\pm$ 5.71	47.28 $\pm$ 8.34	48.58 $\pm$ 4.43	51.79 $\pm$ 6.77

<sup>a,b,c,d</sup> Means within a row with different superscripts differ significantly ( $P < 0.05$ )

### 3.3 Laying performances, eggshell quality, and bone mineralization

Table 4 presents the performance of laying quails fed diets supplemented with various local rock flours - Padang Panjang (P1), Palupuh (P2), Halaban (P3), and Kamang (P4) - compared to a control diet that contained oyster shell (P0). Although statistical differences were not significant ( $p > 0.05$ ), trends in Table 4 indicate performance advantages for Kamang and Halaban. Feed intake was highest for Halaban (27.08 g/day) and Kamang (26.90 g/day), possibly reflecting better palatability and metabolic benefits of their mineral profiles. Kamang produced the most eggs (32.25 per bird), the highest egg mass (333.45 g), and the best feed conversion ratio (FCR:3.42), outperforming the oyster shell control (FCR:4.49). This suggests more efficient nutrient utilisation, possibly due to its complementary calcium-phosphorus ratio, which optimises mineral metabolism and eggshell formation [11,12]. Halaban also performed well but had slightly higher mortality (15%), warranting further safety screening for contaminants [13].

As shown in Table 4, Kamang had the highest eggshell weight (0.78 g; 7.61% of egg weight) and the highest tibia bone ash (50.89%), calcium (18.98%), and phosphorus content (10.73%). These results indicate better systemic mineral retention, supporting both skeletal integrity and eggshell formation.

The combination of high calcium and phosphorus, along with a moderate proportion of magnesium and manganese, may have improved calcite crystal formation in the shell [14]. Additionally, Kamang's coarser particles could allow for a more gradual release of calcium in the gut, matching the prolonged need for calcium during shell formation [12]. Liver weights in Kamang-fed birds were slightly higher but without pathological signs, likely reflecting increased metabolic activity to process and mobilize minerals [15].

**Table 4.** The mean feed intake, egg production, feed conversion ratio (FCR), eggshell quality, tibia bone mineral composition, along with gizzard and liver weight (mean ± standard deviation) of quails supplemented with oyster shells and various sources of local rock flour over 6 weeks.

Parameter	Control diet (Oyster shell)	Diets supplemented with local rock flour derived from:			
		Padang Panjang	Palupuh	Halaban	Kamang
	P0	P1	P2	P3	P4
<b>Feed intake:</b>					
Total feed intake (g/bird)	1029.94±79.54	1028.18±77.77	1039.77±167.85	1137.16±16.88	1129.65±29.49
Daily feed intake (g/bird)	23.92±2.54	24.48±1.85	24.76±4.00	27.08±0.40	26.90±0.70
<b>Egg production :</b>					
Egg weight (g/egg)	10.09±0.33	10.11±0.30	10.79±1.29	10.21±0.02	10.31±0.40
Egg number (eggs/bird)	23.74±5.36	26.88±4.49	25.81±9.97	29.51±3.98	32.25±3.32
Egg mass (g/bird)	240.00±53.56	271.99±47.27	266.41±105.58	301.25±40.75	333.45±37.61
Quail-day egg production (%)	56.53±12.76	63.99±10.69	61.45±23.73	70.32±3.42	76.79±7.91
Feed conversion ratio (FCR)	4.49±1.25	3.83±0.45	4.26±1.19	3.82±0.42	3.42±0.35
Mortality rate (%) (bird)	7.5 (3)	5.0 (2)	7.5 (3)	15.0 (6)	5.0 (2)
<b>Eggshell quality:</b>					
Eggshell weight (g/egg)	0.75±0.03	0.76±0.03	0.75±0.02	0.75±0.03	0.78±0.04
Percentage of eggshell weight (%)	7.42±0.24	7.52±0.14	7.24±0.25	7.42±0.32	7.61±0.18
Eggshell thickness (mm)	0.20±0.00	0.19±0.00	0.20±0.00	0.20±0.00	0.20±0.00
<b>Crude ash and mineral content of tibia bones:</b>					
Crude ash (%)	48.05±1.40	46.53±2.41	49.98±2.54	46.52±4.74	50.89±1.81
Ca (%)	18.59±0.46	17.56±0.96	18.68±1.65	17.28±1.93	18.98±0.57
P (%)	9.89±0.22	10.26±1.02	9.87±0.73	10.38±0.57	10.73±0.36
<b>Gizzard and liver weight (g/bird):</b>					
Gizzard	3.05±0.29	3.12±0.31	3.28±0.72	3.02±0.15	3.20±0.29

Parameter	Control diet (Oyster shell)	Diets supplemented with local rock flour derived from:			
		Padang Panjang	Palupuh	Halaban	Kamang
	P0	P1	P2	P3	P4
Liver	2.85±0.33	2.58±0.41	3.15±0.35	2.67±0.48	3.17±0.16

The present results revealed that Kamang rock flour demonstrated the most promising performance as a calcium supplement in laying quail diets among the tested treatments. It enhanced body weight, feed intake, egg production, and feed conversion ratio (FCR) without increasing mortality. Halaban rock flour also showed good potential but requires further investigation regarding its safety profile.

### 3.4 Eggshell quality and mineralization

As shown in Table 4, Kamang had the highest eggshell weight (0.78 g; 7.61% of egg weight) and the highest tibia bone ash (50.89%), calcium (18.98%), and phosphorus content 15 integrity and eggshell formation. The combination of high calcium and phosphorus, along with a moderate proportion of magnesium and manganese, may have improved the organisation of calcite crystals in the shell [14]. Additionally, Kamang's coarser particles could allow for a more gradual release of calcium in the gut, matching the prolonged need for calcium during shell formation [12]. Liver weights in Kamang-fed birds were slightly higher but without pathological signs, likely reflecting increased metabolic activity to process and mobilize minerals.

Overall, Kamang produced the most favorable outcomes among the tested rock flour sources. Given its high calcium content, balanced macro-mineral profile, and favorable particle size distribution, Kamang rock flour represents a viable, cost-effective, and locally sourced alternative to oyster shells and imported commercial mineral premixes. These findings support the strategic use of locally available mineral resources to enhance poultry productivity and reduce reliance on imported or commercial calcium and mineral sources.

## 4 Conclusion

Local rock flours from different West Sumatran deposits showed clear differences in mineral composition and physical characteristics, which influenced their performance as dietary supplements for laying quails. Incorporating these flours into rations improved egg production, feed conversion efficiency, and eggshell quality, with Kamang rock flour delivering the most consistent benefits.

However, commercialisation should be supported by rigorous quality control measures. Batch-to-batch variation in mineral composition, potential contamination with heavy metals (e.g., lead, cadmium, arsenic), and the presence of excess trace minerals should be monitored to ensure feed safety. Additionally, long-term feeding trials are necessary to evaluate the cumulative effects on bird health, organ function, and product safety for human consumption.

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