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Original

Using Natural Mineral Pre-Mix in the Diet of Growing-Fattening Pigs

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ABSTRACT

Background: Mineral nutrition benefits pigs' bioproductive behavior. **Aim.** To evaluate the inclusion of a natural mineral pre-mix in the diet of growing-fattening YorkLand hybrid Pigs. **Methods:** Overall, 50 growing-fattening pigs were included in the experiment (40±5 kg live weight). The animals were females and castrated males distributed randomly in five groups, for an equal number of experimental diets. Group I was given feedstuff based on imported nutrients, like soy meal, and domestically produced yellow corn meal, L-lysine, and Choline, without the mineral pre-mix. The other four groups were supplied feedstuff based on imported soy meal, and domestically produced yellow corn meal, L-lysine, and Choline, with 0, 1, 2, and 3% inclusion of the mineral pre-mix, respectively. The minerals in blood, live weight gains, and mean daily gain, were determined. **Results:** Groups I, III, IV, and V showed higher calcemia levels ($P<0.05$), whereas groups III and IV had higher levels of cupremia ($P< 0.01$), and magnesemia in group IV ($P< 0.05$). These groups increased live weight and mean daily gain ($P< 0.05$). Every parameter was lower in group II ($P<0.05$). **Conclusion:** Including a natural mineral pre-mix in the diet of growing-fattening pigs from domestic sources increased their mineral status and productive behavior.

Keywords: diet, mean daily gain, live weight, natural minerals (*Source: AGROVOC*)

INTRODUCTION

Minerals are the third nutrient-limiting group in animal production (Suttle, 2010) as mineral nutrition favors the pigs' productive performance. Inorganic minerals are more widely used in swine nutrition. However, they are three-fold less absorbed and have less biological availability than organic minerals (Martínez *et al.*, 2016), since in the latter, the organic fraction (amino

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acids, proteins, organic acids, and saccharides) protect the mineral from the antagonistic effects of nutrients in the daily ration (Bruininx *et al*., 2002).

Mineral-based pre-mixes are essential in commercial feeds and whole mixed rations since they enhance and balance feeds to meet the animals' zootechnical needs. The inclusion rates of these feeds vary largely, from 0.1 to 10%, depending on the animal requirements and the characteristics of nutritional raw materials used (Martínez *et al*., 2016).

The international market offers various mineral pre-mixes, but their high prices cause low or no availability in Cuba. Hence, there is a need to have a national strategy based on natural mineral sources, such as phosphorite, magnesite, dolomite, zeolites, and calcium carbonate, which have already been used alternatively and in combination, as supplements.

The swine sector has become highly competitive recently, so proper mineral nutrition is essential to achieve cost-effective production (Luna *et al.*, 2022).

This paper aims to evaluate the effect of adding a natural mineral pre-mix in the diet of growing-fattening YorkLand hybrid pigs.

MATERIALS AND METHODS

Time-space frame

This study was done at Texico Company, a subsidiary of the Villa Clara Swine Company based in the municipality of Caibarien, which engages in pig fattening. The study lasted 32 days, between October 5 and November 7, 2023.

Formulation of the mineral pre-mix.

It used natural mineral sources from Cuban deposits, whose origin, mineral composition, and pre-set nutrient contribution are shown in Table 1.

Table 1. Origin and mineral composition of the natural mineral sources used, and their nutrient contribution in the pre-mix

Mineral sources	Location of the original deposits	Mineral composition				
		Mg	Ca	P	K	Fe
		(g/kg)				
Magnesite	Minas municipality, province of Camagüey	204.72	19.78	0.00	1.24	0.00
Phosphorite type II	Trinidad de Guedes, Unión de Reyes municipality, province of Matanzas	20.00	156.83	180.00	1.16	73.50
Calcium carbonate	Tanque Viñas, Remedios municipality, province of Villa Clara.	3.86	396.48	1.75	0.24	0.00
Zeolite	Tasajeras, San Juan de los Yeras, Ranchuelos municipality, province of Villa Clara.	5.55	41.27	0.39	12.37	0.00
Natural dolomite 5	Remedios municipality, province of Villa Clara.	108.57	242.76	0.00	0.07	0.01

Mineral sources	Mineral contribution in the pre-mix						
	Ca (g)	P (g)	K (g)	Na (g)	Cl (g)	Mg (g)	Fe (g)
Zeolite	2063.50	19.50	618.50	0.00	0.00	277.50	0.00
Calcium carbonate	99120.00	437.50	60.00	0.00	0.00	965.00	0.00
Phosphorite type II	70573.50	81000.00	522.00	0.00	0.00	9000.00	33075.00

Magnesite		989.00	0.00	62.00	0.00	0.00	10236.00	0.00
Sodium chloride		0.00	0.00	0.00	59010.00	90990.00	0.00	0.00
Natural dolomite 5		12138.00	0.00	3.32	0.00	0.00	5428.53	0.40
Total		184884.00	81457.00	1265.82	59010.00	90990.00	25907.03	33075.40
Percentual composition	%	18.49	8.15	0.13	5.90	9.10	2.59	3.31
Concentration	(g/kg)	184.88	81.46	1.27	59.01	90.99	25.91	33.08

Experimental design

Overall, 50 growing-fattening pigs (starters) were included in the experiment, both females and castrated males, aged 75 ± 5 days, and 40.0 ± 5.0 kg live weight. All the animals were commercial YorkLand supplied by El Negrito breeding facility, belonging to the same company.

Inclusion criteria: Clinically healthy animals, according to the examination performed using the functional invariants of the clinical method suggested by Cuesta, Montejo, and Duvergel, (2007).

Criteria for rejection: Animals that failed to meet the previous requirements, including animal sacrifice or death, and failure to meet the pre-established medical indications.

Five experimental groups were made up, each containing ten animals, which received the same number of diets, according to the humid-base inclusion explained in Table 2.

Table 2. Inclusion levels of different experimental diet ingredients in a humid base

Ingredients	**Group**				
	I	**II**	**III**	**IV**	**V**
Pre-mix	0.00	0.00	0.90	1.81	2.71
L-Lysine	0.00	0.40	0.40	0.40	0.40
Choline	0.00	0.08	0.08	0.08	0.08
Imported feedstuff containing 45% CP	7.93	0.00	0.00	0.00	0.00
Nationally produced yellow corn	80.60	81.63	80.45	79.26	78.07
Imported soy meal	11.47	17.88	18.17	18.45	18.73
TOTAL	100.00	100.00	100.00	100.00	100.00
Crude protein (% dry base)	15.00	15.00	15.00	15.00	15.00
Digestible energy (MJ/kg of DM)	14	14	14	14	14

The five experimental diets evaluated were iso-protein (15% CP dry base), and iso-energetic (14 MJ DE/kg DM). Feeding complied with the nutritional requirements of the NRC 2012, with a daily supply of 3.43 kg per animal/day for 20 days, and 3.49 kg per animal/day from then on, until the study was completed.

The animals in each experimental group were lodged in collective cubicles in the same house, on concrete flooring with brick and mortar walls and a two-sided fiber-cement roof from north to south. The facility ensured 0.75 m^2 of vital space per animal, with a front 28 cm trough.

Measurements

Blood samples and determinations of the mineral profile in blood.

A volume of 5 mL of blood was drawn from the cavernous sinus by venipuncture, and transferred to sterilized and demineralized conical-bottom test tubes, with threaded caps and no anticoagulants.

The samples were centrifuged at 3500 *g* for 15 minutes, then frozen at -10 °C until the spectroscopy laboratory analysis at CIAP. The macro and micro elements were determined by atomic absorption using SP-9 (PYE UNICAM) equipment, following the manufacturer's protocols, Miles, Wilkinson, and McDowell, (2001).

Animal weighing

The live weight of all the animals was measured before (day 0) and after (day 32) supplying the experimental diets. A high-precision digital balance BPE 250 (Pexac, Cuba) was used. The primary data were used to determine weight gains and mean daily gains (MDG).

Statistical analysis

The minerals in the blood were compared between the groups at the beginning and end of the experiment through one-way analysis of variance (ANOVA). In cases where significant statistical differences were observed, the LSD test was performed to compare the means, following checks to variance homogeneity and normal distribution.

Weight gain among the groups was compared through covariance analysis (ANCOVA), with the group as the main effect, and live weight as co-variable. In cases where the main effect was significant ($P<0.05$), the means were compared through LSD following checks to variance homogeneity. Meanwhile, the means were adjusted when the co-variable was statistically significant ($P<0.05$).

StatgraphicsCenturion XV.II, 2006 (StatisticalGraphic Corp., USA) was used for every statistical analysis.

RESULTS AND DISCUSSION

Mineral profile in blood

Table 3 shows the mineral levels in blood, evaluated at the beginning and end of the experiment At the start of the experiment, the Ca, Mg, and Cu concentrations in blood did not differ among the groups. However, after 32 days of supplementation, they were higher (P< 0.01) than the Ca concentration in groups I, III, IV, and V, whereas MG concentration was higher (P< 0.05) in group IV. Group II (without mineral supplementation) showed the lowest mineral values in blood.

Table 3. Average concentrations of minerals in blood at the beginning and end of the experiment in pigs

Variables	M	Group					±SE	Sig
		I	II	III	IV	V		
Ca (mmol/L)	I	3.13^{a}	2.93^{a}	3.07^{a}	3.19^{a}	3.34^{a}	0.14	NS
	F	2.66^{a}	2.34^{b}	2.79^{a}	2.80^{a}	2.75^{a}	0.08	**
Mg (mmol/L)	I	0.86^{a}	0.78^{a}	0.80^{a}	0.76^{a}	0.83^{a}	0.03	NS
	F	0.82^{ab}	0.75^{b}	0.84^{ab}	0.90^{a}	0.84^{ab}	0.04	*
Na (mmol/L)	I	136.60^{ab}	128.00^{c}	141.00^{a}	134.00^{b}	131.50^{bc}	2.44	*
	F	127.60^{a}	127.00^{a}	134.40^{a}	126.20^{a}	132.75^{a}	3.67	NS
K (mmol/L)	I	3.38^{b}	3.90^{a}	3.12^{b}	3.62^{ab}	3.40^{ab}	0.18	*
	F	3.40^{a}	3.10^{a}	3.04^{a}	3.48^{a}	3.45^{a}	0.23	NS
Cu (µmol/L)	I	24.25^{a}	23.13^{a}	22.35^{a}	25.47^{a}	25.58^{a}	1.19	NS
	F	23.99^{b}	23.89^{b}	28.50^{a}	28.87^{a}	27.58^{ab}	1.18	**
Zn (µmol/L)	I	12.05^{a}	11.46^{a}	11.78^{a}	10.60^{ab}	9.23^{b}	0.70	*
	F	12.02^{a}	12.82^{a}	12.10^{a}	11.71^{a}	10.47^{a}	1.34	NS

M: Moment I: Initial F: Final. $^{a, b, c}$: different upper scripts in the rows differed significantly (LSD). *: P< 0.5. **: P<0.1. NS: Non-significant difference

Ca and Mg increases can be explained by the inclusion and further supplementation of both minerals in the pre-mix. Cu was not part of the pre-mix, as shown in Table 1, resulting from the benefit of minerals supplemented for Cu metabolism, especially Fe, which keeps permanent interaction, favoring Cu absorption in the diet (Sutlle, 2010; Hill, 2022).

At the beginning of the experiment, the Na concentrations in blood were higher in groups I and III; K was higher in group II; and Zn was higher in groups I, II, and III, though they did not differ at the end of the experiment (Table 3). The favorable effect of supplementation on them could be influenced by the initial concentrations of NA, K, and Zn.

The most satisfying inclusion level was used in group IV, with significant increases (P< 0.05) of Ca, Mg, and Cu. The blood Zn concentrations did not increase, though not significantly (Table 3), which was remarkable since it indicates that the inclusion percentages in the pre-mix diet, the Zn: Ca ratio is maintained, with no increases in Ca and the main Zn antagonist, blocking the unspecific channels of Zn, reduces its absorption, and triggers Zn deficiency (Lonnerdal, 2000; NRC, 2012).

Animal live weight gains

The analysis of covariance (Table 4) shows that the group/treatment or levels of inclusion in the mineral pre-mix used as the main effect had a significant influence (P<0.05) on live weight increases and MDG of pigs. However, these parameters were not affected by the starting live weight used as covariable. Accordingly, the means of both indicators were compared between groups.

Table 4. Covariance analysis to evaluate the effect of mineral supplementation and initial weight on weight increases and MDG in pigs

Source	Square sum	GI	Mean square	Ratio-F	Value-P
Weight increase (kg)					
Covariable					
Initial live weight	20.43	1	20.43	0.63	0.4320
Main effect					
Group/Treatment	574.71	4	143.67	4.43	0.0045
Residues	1363.39	42	32.46		
Total (corrected)	2001.92	47			
MDG (g)					
Covariable					
Initial live weight	19957.80	1	19957.80	0.63	0.4843
Main effect					
Group/Treatment	561240.00	4	140310.00	4.43	0.0037
Residues	1,33E6	42	31700.70		
Total (corrected)	1,95E6	47			

Table 5 shows how weight increase and mean daily gain were lower (*P*<0.05) in group II, which had no mineral supplementation, compared to groups I, II, IV, and V, whose indicators did not differ among them.

Table 5. Weigh increase and MDG ($\bar{X}$ ±SE) in pigs supplemented with different inclusion levels in the mineral pre-mix

Group	n	Weight increase (kg)	MDG (g)
I	10	18.19 ± 2.19[a]	568.73 ± 68.72[a]
II	9	12.75 ± 2.03[b]	398.68 ± 63.52[b]
III	10	22.16 ± 1.82[a]	692.64 ± 57.06[a]
IV	10	23.47 ± 1.83[a]	733.57 ± 57.33[a]
V	9	24.08 ± 2.81[a]	752.75 ± 87.82[a]

[a,b] Different superscripts in the same row indicate statistical differences (P< 0.05) (LSD).

Higher live weight increases and MDG in the animals supplemented were linked to increases (P<0.05) in blood Ca, Mg, and Cu concentrations (Table 3). These minerals are necessary for bone formation and other major biological functions, and, consequently, favor pig growth and fattening (García-Contreras *et al.*, 2012).

In Ecuador, mineral and vitamin supplementation of feedstuffs to lactating piglets led to greater (P<0.05) weight increase and MDG than the animals that received no supplementation. These indicators were 21.01 kg and 690 g, respectively (Muñoz, 2023).

Two-level supplementation using organic and inorganic mineral traces enhanced the productive performance of pigs weaned at 21 days old, with an average weight of 6.70 ± 0,38 kg, regardless of the level and source (Thomaz *et al*., 2015).

In recent decades, the size of commercial pigs has increased, thus demanding higher levels of Ca and P supplementation than the ones currently recommended (Selle *et al.,* 2012).

Pig weight increase following supplementation is linked to higher Ca concentrations in blood (Table 3). This macro-element and the presence of P are constraints in commercial pig nutrition (Jeon *et al.*, 2021). This experiment did not determine P concentrations in blood, so a discussion on the effect of supplementation on these concentrations, or the repercussions they might have had on animal weight gains is not appropriate.

Considering the Ca and P ratio, and the ratio between these minerals and weight gain, and its increase in the animals supplemented could also be explained by the inclusion of P in the pre-mix, and further supplementation, thus corroborating the finding that every diet portion must be supplied with Ca and P, since diets with deficient Ca and P levels lead to organic failure of the two elements, and limit growth (Zouaoui, Létourneau-Montminy, and Guay, 2018), affecting biological efficiency and bone mineralization (Schlegel and Gutzwiller, 2020).

It must have also influenced weight increases in the animals supplemented (Table 5) and increases in blood Mg concentrations in the animals (Table 3). It can be explained by the fact that Mg is a co-factor of more than 300 enzymes, so the supplementation using this macro-element ensures proper animal health and growth on the farm (Pinotti *et al.*, 2021). Moreover, these authors claim the supplementation with Mg in pigs, raises meat quality and fertility in sows.

A higher Cu in the body augments lipase activity, stimulates growth hormone secretion, regulates the anti-oxidizing system, directly improves the immune response, and increases mRNA presence in genes involved in the post-absorptive metabolism of lipids in pigs (Espinosa and Stein, 2021). Consequently, it improves intake, feed efficiency, growth, and health (Manto, 2014; Hill, 2022).

CONCLUSION

Adding a natural mineral pre-mix in the diet of growing-fattening pigs from domestic sources increased their mineral status and productive behavior. The optimum results were found in the 2% inclusion, which raised Ca, Cu, and MG in blood; live weight and mean daily weight gain also rose.

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AUTHOR CONTRIBUTION STATEMENT

Research conception and design: MRP, JRGD, RLO, LLP, AMT; data analysis and interpretation: MRP, JRGD, RLO, LLP, AMT; redaction of the manuscript: MRP, JRGD, RLO,LLP, AMT.

CONFLICT OF INTEREST STATEMENT

The authors state there are no conflicts of interest whatsoever.