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EFFECT OF ACTIVATED CHARCOAL-AGED PALM SAP ADDITIVE SUPPLEMENTATION ON MINERAL UPTAKE AND LITTER QUALITY IN LAYING HEN

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Abstract
This study investigated the effect of an activated charcoal-aged palm sap feed additive supplementation on mineral uptake and litter characteristics in laying hen. Activated charcoal (AC) was blended with an aged palm sap to produce an activated charcoal-aged palm sap (ACAPS) additive for possible inclusion in the diets. Five experimental layer diets containing levels of AC (L2 and L3) and ACAPS (L4 and L5) at 0.50 and 1.00 % respectively were assigned to laying hen in completely randomized design, while the control diet had zero AC level. Faecal minerals were determined at the end of the experiment (12 weeks). Results obtained highlighted higher levels of minerals in the faeces, than found in the diets. Supplementing AC and ACAPS caused significant reductions ($p<0.05$) in the faecal concentration of the potassium (K), phosphorus (P), magnesium (Mg), iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn) minerals than the control especially at 1.00% levels respectively. Treated hens had higher faecal crude protein and nitrogen content, while litter odour and fly infestations were reduced in the pens housing the charcoal treated birds. Therefore, AC and ACAPS supplementation in the diets improved mineral uptake and litter quality in layers.

Keywords: Activated charcoal, fermented palm wine, faecal characteristics, mineral uptake, laying hen

Introduction

In modern poultry production, the inclusion of feed adsorbents like clay minerals in diet formulation has been widely practiced in order to immobilize toxins, plant metabolites, heavy metal contaminants from poultry diets and their associated metabolic effects on the animals (Prasai *et al.,* 2017).

Activated charcoal have also been employed as a universal adsorbent to effectively adsorb and neutralize ingested toxins and other contaminates in feed, while supplying some essential minerals to the animals (Schmidt *et al.,* 2019). It is a porous carbon product with inherent adsorptive properties (high porosity and surface area) usually produced from the pyrolysis of organic or agricultural biomass materials under limited oxygen condition.

Performance benefits resulting from activated charcoal (AC) supplementation in poultry diets have been reported (Kalus *et al.,* 2020). Even more beneficial attributes have been reported with the dietary supplementation of AC and organic acid blends in poultry diets (Rattanawut *et al.,* 2021). The capacity of AC to modify poultry litter, and faecal characteristics have also been reported. Its inclusion in feeds or litter caused reductions in free faecal moisture content, odour, gaseous emission and nutrient losses, from the faeces (Durunna *et al.,* 2018; Sha, *et al.,* 2019).

This study therefore investigates the impact of activated charcoal-aged palm sap additive on mineral uptake and faecal quality in laying hen.

Materials and methods

Activated charcoal produced from the pyrolysis of agricultural biomass/waste (pig dung, palm kernel shell and bamboo wood chips pyrolyzed in a 2.5-litre clay pot (Ohanaka *et al.,* 2021) were blended with palm wine that was left to ferment for three days to produce ACAPS as the final additive product.

Two hundred and forty (240) Isa brown layer birds, 32 weeks in lay were divided into 5 groups of forty-eight birds and 3 subgroups of 16 birds per replicated subgroup in a completely randomized design (CRD). A basal or control diet (L1) was formulated containing neither AC nor ACAPS supplementation. The L2-L3 diets had graded levels of AC at 0.50 and 1.00% in the feed respectively, while the last two diets (L4 – L5) were only different from L2, and L3 by the addition of aged palm sap. All the diets had equal proportions of all other ingredients. The diets were assayed for proximate and mineral concentration (table 1) and with the aid of atomic absorption spectrophotometry (Bulk scientific model 2010) (AOAC 2010). At the 12 weeks of experiment, faecal samples were collected from each treatment and assayed for mineral content using the AAS as earlier described.

Data collected were subjected to analysis of variance (ANOVA), while the means were separated using the Duncan Multiple Range Test of the IBM SPSS Analytical software (2017).

Table 1: Nutrient and mineral composition of experimental layer ration supplemented with activated charcoal

Parameters	L1 Control	L2 0.50% AC	L3 1.00% AC	SEM
Calcium (mg/kg)	12041.48 ^{c}	12454.74 ^{b}	13197.93 ^{a}	169.17
Magnesium (mg/kg)	2656.01 ^{a}	2110.03 ^{b}	1957.21 ^{c}	106.09
Potassium (mg/kg)	5877.52 ^{a}	5371.94 ^{b}	4986.42 ^{c}	129.22
Phosphorus (mg/kg)	7012.85 ^{a}	5805.26 ^{b}	3907.79 ^{c}	451.94
Sodium (mg/kg)	1830.60 ^{c}	2580.46 ^{b}	3474.50 ^{a}	241.46
Manganese (mg/kg)	90.31 ^{a}	73.57 ^{b}	52.37 ^{c}	5.49
Iron (mg/kg)	718.55 ^{a}	553.75 ^{b}	385.90 ^{c}	48.04
Copper (mg/kg)	10.35 ^{a}	9.00 ^{b}	8.36 ^{c}	0.30
Zinc (mg/kg)	60.91 ^{a}	55.71 ^{b}	37.43 ^{c}	3.56
Chlorine (mg/kg)	11.03 ^{c}	12.78 ^{b}	15.64 ^{a}	0.67
Proximate composition				
Metabolizable energy (ME kcal/kg)	2650.48 ^{c}	2708.88 ^{b}	2776.20 ^{a}	18.46
Crude protein (%)	19.27 ^{a}	18.10 ^{b}	16.65 ^{c}	0.38

Means with different superscript on the same horizontal row are significantly different @ $p<0.05$

Each diet contained 43% Maize, 18% Soya, 9% Palm kernel cake, 1% Fish meal, Wheat offal 18%, 3% Bone meal, 1% Oyster shell, 6% Limestone, 0.25% Salt, 0.25%, Vitamin and mineral premix, 0.25% Lysine and 0.25% Methionine.

AC = activated charcoal, ACAPS = activated charcoal-aged palm sap, L1= Layer control diet or 0.00% AC; L2 and L3 had 0.50 and 1.00% AC respectively, L4 and L5 had 0.50 and 1.00% ACAPS respectively.

Results and discussion

The mineral concentrations in the layer diets summarized in table 1 showed that calcium (Ca), phosphorus (P), potassium (K), magnesium (Mg), and sodium (Na) were the most abundant macro-minerals in the layer diets. Thus, the order of mineral abundance was Ca > P> K>Mg> Na> Fe> Mn> Zn>Cl> Cu. Generally, the supplementation of AC in the feed resulted in either significant reduction ($p<0.05$) in the dietary values of some minerals (Mg, K, P, Mn, Fe, Cu, and Zn) or significant increase ($p<0.05$) in others (Ca, Na, and Cl) beyond the control values.

The mineral content of faeces voided by the experimental laying hens (table 2) again, showed the order of abundance of minerals in the faecal output as K> P> Na> Ca> Mg> Fe> Mn> Zn> Cu > Cl. This mimicked the order of micro mineral concentrations in the layer diets, while macro minerals such as K, and Na displaced Ca, and Mg from their positions. The results suggest that there are higher concentrations of most of the minerals in the faeces, than the levels found in the diets. For example, the levels of K, P, Na, Mn, Fe, Cu voided in faeces by the control birds were much higher than the respective mineral concentrations in the control diet, with K, and Na concentrations more than doubling. The same trend was observed across AC treated groups for these minerals.

Faecal Ca, Na, and Cl concentrations of treated birds were higher than the control values, which also mimicked the trend in the experimental diets. The concentrations of these elements in the AC treated diets may have exceeded the dietary requirements of the birds thereby leading to their increased concentrations in the excreta. However, blending the AC with aged palm wine resulted in slight lowering of the Ca excretion in L5, and Na excretion in L4, and L5 when compared to the L3 diet which had the highest faecal concentrations of these minerals.

Faecal mineral concentrations of K, P, Mg, Fe, Mn, Cu, and Zn decreased significantly ($p<0.05$) below the control values due to the AC, and ACAPS supplementations. The decreasing concentrations of these minerals in the AC, and ACAPS supplemented diets (Table 2) may be responsible for these results and were linked to the adsorption properties of the AC (Wang *etal.,* 2006).

The hen fed the L4 and L5 diets had lower faecal concentrations of Cu compared to other treated groups, while the hen fed the L4 diet had the least Mg, P, Mn, Zn, and N concentrations in their excreta, which indicates better absorption of these minerals by this group.

Table 2: Faecal mineral excretion of laying birds fed AC and ACAPS supplemented diets

Parameters	L1 Control	L2 0.50% AC	L3 1.00% AC	L4 0.50% ACAPS	L5 1.00% ACAPS	SEM
Calcium (mg/kg)	3761.67^{d}	3799.23^{c}	4000.49^{a}	3981.42^{a}	3930.87^{b}	26.10
Magnesium (mg/kg)	3113.80^{a}	2897.55^{b}	2707.82^{d}	2693.21^{d}	2813.75^{c}	41.09
Potassium (mg/kg)	14908.92^{a}	14605.62^{b}	14046.96^{d}	14182.78^{c}	14154.83^{c}	87.37
Phosphorus (mg/kg)	7958.21^{a}	6333.77^{b}	6017.08^{c}	5801.82^{e}	5939.99^{d}	212.15
Sodium (mg/kg)	3850.53^{b}	4125.68^{b}	5363.81^{a}	4702.86^{ab}	4798.24^{ab}	181.50
Manganese (mg/kg)	171.42^{a}	148.12^{b}	138.45^{d}	136.25^{e}	141.29^{c}	3.42
Iron (mg/kg)	809.68^{a}	530.60^{b}	399.32^{c}	401.89^{c}	406.70^{c}	42.28
Copper (mg/kg)	15.19^{a}	12.95^{b}	12.87^{b}	12.25^{c}	12.22^{c}	0.29
Zinc (mg/kg)	54.70^{a}	42.20^{b}	38.80^{c}	38.01^{d}	39.26^{c}	1.66
Chlorine (mg/kg)	8.38^{c}	8.85^{b}	9.23^{a}	8.96^{b}	9.15^{a}	0.08

Means with different superscript on the same horizontal row are significantly different @ $p<0.05$

These findings indicate that AC, and ACAPS enhanced the bioavailability of several minerals in the diet through mechanisms that have not been fully understood. Therefore, the reductions in mineral excretions recorded in this study may have some environmental benefits since the faecal materials will serve as eco-friendly manure when applied to the soil as fertilizer.

Effect of AC and ACAPS supplementation on faecal litter and eco-characteristics

Table 3 shows the results on the effects of AC and ACAPS supplementation on the faecal moisture, crude protein, odour, and fly infestation. The moisture levels were within the 10-12% range needed to discourage fungal growth in such substrates. The L2, and L3 (AC treated group) values however differed significantly ($p<0.05$) from the control, and the L4 and L5 (ACAPS treated) groups.

The faecal materials contained high levels of crude protein (20.07 - 23.51%), with the AC, and ACAPS treated groups recording significantly higher ($p<0.05$) values than the control. This is probably due to the binding of nutrients such as proteins, and fat by the AC, which were voided along with the additives in their faeces (Wang *et al.,* 2006). Reports suggest that the internal surfaces of AC are inundated with organic nutrients as it travels through the gastrointestinal tract, thus increasing its capacity to hold water and exchange nutrients (Joseph *et al.,* 2018; Schmidt *et al.,* 2019). The higher faecal crude protein and nitrogen contents in the treated group could also indicate decreased volatilization of nutrients/gases from the faeces/litter of these birds (Sha *et al.,* 2019), and will serve as excellent fertilizer for crops. This may have been responsible for the observed dark-coloured faeces, lower odour and fly infestation recorded among the AC and ACAPS treated birds. Similar reports have also been reported by Durunna *et al.* (2018) in broilers fed diets supplemented with wood charcoal. The dietary supplementation of AC could therefore be used to improve the air and litter quality, as well as control flies in poultry farms.

Table 3: Effect of AC and ACAPS supplementation on faecal moisture, crude protein, odour and fly infestation

Parameters	L1 Control	L2 0.50% AC	L3 1.00% AC	L4 0.50% ACAPS	L5 1.00% ACAPS	SEM
Faecal moisture	10.62^{b}	9.03^{c}	12.73^{a}	10.95^{b}	10.81^{b}	0.32
Faecal crude protein (%)	20.07^{d}	23.18^{b}	23.51^{a}	22.93^{c}	23.24^{b}	0.34
Odour	High	Low	Low	Low	Low	-
Fly infestation	+	-	-	-	-	-
Nitrogen (%)	3.21^{d}	3.71^{b}	3.76^{a}	3.67^{c}	3.72^{b}	0.05

Means with different superscript on the same horizontal row are significantly different @ $p<0.05$

Conclusion

The AC, and ACAPS supplementation caused improved uptake of K, P, Mg, Fe, Mn, Cu, and Zn by the laying hen, as shown by the lower mineral concentrations in the faeces of the treated birds compared with the control. The AC dietary supplementation improved litter quality through decreased volatilization of nutrients and could also be used to improve the air quality in the poultry pen due to its ability to reduce odour, and flies' infestation of the litter. Further studies can be carried out to determine the microbial ecology of the litter/faecal droppings of laying hen fed activated charcoal-aged palm sap supplemented diets.

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