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DIETARY VITAMIN-MINERAL PREMIX REPLACEMENT WITH LEAF MEAL COMPOSITES IMPROVED THE GROWTH PERFORMANCE OF BROILER CHICKEN

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ABSTRACT

This study was aimed at evaluating the effects of full or partial replacement of dietary vitamin-mineral premix (VmP) with leaf meal composites (LMC) on performance of broiler chickens. In a completely randomised design, one-day old Arbor Acres plus chicks (n = 936) were randomly allotted to thirteen treatments, each replicated eight times. A replicate comprised nine chicks each. Air-dried leaves of *Telfaria occidentalis*, *Celosia argentea*, *Vernonia amygdalina* and *Moringa oleifera* were milled and constituted in equal proportions to a leaf meal composite (LMC). Diets were formulated with the LMC incorporated in the diets at 1.5, 3.0 and 4.5 % and the VMP at 0.000, 0.125, 0.250 and 0.375 % in a (3 x 4) +1 augmented factorial arrangement. Treatments 1 (T_1), 2 (T_2) and 3 (T_3) contained only 1.5, 3.0 and 4.5 % LMC, respectively, without VmP inclusion. Treatments 4 (T_4), 5 (T_5) and 6 (T_6) each contained 0.125 % VmP alongside 1.5, 3.0 and 4.5 % LMC, respectively. Treatments 7 (T_7), 8 (T_8), and 9 (T_9) also had 0.25 % VmP each alongside 1.5, 3.0 and 4.5 % LMC, respectively. Treatments 10 (T_{10}), 11 (T_{11}) and 12 (T_{12}) each contained 0.375 % VmP with 1.5, 3.0 and 4.5 % LMC, respectively, while Treatment 13 (T_{13}) contained 0.25 % VmP only. Chicks were fed from day 1-21 (starter) and 23-42 (finisher). Increasing dietary VMP supplement resulted in reduced ($p < 0.05$) weight gain (WG) and increased feed conversion ratio (FCR), while higher supplemental LMC increased WG but reduced FCR of chicken. Similar result trends were obtained for the chickens at the finisher phase. Effects of LMC combinations with VmP in chickens on T_2 (2.34 ± 0.22), T_3 (2.33 ± 0.17), T_5 (2.30 ± 0.28) and T_9 (2.00 ± 0.19) on FCR were similar ($p > 0.05$) but lower ($p < 0.05$) than in other treatments. Optimal FCR of 2.25 (starter) and 2.44 (finisher) were attained with 3.43 ($R^2 = 0.73$) and 3.06 % ($R^2 = 0.99$) LMC inclusions, respectively. Thus, LMC successfully replaced VmP in broiler chicken diets without any negative implication on growth performance.

Key words: broiler starter; chicken performance; supplemental vitamin premix; dietary leaf meal; feed conversion ratio

INTRODUCTION

Vitamin-mineral premix (VmP) remained an essential component of feed for broiler chicken as the gut of broilers cannot synthesize adequate vitamin and minerals (Islam *et al*., 2004). Synthetic single vitamin and minerals for producing VmP are manufactured by few companies globally. They are, therefore, expensive and subject to sporadic scarcity, which makes it imperative to seek for viable alternatives to address economic challenges faced by farmers in the rural areas of the developing world. The consistent challenge of importation and scarcity of key ingredients also allows loop of variation in quality and claims by manufacturer of vitamin-mineral premix and the means of proving the veracity of products claim are also lacking (Asaduzzman *et al*., 2005, Ogunwole *et al*., 2012).

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Green leafy vegetables have been previously investigated as alternative feed ingredient in form of leaf meal to address economic challenge of high cost of conventional VmP (Tesfaye *et al*., 2013). Leaf meal has been used largely in broiler diets to replace macro feed ingredients like energy and protein (Onyimonyi and Onu, 2009; Gadzirayi *et al*., 2012; Abu *et al*., 2015). Apart from being rich in macro nutrients, such as protein and energy, some green leafy vegetables are known to be innately rich in vitamins and minerals (Rickman *et al*., 2007, Achikanu *et al*., 2013, Uraku *et al*., 2015). The need to find alternative sources of VmP, therefore, places a feasible option on the use of vegetable leaves as ingredient in this category.

The high moisture content of vegetable leaves is, however, a challenge to their use in poultry feed. Different drying methods, employed to retain the inherent nutrients, have been documented (Mosuro, 2018; Mosuro and Ogunwole, 2019). Air drying was the acclaimed method of drying the vegetable leaves (Onayemi and Badifu, 1987; Lakshmi and Vimala, 2000; Krokida and Maroulis, 2007; Sagar and Suresh, 2010; Naikwade, 2014; Mosuro and Ogunwole, 2019).

The VmP developed from locally sourced materials have been successfully used in poultry production in Nigeria (Bolu and Balogun, 2003; Malik *et al*., 2010; Oyewole *et al*., 2013). However, the ingredients employed in the trials were not solely derived from leaf meals. Information on the use of supplemental VmP developed solely from leaf meal in broiler chicken production is still very scanty. Hence, this study was aimed at assessing the effect of replacing dietary VmP supplement with LMC on the growth performance of broiler chicken.

MATERIAL AND METHODS

Experimental location

The experiment was carried out at the Poultry Unit of the Teaching and Research Farm, University of Ibadan, Ibadan, Nigeria. The study area lies between longitude of 7°27.05 north and 3°53.74 of the Greenwich Meridian east at an altitude of 200 m above sea level. Average temperature and relative humidity of the location is between 23-42 °C and 60-80 %, respectively (SMUI, 2018). The trial was undertaken between the month of September and November.

Experimental animals and diets

One-day old Arbor Acres plus broiler chicks (n = 936) were randomly allotted to 13 dietary treatments, each treatment was replicated eight times, a replicate comprised nine chicks. The allocation was done using the Experimental Animal Allotment Program (EAAP) version 1.1 according to Kim and Lindemann (2007). A conventional open-sided deep litter house partitioned into 104 cubicles of one square metre each was used to house the birds. Leaves of *Telfaria occidentalis* (HOOK. f),

Table 1. Layout of experimental diets

Dietary Treatment	LMC Inclusion (%)	VmP Inclusion (%)
Treatment 1	1.5	0
Treatment 2	3.0	0
Treatment 3	4.5	0
Treatment 4	1.5	0.125
Treatment 5	3.0	0.125
Treatment 6	4.5	0.125
Treatment 7	1.5	0.25
Treatment 8	3.0	0.25
Treatment 9	4.5	0.25
Treatment 10	1.5	0.375
Treatment 11	3.0	0.375
Treatment 12	4.5	0.375
Treatment 13	0	0.25

Celosia argentea (LINN), *Moringa oleifera* (LAM) and *Vernonia amygdalina* (DEL) were collected, destalked and washed before indoor air-drying on perforated plastic trays to constant weight. The air-dried leaves were milled and mixed in equal proportion to constitute the leaf meal composite (LMC). Detailed description of air drying of the different leaves and constitution into LMC has been succinctly documented (Mosuro and Ogunwole, 2019). The commercial VmP used in the trial was procured from a popular retail outlet in Ibadan, Nigeria.

The thirteen isocaloric and isonitrogenous experimental diets formulated contained LMC or VmP as well as the different combinations of both the LMC and VmP.

The gross composition of the basal starter and finisher diets is shown in Table 2. The chickens were fed the diets and supplied water *ad libitum*. The experiment was a {1+ (3×4)} augmented factorial arrangement in a completely randomised design. The factorial arrangement had three levels of LMC inclusions at 15, 30 and 45 g.kg^{-1} with four inclusion levels of VMP at 0, 1.25, 2.5 and 3.75 g.kg^{-1}.

The model is as shown below:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \alpha_i\beta_j + e_{ijk}$$

Where:

Y_{ijk} = Observation k in ith level of factor A and Jth level of factor B

μ = Overall mean population

α_i = Effect of ith level of factor A

β_j = Effect of ith level of factor B

$\alpha_i\beta_j$ = Effect of interaction of factor A and factor B

e_{ijk} = Random error with mean 0 and variance σ^2

Standard brooding, rearing protocols and immunisation were strictly adhered to, as scheduled for broiler. The weekly feed intake (FI) was recorded by subtracting the left over feed from the feed supplied. Chickens were weighed weekly and accurate records of body weight changes were taken at the beginning and end of the starter (day 1-21) and finisher (day 21-42) phases. The FI and weight gain (WG) records were used to calculate the feed conversion ratio (FCR) (i.e. feed consumption (kg) per kg weight gain) using this formula:

$$\frac{\text{Total feed intake (kg)}}{\text{Weight gain (kg)}}$$

Table 2. Gross composition of basal starter and finisher diets fed to experimental chicken (g.100 g^{-1})

Ingredients	Starter diet (g.100 g^{-1})	Finisher diet (g.100 g^{-1})
Soybean cake	38.00	30.00
Soya oil	2.00	2.00
Wheat offal	7.24	7.24
Table salt	0.25	0.25
Oyster shell	0.50	0.50
Di-calcium phosphate	1.50	1.50
*Vitamin-mineral premix^{k}	-	-
Leaf Meal Composite^{m}	-	-
Methionine	0.15	0.15
Lysine	0.05	0.05
Coccidostat (Lasalocid)	0.06	0.06
Total	99.75	99.75
Calculated nutrients:		
Crude protein (%)	22.08	19.38
Metabolisable energy (kJ.kg^{-1})	12,686.14	13,131.02

*1kg of vitamin-mineral premix contains: Vitamin A 10,000,000IU; Vitamin D3 - 2,000,000IU; Vitamin E - 20,000IU; Vitamin K - 2,250mg; Thiamine B1 - 1,750mg; Riboflavin B2 - 5,000mg; Pyridoxine B6 - 2,750mg; Niacin - 27,500mg; Pantothenic acid - 7,500mg; Biotin - 50mg; Choline chloride - 400g; Antioxidant - 125g; Magnesium - 80 g; Zinc - 50 mg; Iron - 20 g; Copper - 5g; Iodine - 1.2 g; Selenium - 200 mg; Cobalt - 200 mg

k = The dietary layout in Table 1 contains the level of VmP in the respective experimental diets

m = See Table 1 for the corresponding levels of LMC in the respective experimental treatment

Data were subjected to analysis of variance (SAS, 2012). Means were separated using orthogonal contrast of the same software at $\alpha_{0.05}$.

RESULTS

The main effect of varying supplemental VmP on growth performance of broiler chicken at the starter phase is shown in Table 3. The FI of broiler chicks was not significantly affected ($p > 0.05$) by dietary inclusion of supplemental VmP at the starter phase. The FI ranged from 921.37 g in broiler chicks with no dietary inclusion of VmP to 967.25 g in those on 0.25 % supplemental VmP. However, WG in broiler chicks fed diets without VmP (421.90 g) was higher ($p < 0.05$) than in other dietary treatments. The WG of 403.75 g and 403.78 g in chicks on 0.125 % and 0.375 % supplemental VmP, respectively, were similar ($p > 0.05$). Lower ($p < 0.05$) WG of 379.58 g was observed in chicks on 0.25 % dietary VmP supplement. The FCR of 2.35, 2.55 and 2.39 in chicks on 0.125, 0.25 % and 0.375 % levels of VmP inclusions, respectively, were similar ($p > 0.05$) to 2.18 in those on diets without supplemental VmP.

The main effect of varying inclusion levels of LMC on performance of broiler chickens at the starter phase is shown in Table 4. The FI was not significantly affected ($p > 0.05$) by the different dietary supplementation of LMC for broiler starter chickens. However, the 305.61 g WG of chicks on diets without dietary LMC supplement was significantly lower ($p < 0.05$) than in other treatments. Broiler chicks on 1.5 % LMC had 418.57 g of WG, which was higher ($p < 0.05$) than in those on other dietary treatments. The FCR followed the same trend with lower but similar ($p > 0.05$) FCR in chicks on supplemental LMC compared with the higher ($p < 0.05$) FCR of 3.16 for those on diets without LMC.

Effects of interaction of dietary VmP and LMC supplements on performance indices of broiler starter chicks are shown in Table 5. There were significant variations ($p < 0.05$) in WG and FCR. The FI was not significantly affected ($p > 0.05$) by the treatments. The WG of broiler chicks on T_1 (417.88 g) T_2 (417.40 g), T_3 (430.42 g), T_4 (417.94 g), T_7 (415.01 g), T_8 (409.86 g) and T_{10} (423.44 g) were similar ($p > 0.05$) but significantly higher ($p < 0.05$) than those on the control diets T_{13} (305.61 g). Broiler chicks on other five diets (T_{12}, T_{11}, T_9, T_6 and T_5) had similar WG ($p > 0.05$) values ranging from 387.82 g

Table 3. Main effect of dietary supplement of vitamin-mineral premix on performance of starter broiler chickens

VMP Inclusion (%)	0.00	0.125	0.25	0.375	SEM	p value
Feed intake (g/bird/21days)	921.37	949.91	967.25	963.78	12.34	0.055
Weight gain (g/bird/21days)	421.90^{a}	403.75^{ab}	379.58^{b}	403.78^{ab}	5.82	0.041
Feed-conversion ratio	2.18^{b}	2.35^{ab}	2.55^{b}	2.39^{ab}	0.02	0.038

SEM: Standard error of the mean; VMP: Vitamin-mineral premix
Means along the same row with different superscripts are significantly different ($p < 0.05$)

Table 4. Main effect of dietary supplement of leaf meal composite on performance of broiler starter chicks

LMC Inclusion (%)	0.00	1.50	3.00	4.50	SEM	p value
Feed intake (g/bird/21days)	965.19	973.15	941.15	937.94	12.34	0.067
Weight gain(g/bird/21days)	305.61^{b}	418.57^{a}	406.50^{a}	405.71^{a}	5.82	0.003
Feed conversion ratio	3.16^{a}	2.32^{b}	2.32^{b}	2.31^{b}	0.02	0.005

Means with different superscripts along the same row are significantly different ($p<0.05$); SEM: Standard Error of Mean
LMC: Leaf meal composite

Table 5. Effects of interaction of dietary vitamin-mineral premix and leaf meal composite supplementation on performance of broiler starter chicks

VMP (g.100 g^{-1})	LMC (g.100 g^{-1})	FI (g)	WG (g)	FCR
	1.5	982.44	417.88^{a}	2.39^{ab}
0.0	3.0	902.86	417.40^{a}	2.18^{b}
	4.5	878.81	430.42^{a}	2.13^{b}
	1.5	930.49	417.94^{a}	2.25^{b}
0.125	3.0	936.41	394.38^{ab}	2.49^{ab}
	4.5	982.83	398.95^{ab}	2.50^{ab}
0.25	0.0	965.19	305.61^{b}	3.28^{a}
	1.5	953.35	415.01^{a}	2.35^{ab}
0.25	3.0	1012.73	409.86^{a}	2.50^{ab}
	4.5	937.75	387.82^{ab}	2.52^{ab}
	1.5	1026.34	423.44^{a}	2.50^{ab}
0.375	3.0	912.61	404.38^{ab}	2.32^{ab}
	4.5	952.39	405.64^{ab}	2.45^{ab}
P value		0.731	0.033	0.001
SEM		12.27	6.23	0.06

Means with different superscript in the column are significantly different (P < 0.05) LMC = leaf meal composite; FI = feed intake; WG = weight gain; FCR = feed conversion ratio; VMP: Vitamin-mineral premix; SEM: Standard error of mean

(T_9) to 405.64 g (T_{12}). The FCR differed significantly ($p < 0.05$) due to dietary treatments. Similar ($p > 0.05$) FCR of 2.13 (T_3), 2.18 (T_2) and 2.25 (T_4) recorded in chicks on various diets were significantly lower ($p < 0.05$) than 3.28 (T_{13}) in chicks on control diets. Chicks had similar FCR, which ranged from 2.32 in chicks on T_{11} to 2.49 in chicks on T_5.

The main effect of varying dietary levels of supplemental VmP on performance of broiler chickens at the finisher phase is shown in Table 6. There were significant differences ($p < 0.05$) in WG, FI and the FCR as a result of the dietary VmP supplement. The WG of chickens fed 0.00 % supplemental VmP was 971.42 g, which was significantly higher ($p < 0.05$) than in other treatments. The 894.41 g and 889.20 g WG in chickens fed 0.25 and 0.375 % dietary VmP, respectively, were similar ($p > 0.05$) but lower ($p < 0.05$) than in other treatments. The WG of 917.36 g in chickens fed 0.125 % VmP was significantly higher ($p < 0.05$) than in those on 0.25 and 0.375 % VmP but lower ($p < 0.05$) than those on 0.00 % VmP. The FI of 2196.88 g in chickens fed 0.125 % dietary VmP was significantly lower ($p < 0.05$) than in other treatments. There were no significant differences ($p > 0.05$) in the FI of chickens given 0.25 % (2256.97 g) and 0.375 % (2268.83 g) supplemental VmP at the finisher phase. The FCR of 2.41 and 2.43 in chickens fed 0.00 and 0.125 % VmP were significantly lower

Table 6. Main effect of dietary supplement of vitamin-mineral premix on performance of finisher broiler chickens (days 22-42)

VMP Inclusion (%)	0.00	0.125	0.25	0.375	P value	SEM
Weight gain (g)	971.42^{a}	917.36^{ab}	894.41^{b}	889.20^{b}	0.043	11.40
Feed intake (g)	2319.17^{a}	2196.88^{b}	2256.97^{ab}	2268.83^{ab}	0.048	17.51
FCR	2.41^{b}	2.43^{b}	2.62^{a}	2.59^{ab}	0.044	0.03

Means with different superscripts are significantly different (P<0.05); SEM = Standard Error of Means; FCR = Feed conversion ratio

Table 7. Main effect of leaf meal composite inclusion on performance of broiler finisher chickens

LMC (%)	0	1.5	3.0	4.5	P value	SEM
Weight gain (g)	926.60	888.52	931.97	925.76	0.062	17.52
Feed intake (g)	2540.88[a]	2231.47[b]	2257.75[b]	2221.19[b]	0.039	11.39
FCR	2.77[a]	2.57[ab]	2.47[b]	2.46[b]	0.004	0.03

SEM = Standard Error of Means; Means with different superscripts across rows are significantly different (P < 0.05); FCR = Feed Conversion Ratio; LMC = leaf meal composite

($p < 0.05$) than 2.62 and 2.59 in chickens fed 0.25 % and 0.375 % VmP, respectively, at the finisher phase.

The main effect of dietary supplement of LMC on performance of broiler finisher is shown in Table 7. There were significant differences ($p < 0.05$) in FI and FCR due to the dietary LMC inclusion. The WG of chickens fed varying levels of LMC was not significantly different ($p > 0.05$) at the finisher phase and ranged from 888.52 g in chickens on 1.5 % dietary LMC inclusion to 931.97 g in those on 3.0 % supplemental LMC. The FI of birds on 0.0 % LMC (2540.88 g) was significantly higher ($p < 0.05$) than in other dietary treatments. Similar ($p > 0.05$) FI were observed in chicks on 1.5 % (2231.47 g), 3.0 % (2257.75 g) and 4.5 % (2221.19 g) LMC at the finisher phase. The FCR of chicks fed varying level of LMC showed significant differences ($p < 0.05$). Chickens fed 0.0 % LMC with FCR of 2.77 was higher ($p < 0.05$) than in other treatments. However, the FCR of chickens on 3.0 % (2.47) and 4.5 % (2.46) LMC supplements were similar and significantly lower ($p < 0.05$) than those on 1.5 % (2.57) and 0.00 % (2.77) supplemental LMC.

The effect of interaction of varying inclusion levels of VmP and LMC on performance of broiler chickens at the finisher phase is shown in Table 8. The higher ($p < 0.05$) WG of 1099.57 g in chickens on T_9 with equally higher ($p < 0.05$) 2200.00 g FI resulted in the lowest FCR as a result of the interaction of dietary VmP and dietary LMC. Chickens fed T_9 (1099.57 g) had significantly higher ($P < 0.05$) WG than those on T_6 (825.28 g), T_7 (767.78 g), T_8

Table 8. Effects of interaction of premix and leaf meal composite on the performance of broiler finisher chickens

Treatments	VMP (%)	LMC (%)	WG (g)	FI (g)	FCR
T1		1.50	914.41[abcd]	2310.37[ab]	2.54[abc]
T2	0	3.00	1008.80[ab]	2346.25[ab]	2.33[bc]
T3		4.50	991.03[ab]	2300.87[ab]	2.34[bc]
T4		1.50	958.70[abc]	2272.50[ab]	2.38[abc]
T5	0.125	3.00	968.09[abc]	2199.37[b]	2.30[bc]
T6		4.50	825.28[bcd]	2118.75[b]	2.58[ab]
T13		0.00	926.59[abcd]	2540.87[a]	2.76[ab]
T7	0.25	1.50	767.78[d]	2180.37[b]	2.93[a]
T8		3.00	783.68[cd]	2106.62[b]	2.76[ab]
T9		4.50	1099.57[a]	2200.00[b]	2.00[c]
T10		1.50	913.16[abcd]	2162.62[b]	2.40[abc]
T11	0.375	3.00	967.29[abc]	2378.75[ab]	2.46[abc]
T12		4.50	787.15[cd]	2265.12[ab]	2.91[a]
P value			0.002	0.001	0.001
SEM			41.069	63.15	0.111

SEM = Standard Error of Means; Means with different superscripts in the same colums are significantly different (P < 0.05); Tx = treatment; FCR = Feed Conversion Ratio; WG: Weight gain; FI: Feed intake; LMC: Leaf meal composite; VMP: Vitamin-mineral premix

(783.68 g) and T_{12} (787.15 g), but similar ($P > 0.05$) to chicks on other treatments at the finisher phase. The FI of chickens fed diet T_{13} (2540.87 g) was significantly higher ($p < 0.05$) than those on T_5 (2199.37 g), T_6 (2118.75 g), T_7 (2180.37 g), T_8 (2106.62 g), T_9 (2200.00 g) and T_{11} (2378.75 g) at the finisher phase due to combinations of supplemental VmP and LMC. Significantly higher ($P < 0.05$) FCR was observed in chicks on T_7 (2.93), T_8 (2.76) and T_{13} (2.76) compared to those on T_9 (2.00), T_2 (2.33), T_3 (2.34) and T_5 (2.30).

The relationship between dietary supplementation of LMC and the FCR of broiler chicks at the starter phase is shown in Figure 1. The regression curve showed a linear relationship between dietary LMC inclusion and FCR. A significant optimum FCR of 2.3 was obtained at 3.0 % supplemental LMC ($R^2 = 0.98$). The regression is shown in the equation 1 as follows:

$$Y = 0.21x^2 - 1.416x + 4.46 \quad (R^2 = 0.984) \qquad (1)$$

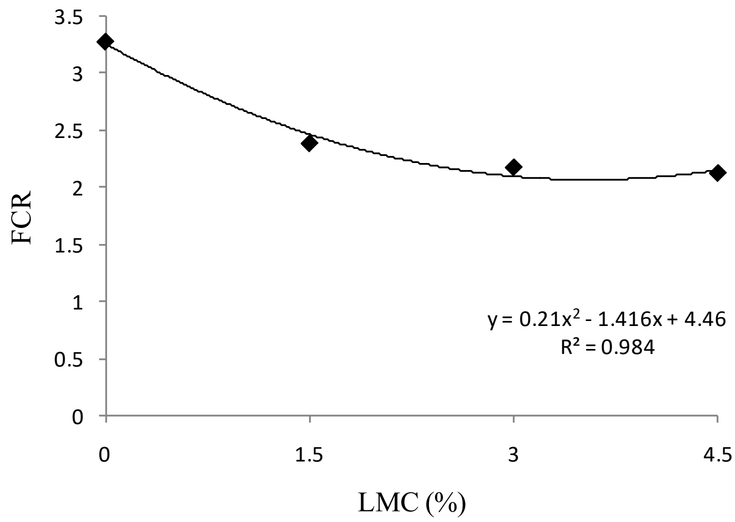

Figure 1. Relationship between leaf meal composite and feed conversion ratio in broiler starter chicks

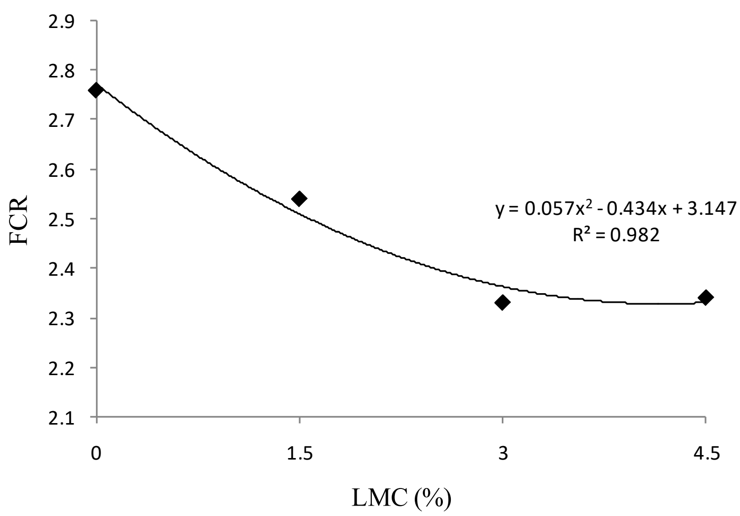

Figure 2. Relationship between leaf meal composite and feed conversion ratio of finisher broiler chickens

The relationship between dietary supplement of LMC and broiler chicken FCR at the finisher phase is shown in Figure 2. The regression curve showed that optimum FCR of 2.38 was obtained with 3 % supplemental LMC level. The regression equation is as shown in the equation 2 below:

$$Y = 0.057x^2 - 0.434x + 3.147 \quad (R^2 = 0.982) \qquad (2)$$

DISCUSSION

The reported reduced weight gain of broiler chickens fed diets containing 3 % moringa leaf meal was attributed to high levels of dietary crude fibre and this lowered FI of chickens (Banjo, 2012). Earlier observations (Ige *et al*., 2006; Olugbemi *et al*., 2010) similarly attributed lower weight gain of chickens to the inherent phyto-chemicals in *Moringa oleifera*. However, other authors (Garcia *et al*., 2007; Nworgu *et al*., 2007; Nkukwana *et al*., 2014) observed positive effects of feeding leaf meal from vegetables to broiler chickens, and the improved performance of broiler chickens was ascribed to gut health improvement. In the present study, the LMC was prepared using four different leaves of vegetables but not just from only moringa. Also, the tested LMC samples were properly air-dried. Broiler chicken, given diets supplemented solely with LMC, had improved performance compared to their counterparts on sole dietary supplement of VmP at the starter phase. This observation suggests that the innate phytonutrients, particularly vitamins and minerals in the LMC, were properly preserved by the drying method and that the innate nutrients were available to the experimental chicks for metabolic processes compared to the commercial VmP. This finding also corroborates the observation of other authors and that dietary LMC positively influenced gut health of broiler chickens (Fasuyi *et al*., 2005; Ihekwumere *et al*., 2008). The reported FCR range of 2.31-2.32 by starter chicks on 3.0 and 4-5 % LMC in this study was higher than reported range of 2.59-2.88 by Odunsi *et al*. (1999).

The FI was not reduced with increasing levels of LMC in broiler diets. However, WG of chickens on 0.00 % (305.61 g) supplemental LMC was significantly lower compared to those on other dietary treatments. Chicks on LMC supplemented diets had similar ($p > 0.05$) weight gain as those on the control diet. This observation may be because the chicks gained more nutrients from the supplemental LMC. Also, the fibre level was relatively higher and the diets supplemented with LMC would elicit earlier satiation compared to those on control diets. This is in agreement with the report of Opara (1996) that leaf meals do not only serve as protein source but also provide other vital bioavailable nutrients like vitamins, minerals and carotenoids.

The FCR in broiler chicken is an important determinant of feed suitability for efficient and profit-orientated production by farmers. A lower FCR meant cheaper rate of production, which will be beneficial to both the consumers and producers; thus, the lower the FCR, the better. The effect of interaction between VmP and LMC on starter broiler chicken performance was significant. All chicks fed diets supplemented with LMC recorded lower FCR than chicks on the control diets. Also, chicks on combined supplemental LMC and VmP had the FCR values which were numerically lower than were recorded in control. This finding suggests that dietary LMC supplementation was the main contributor to the observed difference in FCR. The LMC inclusion in the diets has been reported to improve gut health in broiler chicken (Nworgu *et al*., 2007; Windisch *et al*., 2007; Seyed and Homa, 2011; Nkukwana, *et al*., 2014). The improved FCR observed in this study suggests that LMC may have positively enabled feed utilisation which agrees with the report of Onunkwo and George (2015). The observed improvement in FCR of chicks on sole supplemental LMC or in combination with commercial VmP may also have been due to freshness and properly preserved nutrients in the LMC. The length of storage and handling in manufacturing process may have reduced the potency of commercial dietary VmP supplements (Oyewole *et al*., 2013). Findings in this report are indications that LMC at 3.0 – 4.5 % levels of inclusion would successfully replace dietary VmP in broiler starter chicken diets.

Observations on performance of broiler chickens at the finisher phase indicated that highest FCR was obtained in chickens on 0.25 % dietary VmP supplement. The standard recommendation for optimum performance of commercial broiler chickens (OVN, 2016) ought to be met by the 0.25 VmP provision used for the control diet in this study.

However, earlier reports on effects of dietary supplement of commercial VmP in Nigeria on performance of broiler chickens (Ogunwole *et al*., 2012) and laying pullets (Ojelade and Ogunwole, 2018) showed that commercial VmP were of varying compositions and efficacy. The reports gave credence to vitamin use as production tool rather than just being a nutritional additive solely for disease prevention (Whitehead, 2002; Klasing, 2007; Leeson, 2007). The present recommendation of 0.25 % supplemented VMP may, therefore, be only ideal for chicken raised in optimum conditions (Leeson, 2007; Briz and Perez, 2012) compared to those kept in the open-sided housing type, under which the present research was undertaken. The inclusion of LMC into other dietary treatment groups may have added greater potency to the 0.125 and 0.375 % VmP levels, thus giving a better performance in those groups compared to the control diet, which had only 0.25 % VmP without supplemental LMC. This also in agreement with the popular concept of optimum vitamin-mineral nutrition (OVN, 2016).

Reports have shown that the supplemental LMC contained important vitamins, amino acids and minerals (Makkar and Becker, 1996; Kakengi *et al*., 2005; Mensah *et al*., 2008; Ogbe and Affiku, 2011; Mosuro and Ogunwole, 2019), which could adequately replace the conventional VmP in livestock diets, when used either solely or as leaf composites. According to Ilodibia *et al*. (2016), *Celosia argentea* is a power house of nutrients, with enormous composition of crude protein, fat, zinc, phosphorus, iron, beta carotene and vitamin C – an indication that *Celosia argentea* could contribute significantly to the supply of required nutrients.

The results obtained for finisher chickens had similar trend as in the case of starter chickens. This finding may be because 1.5 % LMC inclusion level in T_1 was the lowest and perhaps inferior to the standard 0.25 % VmP dietary inclusion T_{13}, in terms of efficacy of the inherent vitamins and minerals. Effects of interaction of supplemental dietary VmP and LMC on performance of finisher broiler chickens were significant. There were variations across the different test diet combinations contrary to the trend in the findings for chickens at the starter phase. The highest FCR values were in two of the combined treatment groups, the group with a combination of 0.25 % VmP and 1.5 % LMC in T_7 and those on 0.375 % VmP and 4.5 % LMC in T_{12}. The outcome of the 0.25 % VmP + 1.5 % LMC treatment group was unexpected, especially that the treatment group with a lower 0.125 % VmP and 1.5 % LMC (T_4) and the treatment group with the higher combination of 0.375 % VmP and 1.5 % LMC (T_{10}) had lower FCR than the 0.25/1.5 combination (T_7) test group of chickens. No logical reason could be adduced to this outcome, because all the chickens were under the same ambient conditions and the only variation was in the dietary composition.

The higher FCR of chickens on T_{12} may possibly be attributed to hypervitaminosis syndrome, which may have occurred with higher than the recommended 0.25 % level of VmP in combination with highest level of LMC at 4.5 %. This dietary combination had the highest level of vitamins and minerals among all the treatment groups. Hypervitaminosis is a term, which refers to the body reactions and physiological disorderliness incident on the ingestion of excessive vitamins beyond the requirements of the animal, depending on the levels and the type of vitamins. Symptoms qualifying the toxicity in broiler chickens ranged from mild to severe in nature. Hypervitaminosis in broiler chickens is rare and only a few reports are available (Tang *et al*., 1984; Hamdoon and Rahman, 1990; Surai, 2002). Information on hypervitaminosis of different vitamins does not seem to match the FCR values in this study.

The regression of LMC inclusion on FCR in this study shows that an optimum FCR was obtained at 3.00–4.5 % sole dietary LMC inclusion; while the combination of 0.25 % dietary VmP + 4.5 % LMC in T_9 resulted in the lowest FCR of 2.0 across all the treatment groups. The higher LMC inclusion at 3.0 % or above resulted in a lower FCR. Alahyari-Shahrasb (2012) reported lower performance of broiler chicken without effect on immunocompetence with withdrawal of VmP at the end of finisher phase (day 36-42). Supplemental VmP removal from the starter and finisher chicken on corn-soybean meal diets was noted to decrease weight gain in the Arbor Acres broiler strain (Ogunwole *et al*., 2011). Other authors (Skinner *et al*., 1992; Maiorka *et al*., 2002; Khajali *et al*., 2006) reported varied effects of VmP removal from the diets of broilers on FI, growth performance, carcass yield and FCR. Ogunwole *et al*. (2015) concluded that profitable production of broiler chickens could not be undertaken without dietary supplement of VmP. The authors reported

100 % mortality in broiler chicken raised on VmP-free diets. The role of VmP in broiler starter diets can therefore not be overestimated.

The lowest FCR of 2.0 was obtained in chicken on 0.25 % VMP in combination with 4.5 % LMC in T_9. This observation agrees with the statement of Barroeta *et al*. (2012) that the OVN concept must be engaged in efficient livestock performance and productivity. The question mark on the adequacy of 0.25 % supplemental VmP for broiler chickens becomes valid with this result, as the treatment groups with graded levels of LMC in combination with VmP at 0.125 and 0.25 % showed improved performance. Tian *et al*. (2002) assert that the NRC standard recommendations were for the broilers reared with minimum stressors.

The environmental stressors, such as extreme environmental humidity and temperatures at different times of the day, may have not been taken into account. Under the conditions of the stressors experienced by chickens in this study, the supplemental VmP with LMC would have contributed extra vitamin required above the 0.25 % standard VmP threshold, thereby resulting to improved FCR.

Chicken on sole supplement of 4.5 % LMC (T_3) also performed better than the control group. This finding is in agreement with the report of Oyewole *et al*. (2013), which attributed this improvement to the freshness and natural source of the locally produced condiment used in their study.

CONCLUSION

Air-dried LMC made from mixing of equal proportion of *Vernonia amygdalina*, *Celosia argentea*, *Telfaria occidentalis* and *Moringa oleifera* successfully replaced commercial dietary supplement of VmP in broiler chicken diets.

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