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Evaluation of Growth Performance and Economic Efficiency of Immature Lohmann Brown Layers Fed Graded Levels of Undeshelled Defatted *Moringa oleifera* Seed Cake

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In a 22-weeks experiment, the impact and economic efficiency of feeding undeshelled defatted *Moringa oleifera* seed cake (UDMOSC) to Lohmann Brown layer chicks and pullets were investigated. The study had two phases, focusing on chicks (0-8 weeks) and pullets (9-22 weeks). A total of 150-day-old chicks were randomly assigned to five dietary treatments (0%, 5%, 10%, 15% and 15% with Burgazyme inclusion), each replicated three times, and each replicate containing ten (10) birds in a completely randomised design. Data collected was subjected to analysis of variance (ANOVA) using the GenStat statistical package (2008). In the initial phase, chicks fed dietary UDMOSC consumed less feed but had similar ($p > 0.05$) final body weight compared to the control group. Chicks fed the control, and 5% UDMOSC gained more weight with better feed conversion. Chicks fed 10% UDMOSC had higher mortality. In the second phase, pullets fed the control diet and 15% UDMOSC with the enzyme (UDMOSC^{15E}) showed significantly higher ($p = 0.01$) feed intake. Final body weight and body weight gain were notably higher ($p = 0.001$) in pullets fed the control diet. Feed conversion ratio and mortality rate did not significantly differ ($P > 0.05$) among treatments. Dietary UDMOSC reduced feed cost per kilogram of body weight gain for starters and pullets. While dietary UDMOSC did not significantly affect starter growth, it lowered total feed cost per bird for starters and pullets except for UDMOSC^{15E}, accruing 20.54 – 27.81%. and 25.39 – 40.19% percentage profit range, respectively. Dietary UDMOSC depressed the growth of starters and pullets, but it was economically advantageous by reducing the cost per kilogram of body weight gain for both groups. The negative impact of dietary UDMOSC on the growth of starters and pullets suggests that including UDMOSC in the immature layer diets should be cautiously approached for economic gain and, therefore, recommended for the pullet stage at an inclusion level not exceeding 10%.

Keywords: Brown layers; economic efficiency; growth performance; Moringa oleifera seed cake; pullets; undeshelled defatted.

1. INTRODUCTION

Poultry production is essential in bridging the protein gap in developing countries where the average daily consumption is far below the recommended standards [1,2]. The prospect of this vital industry today is undermined by the high cost of production due to the high prices of feed ingredients, especially protein sources [3,4,5]. According to Abdelnour et al. [6], scarcity and higher prices of conventional protein source ingredients limit poultry production in developing countries. Despite the associated higher costs, this vital nutrient in poultry nutrition plans remains imperative, given its indispensable role. It is well-established that protein, the primary building block for numerous bodily tissues and muscles, stands alone in its significance. According to Sá et al. [7], proteins are the primary sources of nitrogen for animals. Proteins play a vital role in poultry nutrition by supplying the essential amino acids necessary to grow and repair body proteins and tissues. As the study explores ways to enhance and sustain poultry production, seeking alternative protein sources that serve as valuable ingredients in poultry diets becomes increasingly essential. Among these potential resources, *Moringa oleifera* seed cake is a promising candidate.

Moringa oleifera has garnered substantial attention as a protein source for livestock worldwide, owing to its rich protein content and essential minerals [8,9,10]. Saa et al. [11] emphasised its significance in addressing global food grain shortages exacerbated by the burgeoning human population. Given its adaptability to arid conditions prevalent in sub-Saharan regions, where food crises often loom, *Moringa oleifera* is a promising conventional feed resource poised to alleviate food scarcity challenges. *Moringa oleifera* stands out as a remarkably versatile plant, with nearly all its parts finding valuable use in medicine [12] and nutrition [13,14]. Moreover, our findings highlight *Moringa oleifera* as a potent indigenous source of easily digestible protein and rich reserves of vital nutrients such as calcium, iron, vitamin C, and carotenoids [15].

A proximate analysis conducted by Sodamate et al. [16] asserted that *M. oleifera* seeds boast an impressive crude protein content of approximately 43.71±1.64 mg/100 g. Furthermore, research by Alagbemide et al. [17], focused on the nutrient and mineral composition of *M. oleifera* seeds, reported a similarly substantial crude protein content of about 35.97%. This notably high crude protein content suggests that *M. oleifera* seeds could serve as a viable alternative or supplement to traditional plant protein sources like soya bean meal or groundnut cake in poultry diets. Beyond their rich protein content, the seeds are also enriched with essential vitamins such as A and B_1, as highlighted by the work of Mbah et al. [18]. This nutritional profile implies that including Moringa seeds in poultry feed contributes to enhanced growth through protein supply and supports overall avian health by providing essential vitamins. Moreover, a report by Aderinola et al. [19] underscores the antioxidative properties of *M. oleifera*. A feed trial conducted by Lin et al. [20] further reinforces the positive effects of Moringa seed polypeptides to safeguard erythrocytes from oxidative damage. These findings strongly suggest that *M. oleifera* holds substantial promise as a valuable protein source ingredient for poultry nutrition, offering both growth-promoting protein and health-enhancing nutritional components and thus necessitating the study to evaluate the growth performance and economic efficiency of immature Lohmann Brown Layers fed dietary graded levels of undeshelled defatted *Moringa oleifera* seed cake.

2. MATERIALS AND METHODS

2.1 Feed Source and Preparation

The undeshelled defatted *Moringa oleifera* seed cake (UDMOSC) was sourced from the Ghana Permaculture Institute in Techiman. The Feed enzymes (Burgazyme) were obtained from Agricare Limited, Kumasi. At the permaculture Institute, moringa seeds in its outer hull were oven-dried, followed by mechanical pressing to extract oil. The defatted moringa cake was then milled into powder at the Poultry Section of the Department of Animal Science Akenten Appiah Menka University of Skills Training and Entrepreneurial Development (AAMUSTED Mampong campus).

2.2 Experimental Design and Feed Formulation

One hundred and fifty (150) day-old chicks (0 – 8 weeks) from the Lohmann Brown layer strain were divided into five (5) groups, each containing three (3) replicates with ten (10) starter birds. The pullet phase also had three (3) replicates, but accounting for mortality in starter chicks resulted in eight (8) birds per replicate in a completely randomised design. The treated moringa (UDMOSC) was used to formulate five experimental diets with the inclusion levels of 0% (control), 5%, 10%,15%, and 15% with enzyme (Burgazyme) to partially replace soybean for birds on an as-fed basis which corresponds to diets UDMOSC ^{0}, UDMOSC ^{5}, UDMOSC ^{10}, UDMOSC ^{15}, and UDMOSC ^{15E} respectively for both starters (Table 1) and pullets (Table 2).

2.3 Management of Experimental Chicks

All the chicks were reared in a deep litter system and were fed the respective diets *ad libitum* during the experimental period of 8 weeks for starters and 13 weeks for pullets. Stringent adherence to standard management protocols guaranteed the optimal well-being of the experimental birds, ensuring they received appropriate care. Additionally, a continuous supply of clean drinking water was available *ad libitum* throughout the experimental period. To monitor the birds' growth effectively, individual weight assessments were conducted on both the chicks and pullets, using a precision electronic digital balance obtained from Zhejiang, China, renowned for its accuracy to the nearest 0.01 units. This process facilitated the precise recording of birds' initial and final body weights. The feed given to the birds was carefully measured using a weighing balance. Any unconsumed feed was also weighed and documented daily to manage their diet effectively.

2.4 Parameters Measured

2.4.1 Feed and water intake

Weekly feed intake was calculated by subtracting the leftover feed from the total supply of the previous week and dividing the resulting amount by the number of birds to estimate the average weekly feed intake per bird. The total feed consumption over the experimental period was calculated by aggregating the weekly intake. Concurrently, daily water intake was determined by subtracting the water left over from the total quantity provided on the prior day. This process was then used to calculate the weekly and overall water intake for the experiment period.

Table 1. Composition and chemical analysis of experimental starter diets (week 0-8)

	Dietary treatment				
Ingredients	**UDMOSC^{0}**	**UDMOSC^{5}**	**UDMOSC^{10}**	**UDMOSC^{15}**	**UDMOSC^{15E}**
Maize (Kg)	56.5	55	53.5	53	53
Wheat bran (Kg)	13	12.5	12	10.5	10.5
Soybean (Kg)	9	6	2	0	0
UDMOSC (Kg)	0	5	10	15	15
Anchovy (Kg)	8.5	8.5	8.5	8.5	8.5
Tuna fish (Kg)	10	10	11	10	10
Dicalcium (Kg)	0.5	0.5	0.5	0.5	0.5
Vit/premix (Kg)	0.5	0.5	0.5	0.5	0.5
Oyster shell (Kg)	1.5	1.5	1.5	1.5	0.5
Salt (Kg)	0.5	0.5	0.5	0.5	0.5
Total	**100**	**100**	**100**	**100**	**100**
	Calculated Analysis				
CP (%)	21.09	21.11	21.16	21.08	21.08
CF (%)	3.49	4.23	4.92	5.64	5.64
EE (%)	3.53	3.65	3.81	3.90	3.90
ME (Kcal/Kg)	2717.55	2713.90	2711.50	2727.10	2727.10

UDMOSC - Undeshelled defatted Moringa oleifera seed cake; CP-Crude protein; CF-Crude Fibre; EE-Ether Extract; ME-Metabolisable Energy; Vit premix-All Essential Vitamins

Table 2. Composition and chemical analysis of experimental pullet diets (week 9-22)

	Dietary treatment				
Ingredients	**UDMOSC^{0}**	**UDMOSC^{5}**	**UDMOSC^{10}**	**UDMOSC^{15}**	**UDMOSC^{15E}**
Maize (Kg)	60	60	59.6	60	60
Wheat bran (Kg)	20	18	16	13	13
Soybean (Kg)	7.5	5.5	3.5	2.3	2.3
UDMOSC (Kg)	0	5	10	15	15
Anchovy (Kg)	0	0	0	0	0
Tuna fish (Kg)	7.4	6.8	6.3	5	5
Dicalcium (Kg)	0.5	0.5	0.5	0.5	0.5
Vit/premix (Kg)	0.5	0.5	0.5	0.5	0.5
Oyster shell (Kg)	3.6	3.1	3.2	3.2	3.2
Salt (Kg)	0.5	0.5	0.5	0.5	0.5
Total	**100**	**100**	**100**	**100**	**100**
	Calculated Analysis				
CP (%)	15.23	15.30	15.39	15.37	15.37
CF (%)	4.12	4.80	5.47	6.09	6.09
EE (%)	3.25	2.90	3.51	3.58	3.58
ME (Kcal/Kg)	2611.74	2526.99	2427.85	2348.19	2348.19

UDMOSC - Undeshelled defatted Moringa oleifera seed cake; CP-Crude protein; CF-Crude Fibre; EE-Ether Extract; ME-Metabolisable Energy; Vit premix-All Essential Vitamins

2.4.2 Body weight gain (BWG)

Body weight gain was calculated, finding the final and initial weight difference. Body weight gained per bird was estimated as

$$BWG = \frac{Final\ body\ weight - Initial\ body\ weight}{Number\ of\ birds}$$

2.4.3 Feed conversion ratio (FCR)

The feed conversion ratio was computed as the ratio of total feed intake and body weight gain to estimate the efficiency with which birds convert feed into body weight.

$$FCR = \frac{Total\ feed\ intake\ (kg)}{Body\ weight\ gain\ (Kg)}$$

2.4.4 Mortality rate (MR)

The mortality rate was accounted for as

$$MR = \frac{Number\ of\ dead\ birds}{Initial\ number\ of\ birds} \times 100\%$$

2.5 Economics of Production

The economic efficiency of UDMOSC in the production of starters and pullets was determined using the prevailing price per kilogram of conventional feed, price per kilogram of UDMOSC, kilogram body weight gain of starters and pullets, and uniform distribution of all other costs at the time of the experiment. The price per kilogram of conventional feed was multiplied by the total kilograms of conventional feed consumed per bird to get the cost of conventional feed per bird. The price per kilogram of UDMOSC was multiplied by the total kilograms of UDMOSC consumed per bird to get the cost of UDMOSC per bird. The cost of conventional feed and the dietary UDMOSC per bird were summed up to get the total cost of feed per bird. The cost per kilogram body weight gain was determined by dividing the cost of feed per bird by the kilogram body weight gain per bird

2.6 Statistical Analysis

The data on parameters such as initial body weight gain, feed intake, final body weight, body weight gain, feed conversion ratio, and mortality rate were analysed using the ANOVA tool in the GenStat statistical package (2008). The means were then separated using the Least Significant Difference (LSD) test at a significance level of 5% ($P < 0.05$). The statistical model used was defined as follows:

$$\mathbf{Y = \beta_0 + \beta_1 x + e_i}$$

Where:

- **Y** Response variable, which could represent overall performance or economic efficiency.
- **x** Predictor variable representing **growth performance** (influenced by dietary UDMOSC on Body Weight Gain or Feed Conversion Ratio).
- $\boldsymbol{\beta_0}$ Intercept (the baseline performance when growth performance is zero).
- $\boldsymbol{\beta_1}$ Coefficient showing the effect of growth performance on the response variable.
- $\mathbf{e_i}$ Error term, accounting for random variations.

3. RESULTS

The undeshelled defatted *Moringa oleifera* seed cake sample had a crude protein content of 31.67%. Moisture, crude fibre, ether extract, ash, and nitrogen-free extracts were 9%, 20.87%, 4.30%, 5.50%, and 28.66%, respectively. The metabolisable energy calculated for the test sample was 2841.63 Kcal/kg (Table 3).

3.1 Effect of UDMOSC on the Growth Performance of Starter Chicks

The result showed that the starters responded differently to varying inclusion levels of UDMOSC. Dietary treatment had a significant ($P = 0.01$) effect on total feed intake. The chicks receiving dietary UDMOSC treatment consumed similar lower ($P = 0.01$) feed, with the control group consuming the highest feed (Table 4). Final body weight was not affected by the treatment diet ($P > 0.05$). However, body weight gain was significantly affected ($P = 0.02$), with chicks nourished with $UDMOSC^{0}$ and $UDMOSC^{5}$ diets demonstrating a significant weight gains, with both groups showing very similar results (P > 0.05). In contrast, the chicks fed $UDMOSC^{10}$, $UDMOSC^{15}$, and $UDMOSC^{15E}$ exhibited slightly lower but comparable weight gains (P > 0.05). The feed conversion ratio was also significantly ($P = 0.03$) better for chicks fed $UDMOSC^{5}$. A significant difference ($P = 0.01$) was also observed in mortality rate, with starter chicks fed dietary $UDMOSC^{5}$ (1.67) and $UDMOSC^{10}$ (3.00) recording a relatively higher mortality rate. Relatively lower mortality rate was recorded for starter chicks fed dietary $UDMOSC^{15}$ with or without enzyme inclusion. Conversely, zero mortality was recorded for chicks fed the control diet ($UDMOSC^{0}$) (Table 4).

Table 3. Proximate chemical composition of UDMOSC

Fractions on as fed basis	Composition
Moisture (%)	9.00
Crude protein (%)	31.67
Crude fibre (%)	20.87
Crude fat (%)	4.30
Ash (%)	5.50
Nitrogen-free extract (NFE) (%)	28.66
Metabolisable energy (ME) (Kcal/kg)	2841.43

ME (kcal/kg) = Gross Energy (GE) of Feed − (Energy in Feces + Energy in Urine) as proposed by Bilgili [21]

Table 4. Effect of UDMOSC on the growth performance of starter chicks

Parameters	$UDMOSC^0$	$UDMOSC^5$	$UDMOSC^{10}$	$UDMOSC^{15}$	$UDMOSC^{15E}$	LSD	P- value
MIBW(g/bird)	34.53	33.77	33.93	33.63	33.77	1.09	0.06
MFI(g/bird)	2781^a	2316^b	2242^b	2326^b	2187^b	303.80	0.01
MFBW(g/bird)	416	348	401	399	357	82.70	0.33
MBWG(g/bird)	440.30^a	392.60^{ab}	368.40^{bc}	368.40^{bc}	324.50^c	64.61	0.02
FCR	6.30^{ab}	5.57^b	6.13^{ab}	6.33^{ab}	6.70^a	1.01	0.03
MMR	0.00^b	1.67^{ab}	3.00^a	0.67^b	1.33^{ab}	1.99	0.01

Means within rows with different superscripts are significantly (P < 0.05) different. UDMOSC= Undeshelled defatted Moringa oleifera seed cake, MIBW = mean initial body weight, MFI = mean feed intake, MFBW = mean final body weight, MBWG = mean body weight gain, FCR = feed conversion ratio, MMR = mean mortality rate, LSD = least significance difference

3.2 Effect of Dietary UDMOSC on Growth Performance of Pullets

The final weight for phase 1 (Table 4), which served as the initial weight of the pullets, did not vary significantly (*P* = 0.07) (Table 5). The feed conversion ratio and the pullets' mortality rate were not significantly affected (*P* > 0.05). However, feed intake (*P* = 0.01), final body weight (*P* = 0.001) and body weight gain (*P* = 0.001) of the pullets were affected significantly. The pullets fed $UDMOSC^0$ inclusion level performed better regarding feed intake, final body weight and body weight gain (Table 5). Pullets fed $UDMOSC^{15E}$ also performed better (*P* = 0.01) in terms of feed intake, outperforming those birds fed $UDMOSC^5$, $UDMOSC^{10}$ and $UDMOSC^{15,}$ which consumed less feed (*P* > 0.05). Final body weight was lowest for pullets fed $UDMOSC^{10}$, $UDMOSC^{15,}$ and $UDMOSC^{15E}$ (*P* > 0.05). Pullets recorded significantly (*P* = 0.001), the highest final body weight gain (1758 g) when fed $UDMOSC^{0,}$ followed by $UDMOSC^5$ (1477 g). On the contrary, pullets fed $UDMOSC^{15E}$ had the lowest final body weight gain (1113 g) (Table 5).

3.3 Economic Efficiency of UDMOSC in the Production of Starter Layer Chicks

Analysis of the economic efficiency of UDMOSC (Table 6) reveals notable findings. Specifically, when producing layer chicks, it is evident that the control diet incurred a higher feed cost, totalling GHC 15.82 than the test diets. These test diets ($UDMOSC^5$, $UDMOSC^{10}$, $UDMOSC^{15}$, and $UDMOSC^{15E}$) demonstrated reduced feed costs per bird, amounting to GHC 12.57, GHC 11.56, GHC 11.42, and GHC 11.39, respectively. Notably, the mean total feed cost showed a consistent decrease with increasing UDMOSC levels, with one exception in the case of $UDMOSC^{15E}$, attributed to including an enzyme. Interestingly, the cost per kilogram of body weight gain is higher when UDMOSC is incorporated, as opposed to the control diet, thus challenging the economic benefits of utilising dietary UDMOSC when the total feed cost is lower (Table 6).

3.4 Economic Efficiency of Dietary UDMOSC in the Production of Pullets

The analysis of the economic efficiency of UDMOSC in pullet production reveals that the conventional diet is more costly (GHC 40.53) compared to the test diets (GHC 30.34, GHC 27.43, GHC 24.24, and GHC 38.25 for $UDMOSC^5$, $UDMOSC^{10}$, $UDMOSC^{15}$, and $UDMOSC^{15E}$ respectively). The mean total feed cost decreases with increasing UDMOSC levels, except for pullets fed the $UDMOSC^{15E}$ diet, which accounts for cost inflation driven by the inclusion of the enzyme (Burgazyme). Notably, pullets fed $UDMOSC^{15E}$ had the highest cost per kilogram of body weight gain, followed by those on $UDMOSC^0$. Pullets fed dietary UDMOSC at graded levels 5%, 10% and 15% accrued the most cost-effective weight gain, thus making UDMOSC economically beneficial for pullets compared to the starter layer chicks (Table 7).

4. DISCUSSION

4.1 Effect of UDMOSC on the Growth Performance of Starters

The performance of starter layer chicks fed graded levels of UDMOSC indicates that chicks fed $UDMOSC^{15}$ had the lowest initial body weight; the similar but slightly different initial body weights of chicks used for this experiment could be attributed to differences in their weight at hatch. Chicks on the control diet consumed significantly higher feed than their counterparts on the test diets. The marked reduction in feed

Table 5. Effect of dietary UDMOSC on the growth performance of pullets

Parameters	UDMOSC0	UDMOSC5	UDMOSC10	UDMOSC15	UDMOSC15E	LSD	*P*-value
MIBW (g/bird)	416	348	401	399	357	82.70	0.07
MFI (g/bird)	8337a	6536b	6222b	5874b	7370a	1333.50	0.01
MFBW (g/bird)	1758a	1477b	1349bc	1194bc	1113c	252.5	0.001
MBWG (g/bird)	1342a	1129b	948c	915c	756d	155.10	0.001
FCR	6.20	5.83	6.53	6.00	6.17	0.82	0.45
MM	1.67	2.33	2.33	1.33	2.33	1.76	0.60

Means within rows with different superscripts are significantly (P < 0.05) different. UDMOSC = Undeshelled defatted Moringa oleifera seed cake, MIBW = mean initial body weight, MFI = mean feed intake, MFBW = mean final body weight, MBWG = mean body weight gain, FCR= feed conversion ratio, MM = mean mortality rate, LSD = least significance difference

Table 6. Economic efficiency of UDMOSC in the production of starter layer chicks

Parameters	UDMOSC0	UDMOSC5	UDMOSC10	UDMOSC15	UDMOSC15E
CCI (GHC/Kg/bird)	5.69	5.42	5.16	4.90	5.20
MFI (Kg/bird)	2.78	2.32	2.24	2.33	2.19
TFC (GHC/bird)	15.82	12.57	11.56	11.42	11.39
MBWG (kg)/bird	0.44	0.39	0.37	0.37	0.32
Cost/kg BWG	21.09	32.24	31.24	30.86	35.59

GHC 10.1 = 1$ at the time of the experiment, UDMOSC = Undeshelled defatted Moringa oleifera seed cake, CCI= Cost of conventional ingredients, GHC = Ghana cedis, MFI = Mean feed intake, TFC = Total feed cost, MBWG = mean body weight gain, E = enzyme

Table 7. Economical efficiency of UDMOSC in the production of pullets

Parameters	UDMOSC0	UDMOSC5	UDMOSC10	UDMOSC15	UDMOSC15E
CCI (GHC)	4.86	4.64	4.41	4.18	5.19
MFI (GHC/Kg/bird)	8.34	6.54	6.22	5.87	7.37
TFC (GHC/bird)	40.53	30.34	27.43	24.24	38.25
MBWG (kg)/bird	1.34	1.13	0.95	0.92	0.76
Cost/kg BWG	30.24	26.85	28.87	26.67	50.33

GHC 10.1 = 1$ at the time of the experiment, UDMOSC = Undeshelled defatted Moringa oleifera seed cake, CCI = cost of conventional ingredients, GHC = Ghana cedis, MFI = Mean feed intake, TFC = Total feed cost, MBWG = mean body weight gain, E = enzyme

intake of the starters on the test diets could be attributed to the hard and sticky nature of the seed cake, which resulted in visible vent sticking in starters that received higher levels of the cake. The reduced feed intake of chicks on the test diet could further be attributed to the reduced palatability of the test diet [22]. Onu and Otuma [23] reported that the unpalatable nature of a feed will eventually prevent chicks from consuming an adequate quantity of the feed.

Final body weight did not vary significantly between chicks; however, body weight gain varied significantly, with chicks on the control diet and UDMOSC5 having the highest body weight gain. Body weight gain of chicks fed dietary UDMOSC10, UDMOSC15 and UDMOSC15E did not vary significantly, suggesting that the addition of the enzyme (Burgazyme) did not have a notable impact on nutrient digestibility and did not enhance the conversion of nutrients, especially proteins, into a form that the birds could readily utilise. According to Zanella et al. [24], enzyme supplementation could not improve overall crude protein digestibility, and this could have occurred to chicks that received the enzyme supplementation. The reduced weight gain of chicks on UDMOSC10, UDMOSC15 and UDMOSC15E could partly be attributed to the high crude fibre content of UDMOSC, which might have impaired feed digestion and nutrient absorption [25,22] and Onu (2010), as cited in [26]. The relatively higher body weight gain by chicks fed UDMOSC5 could be attributed to reduced fibre in the UDMOSC5 compared to UDMOSC10, UDMOSC15 and UDMOSC15E.

Chicks on UDMOSC^{0}, UDMOSC^{5}, UDMOSC^{10}, and UDMOSC^{15} had the best feed conversion ratio, suggesting that the chicks adequately utilised the nutrients from the feed regardless of consuming slightly less feed. The mortality rate was significantly high in chicks fed UDMOSC^{10}, and this did not vary considerably with chicks fed UDMOSC^{5} and UDMOSC^{15E}. The high mortality rate could, however, be attributed to neonatal infections that might have predisposed the chicks to fatal disease conditions.

4.2 Effect of UDMOSC on the Growth Performance of Pullets

The final body weight of the chicks, which served as the initial body weight of the pullets, did not vary significantly However, the chicks on the control diet had slightly higher final body weight. This can be attributed to the fact that chicks on the control diet consumed feed better than those on the test diets. Feed intake was significantly higher in pullets fed UDMOSC^{0} and UDMOSC^{15E}, suggesting that the pullets fed UDMOSC15^{E} accepted the feed at this growth stage. The fact that only growers fed UDMOSC^{15E} performed better in feed intake further indicates that the hard and sticky nature of the UDMOSC reduced the palatability of the feed and affected the feed intake. The pattern of feed intake observed is lower than expected. Dietary energy levels regulate avian feed intake. Birds typically consume more feed when energy is low and less when it's high. However, birds fed UDMOSC show reduced feed intake even at lower energy levels than the control group. This could be attributed to reduced feed palatability, which did not allow the birds to consume higher amounts regarding energy level [27].

According to Ginindza et al. [28], lower dietary crude fibre levels optimised growth rate, whereas higher dietary crude fibre levels resulted in lower feed intake and digestibility of unsexed Venda chickens. The relatively lower body weight gained by pullets on the test diets could, therefore, be attributed to the high crude fibre content in the test diet, which could have impaired digestibility and nutrient absorption. Feed conversion ratio did not vary significantly between birds on the control diet and their counterparts on the test diets, and this was in line with the results of Molepo [29], who found no significant effect on feed conversion ratio when he investigated the effects of *Moringa oleifera* whole seed meal in broilers. Similarly, there was no significant difference in mortality rate between growers on the control and those on the test diets, suggesting an equal health status for all the growers at this stage.

4.3 Effect of UDMOSC on Economic Efficiency in Production Starters and Pullets

The results on the economic efficiency of dietary UDMOSC in producing starters and pullets showed that it would cost less with the inclusion of graded levels of the test diet (UDMOSC) of starters and pullets; conversely, a relatively higher cost was incurred to gain per kilogram body weight of starters but not for pullets with dietary UDMOSC inclusion. This suggests that UDMOSC can potentially reduce the feed cost of producing starters and pullets; however, to achieve a corresponding gain per kilogram body weight at a relatively reduced feed cost, it is advisable to incorporate the test diet (UDMOSC) at the pullet rather than starter stage to achieve efficiency and economise production cost. The consistent decrease in feed cost per kilogram body weight of starters fed UDMOSC^{5} (GHC 32.24), UDMOSC^{10} (GHC 31.24) and UDMOSC^{15} (GHC 30.86), as compared to birds fed UDMOSC^{15E} (GHC 35.59) suggests that the surge in feed cost per kilogram weight gain of starters and pullets fed UDMOSC^{15E} (GHC 50.33) cannot be attributed to the cost of UDMOSC but their inability to make efficient use of feed as corroborated by Amevor [30] as well as the cost of the enzyme supplemented [31]. The cost per kilogram body weight gain is economically effective when dietary inclusion of UDMOSC is practised at the pullet production rather than the starter stage of growth due to the ability of the pullets to manage fibre and palatability of the feed better than the chicks.

5. CONCLUSION

Including graded levels of dietary UDMOSC depressed growth and affected the efficiency of feed utilisation but was economically viable at the pullet stage. Dietary endogenous enzymes did not influence growth performance positively and economically. Dietary Undefatted *Moringa oleifera* seed cake is therefore recommended for the pullet stage at an inclusion level not exceeding 10% inclusion level.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models

(ChatGPT, COPILOT, etc) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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