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Research Article
Feeding Maintenance Diet During Unproductive Season and Effects on Ensuing Productive Season with Restored Layer Diet: Egg Production and Cost Savings of Pearl Breeder Guinea Fowls

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Abstract
Objective: This study investigated the effect of feeding a maintenance diet during the lean season after the first productive laying season on the productivity and cost savings of Guinea fowls in the second season. **Materials and Methods:** Seventy-two Pearl Guinea fowls, aged 70 weeks, were allotted to four treatments with three replicates each. A completely randomised design with a 2×2 factorial pattern was used. Each replicate included five Guinea hens and one Guinea cock. Parameters measured included productive characteristics, blood profile and feed cost analysis. Data were analysed using the General Linear Model procedure of Statistical Analysis System (SAS). **Results:** Results indicated that during the lean season, daily feed intake was significantly ($p<0.001$) higher (93.19 g/bird) for Guinea fowls fed the maintenance diet compared to those on the normal layer diet (85.15 g/bird). During the second productive season, daily feed intake was higher for the normal layer diet. The next laying season delayed by seven days for the maintenance diet. Egg production was not significantly affected ($p>0.05$) by diet but egg weight was higher ($p = 0.036$) for the maintenance diet with eggshell thickness decreasing by 12.5%. Haematological characteristics were generally non-significant but biochemical parameters were higher ($p<0.05$) for the normal diet. Feeding a maintenance diet during the lean season reduced feed costs by 13%. **Conclusion:** The study concluded that feeding a maintenance diet during the lean season did not adversely affect the productive performance of Guinea hens in the subsequent production season but could reduce eggshell thickness. Feeding a maintenance diet (14-15% CP) during the lean season and a switch to a layer diet two weeks before the next laying season is recommended for cost savings and profitability.

Key words: Egg production, feed cost, guinea fowl, maintenance diet, seasonal egg production

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Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Guinea fowl is considered a national delicacy and the second most consumed poultry in Ghana after chicken. Guinea fowl production in many parts of West Africa, particularly Ghana, predominantly relies on an extensive system (free range)[1,2]. The recent call for an increase in the production of birds for food security has promoted the establishment of considerable intensive commercial Guinea fowl breeder farms. However, there is relatively poor fertility among many commercial Guinea fowl breeders arising from unfertilised eggs due to the non-promiscuous behaviour (pair-bonding) of the bird, where many Guinea hens are not mated by Guinea cocks due to the lack of marriage[3]. These challenges have been aggravated by high feed costs incurred in feeding Guinea fowl breeders, principally when the birds are out of egg production (seasonal breeders) season (October to March)[4]. A potential strategy to minimise the high feed cost impact on production during the lean season and to make it sustainable is to introduce diets that maintain the Guinea fowls nutritionally during the out-of-productive season[5] and restore the nutritional status of the layer diets when the next productive season is about due[6]. This strategy could be adopted when it has no adverse effects on egg production during the ensuing laying season and cuts down significantly the feed costs. However, there is limited literature on feeding maintenance diets to Guinea fowls when the birds are out of laying season, the effect on the next laying season when diets have been normalised and the extent of monetary savings made in intensively reared Guinea fowls, which necessitated this study to be carried out.

MATERIALS AND METHODS

Housing and management of birds: Water and feed were provided *ad libitum* to the birds. Water troughs were washed daily in the morning, after which fresh and clean water was served. Birds were reared on a deep litter system with wood shavings as the litter material to a depth of 4.5 cm. The heating and lighting were adapted to meet their recommended living conditions. The Veterinary Service Directorate's guidelines[7] for disease control and vaccination were followed.

Ethical approval: All experimental procedures were approved by the Animal Research Ethics Committee (AREC), Kwame Nkrumah University of Science and Technology, Kumasi-Ghana, Quality Assurance and Planning Unit (KNUST POLICY0016) (AREC 2018).

Experimental birds and design: The experiment involved 72 Pearl Guinea fowls aged 70 weeks old. For this study, birds were obtained from the Animal Science Department, AAMUSTED. The birds had finished laying for the first productive season in November and had three months to the next productive season in March. A completely randomised design with a 2×2 factorial pattern was used. Each treatment had three replicates. Each replicate also had five pearl Guinea hens and a cock. Two dietary treatments were prepared; one was a normal layer diet and the other was a maintenance diet. The two dietary treatments were fed to the Guinea fowls and replaced with a common layer diet at two different times (one week to the start of egg production and two weeks to the start of egg production). The treatments were:

- Layer diet changed to new layer diet at one week to start of egg laying
- Layer diet changed to new layer diet at two weeks to start of egg laying
- Maintenance diet replaced with layer diet one week to start of egg laying
- Maintenance diet replaced with layer diet two weeks to start of egg laying

Experimental diets: The experimental diets used for the study are shown in Table 1.

Parameters measured: Parameters measured were feed and water intake, hen-day egg production, egg characteristics, blood profile and cost-benefits assessment of feeding maintenance diet to Guinea fowls.

Feed and water intake: Weekly feed consumed per bird was calculated by subtracting feed not consumed from the feed supplied in the previous week and the resulting feed was divided by the number of birds. Weekly feed consumed was summed up to obtain feed intake for the experimental period. Daily water intake was calculated by subtracting water left over from the amount of water given in the previous day. This was summed up to obtain weekly water intake. Weekly water intake for the weeks was added to obtain water intake for the study period.

Hen-day egg production: Hen-day egg production for the study period was calculated as the average of the respective hen-day egg production for the experimental period. Hen-day egg production was determined for daily egg production according to the equation:

$$\text{Hen}-\text{day egg production}=\frac{\text{No. of eggs collected a day}}{\text{No. of layers alive}}\times 100$$

Table 1: Composition and chemical analysis of maintenance and layer diets of pearl guinea fowls

Feed ingredients	Initial layer diet	Maintenance diet	New layer diet
Maize grain	58.30	54.90	56.57
Tuna Fishmeal	6.20	3.00	6.00
Anchovy	4.50	1.00	4.20
Wheat bran	16.82	30.45	19.00
Soybean meal	7.95	5.60	8.10
Oyster shells	5.20	3.82	5.00
Dicalcium phosphate	0.50	0.50	0.50
*Premix	0.25	0.30	0.30
Lysine	0.02	0.02	0.02
Methionine	0.01	0.01	0.01
Salt	0.25	0.40	0.30
Total	100.00	100.00	100.00
Calculated nutrient composition			
Crude protein (%)	17.06	14.31	17.06
Crude fibre (%)	3.73	4.96	3.94
Ash (%)	11.21	9.73	11.02
Ether extract (%)	3.01	3.09	3.00
ME (kcal/kg)	2681.25	2522.30	2640.20

*Premix contained the following per kilogram of diet: Fe: 100 mg, Mn: 110 mg, Cu: 20 mg, Zn: 100 mg, Se: 0.2 mg, Co: 0.6 mg, Synoquin: 0.6 mg, Retinal: 2000 mg, Cholecalciferol: 25 mg, α-tocopherol: 25 mg, Menadione: 1.33 mg, Cobalamin: 0.03 mg, Thiamin: 0.83 mg, Riboflavin: 2 mg, Folic acid: 0.33 mg, Biotin: 0.03 mg, Pantothenic acid: 3.75 mg, Niacin: 23.3 mg, Pyridoxine: 1.33 mg and ME: Metabolisable Energy

Egg characteristics: Egg weight (g) was determined by weighing individual eggs collected daily using A&D Weighing EK-6000i electronic balance. The eggs' length, width and shell thickness were determined using a digital Vernier calliper. Eggshell thickness was measured at 3 different planes after carefully removing the tissue lining of the shell. The average value was recorded as the shell thickness.

Feed conversion ratio (FCR): The feed conversion ratio was determined based on the daily average feed intake and average egg mass[8]. In order to calculate egg mass, average egg weight was multiplied by the weekly eggs laid[9]. The mean FCR for the study period was determined by averaging the weekly FCR using the following formula:

$$\text{FCR} = \frac{\text{Feed intake}}{\text{Egg mass}}$$

Body weight gain: The initial body weight of the respective replicates was measured at the start of the experiment, so the body weights of birds among the replicates were similar. At the end of the experimental period (12 weeks), the body weight of birds in replicates was measured as the final body weight. In order to calculate the mean body weight gain of the birds, the average weight of the birds at the start of the experiment was subtracted from the average weight at the end of the study[10]:

$$\text{Body weight gain} = \frac{\text{Final average body weight} - \text{initial average body weight}}{\text{Number of birds}}$$

Haematological and biochemical characteristics: At the end of the feeding trial, blood was analyzed to determine the effect of maintenance diet on haematology and biochemical characteristics. The birds taken for the blood profile were weighed and body temperature was measured with a Thermometer gun. Using a sterilized 5 mL syringe, 4 mL of blood was drawn from each bird's right-wing vein, which 2 mL was immediately discharged into sterilized vacutainer test tubes containing Ethylene Diamine Tetra Acetic Acid (EDTA) after the area was disinfected with cotton wool dampened with methylated alcohol spirit. The blood sample in each tube was shaken to mix uniformly with the EDTA to prevent coagulation. The samples were analyzed for red blood cells, White Blood Cells, Platelets, Haemoglobin, Packed Cell Volume, Lymphocytes, Mean Corpuscular Haemoglobin/Mean Cell Haemoglobin, mean cell volume and Mean Corpuscular Haemoglobin Concentration, using three-part Rayto Haematology Auto Analyzer. The remaining 2 mL of the blood sample was dispensed gently into plain vacutainer tubes without EDTA and kept in a vacuum flask with ice cubes for blood biochemical analysis. Total lipid and protein parameters such as total cholesterol, triglycerides, high-density lipoprotein, low-density lipoprotein, total protein, albumin and globulin were determined.

Cost savings assessment: Based on the variable cost of production, feed cost was assessed. The cost of feed ingredients served as the basis for costing the formulated diets. The total feed intake of respective treatments was multiplied by the corresponding unit feed cost to obtain the total feed cost per treatment. The resulting values were used to calculate monetary savings from the respective dietary treatments.

Statistical analysis: Data collected was subjected to a two-way analysis of variance (ANOVA) using the Proc. GLM procedure of SAS. Differences among treatment means were tested at a 5 % significant level. The following statistical model was used:

$$Y_{ij} = \mu+\alpha_i+\beta_j+\gamma_{ij}+\varepsilon_{ij}$$

Where:

- Y_{ij} : The response variable (e.g., egg production, egg characteristics, haematology, biochemical characteristics, cost savings)
- μ : The overall mean or the intercept term, representing the baseline or average response when all the explanatory variables are zero
- α_i : Represents the main effect of the first factor (dietary treatments) with two different diets (layer diet and maintenance diet)
- β_j : Represents the main effect of the second factor (replacement time with layer diet) with two levels (one week to start of laying and two weeks to start of laying)
- γ_{ij} : Represents the interaction effect between the dietary treatment and replacement time
- ε_{ij} : Represents the residual error term

RESULTS

Proximate composition of the study diets: The experimental diets had similar dry matter content compared to the moisture content (12.98-13.12%) (Table 2). Crude protein content was lower for the maintenance diet (14.46%) compared to the layer diets with similar values (17.40 and 17.37%). The crude protein of 14.46% was enough to meet the maintenance requirement of the Guinea hens. Crude fibre level (5.74%) was marginally higher for the maintenance diet than the layer diets (4.06 and 3.78%) (Table 2). This resulted in a lower fat content (3.21%) than layer diets (3.86 and 4.53%) and thus culminated in relatively lower metabolisable energy for the maintenance diet (2652.6 kcal kg^{-1}). However, the nitrogen-free extract was marginally higher for the maintenance diet than the layer diets (Table 2). In general, maintenance diets and layer diets were formulated to meet the nutrient requirements for maintaining the birds and laying eggs.

Effect of feeding maintenance diet on Guinea hens in the lean (unproductive) season: Daily feed intake (DFI) of Guinea fowls fed the maintenance diet was significantly ($p<0.001$) higher (93.19 g/bird) than those of the birds fed the normal layer diet (85.15 g/bird) (Table 3). However, the time of introduction of the layer diet (week 1 and week 2 to laying season) did not significantly affect the DFI and had no interaction effect with the dietary treatments during the out-of-laying season. Daily water intake (DWI) followed a similar pattern as the DFI. Guinea fowls fed the maintenance diet had higher water consumption (211 mL/bird) than those of the birds fed on the normal layer diet (175.2 mL/bird) (Table 3). The final body weight of the normal layer diet group (1914 g/bird) and the maintenance diet group (1939 g/bird) were also similar. There was no significant interaction between dietary treatments and the introduction time of the layer diet.

Table 3 shows that feeding a maintenance diet to Guinea fowls during their unproductive season has notable effects on their production parameters.

The lower metabolizable energy content of the maintenance diet significantly influenced daily feed intake ($p<0.001$), resulting in higher feed consumption than the normal diet.

Effect of feeding maintenance diet during the lean on production characteristic in the next laying season: The final body weights of the previous phase served as the initial body weight and were not significantly different among treatments (Table 4). Final body weight (FBWT) at the end of the 3-month

Table 2: Proximate composition of maintenance diet and layer diets

Description	Maintenance diet	Layer diet (1)	Layer diet (2)
Moisture %	12.98	13.12	13.04
Crude protein %	14.46	17.40	17.37
Crude fibre %	5.74	4.06	3.78
Ether extract %	3.21	3.86	4.53
Ash %	10.61	9.13	9.24
NFE %	53.00	51.03	52.04
ME kcal kg^{-1}	2652.6	2745.60	2834.64

NFE: Nitrogen free extract, ME: Metabolisable Energy (kcal/kg) was calculated according to the formula derived by Pauzenga[11], ME: kcal/kg = (37×% CP) +(81.8×% EE) +(35×% NFE)

Table 3: Effect of feeding maintenance diet on production parameters during the lean season

Dietary treatments	IBWT (g)	FBWT (g)	DFI (g)	DWI (mL)	BWTG (g)	AFCR
Normal diet	1802.00	1914	85.150^{b}	175.20^{b}	111.8	66.60
Maintenance diet	1806.00	1939	93.190^{a}	211.00^{a}	133.3	60.80
SEM	8.87	21.8	0.753	2.62	17.03	8.13
Layer diet introduction time						
Week 1 early	1811.30	1930	89.160	191.60	118.8	62.50
Week 2 early	1796.70	1923	89.190	194.70	126.3	64.80
SEM	8.87	21.8	0.753	2.62	17.03	8.13
Interaction						
Normal diet×week 1	1814.00	1918	85.570	175.80	104.0	69.54
Normal diet×week 2	1790.00	1910	84.740	174.80	119.7	63.62
Maintenance diet×week 1	1809.00	1943	92.740	207.30	133.7	60.14
Maintenance diet ×week 2	1803.00	1936	93.640	214.80	133.0	61.41
SEM	12.54	30.8	1.064	3.71	55.55	11.50
p-value						
Dietary treatments	0.664	0.275	<.001	<.001	0.242	0.495
Layer diet introduction time	0.137	0.751	0.964	0.269	0.671	0.782
Interaction	0.357	0.982	0.282	0.134	0.644	0.670

Means with different superscripts in a column are significantly different, IBWT-Initial body weight, FBWT-Final body weight, DFI- Daily feed intake, DWI-daily water intake, BWTG- Body weight gain, AFCR- Average feed conversion ratio, SEM- standard error of means

laying period did not differ among the dietary treatments, restoration time of layer diet and their interaction. However, the daily feed intake (86.65g/bird) of Guinea fowls fed the normal layer diet from the previous phase was significantly higher (p = 0.014) than those of the Guinea hens fed the maintenance diet (84.13 g/bird). The time of restoration of the layer diet had no significant effect on feed intake and no interaction was observed between introductory time and dietary treatments (Table 4). At the end of the study, the mean body weight gain (209.5 g/bird) of Guinea fowls fed the maintenance diet was significantly (p<0.001) higher than those fed the normal layer diet (173.7 g/bird) from the previous phase.

The average feed conversion ratio was insignificant (p>0.05) among dietary treatments but tended to be higher numerically in the normal layer diet group (3.48) and thus less efficient as compared to the maintenance diet group (3.28) (Table 4). The interactions (the normal diet at weeks 1 and 2) showed no significant differences (p>0.05) for any of the parameters; likewise, in the maintenance diet at weeks 1 and 2, none of the parameters exhibited statistically significant differences (P > 0.05).

Effect of feeding maintenance diet during the lean season on egg production and characteristics in the next productive season: In the lean season, maintenance diet feeding resulted in a significant delay (p<0.009) in the next laying season (ToNL) by approximately 14 days (2.17 weeks after due time), compared to a relatively shorter delay of just 7 days (1.17 weeks) after due time for next laying when feeding the normal layer diet. (Table 5). This makes the laying time interval between the normal layer diet and the maintenance diet 7 days. Similarly, When layer diet was introduced two weeks prior (p = 0.05) to the expected laying time, Guinea hens laid eggs relatively sooner (1.33 weeks after due time) than when layer diet was introduced one week prior to the expected laying time (Table 5).

However, there was no significant difference in initial egg weight (p>0.05) among dietary treatments (Table 5) regardless of the difference in laying times. The average egg weight (46.56 g) was heavier (p = 0.034) for eggs of Guinea hens fed the maintenance diet in the lean season than eggs laid by birds fed the normal layer diet (44.13 g). The time of layer diet restoration had non-significant effect on the average egg weight. Egg width (EW) and egg length (EL) did not show significant differences (p>0.05) among dietary treatments and time of layer diet restoration. Mean eggshell thickness was higher (p = 0.013) for Guinea fowls fed the normal layer diet (0.54 mm) in the previous phase as compared to the thickness of eggshells (0.48 mm) of Guinea fowls fed the maintenance diet (Table 5). However, the time of layer diet restoration had no significant (p = 0.274) effect on the eggshell thickness.

There were no significant interactions between the dietary treatments and times of layer diet restoration (Table 5) among the parameters measured except hen-day egg production which recorded a significant (p = 0.016) interaction. The maintenance diet interacted with the layer diet introduction time (two weeks to laying) to produce higher (60.34 %) hen-day egg production.

Effect of feeding maintenance diet during the lean season on haematological characteristics: There were no significant differences (p>0.05) (Table 6) in most of the haematological parameters among the dietary treatments and Time of layer

Table 4: Effect of feeding maintenance diet on production parameters in the next laying season

Dietary treatments	IBWT (g)	FBWT (g)	DFI (g)	DWI (mL)	BWTG (g)	AFCR
Normal diet	1914	2062	86.65[a]	185.2[b]	173.7[b]	3.480
Maintenance diet	1939	2018	84.13[b]	201.0[a]	209.5[a]	3.280
SEM	21.8	35.8	1.862	2.62	2.62	0.108
Layer diet introduction time						
Week 1 Early	1930	2071	85.59	191,6	190.6	3.260
Week 2 Early	1923	2009	86.65	194.7	192.7	3.500
SEM	21.8	52.6	1.862	2.62	2.62	0.108
Interaction						
Normal diet×week 1	1918	2007	87.57	175.8	174.8	3.280
Normal diet×week 2	1910	2117	85.74	174.6	172.6	3.680
Maintenance diet×week 1	1943	2025	83.61	207.3	206.3	3.250
Maintenance Diet×week 2	1936	2010	84.65	214.8	212.8	3.320
SEM	30.8	50.70	2.633	3.71	3.710	0.153
p-value						
Dietary treatments	0.275	0.249	0.014	<0.001	<0.001	0.105
Layer diet introduction time	0.751	0.121	0.635	0.269	0.443	0.059
Interaction	0.982	0.224	0.113	0.134	0.134	0.162

Means with different superscripts in a column are significantly different, IBWT: Initial body weight, FBWT: Final body weight, DFI: Daily feed intake, DWI: Daily water intake, BWTG: Body weight gain, AFCR: Average feed conversion ratio, SEM: Standard error of means

Table 5: Effect of prior feeding of maintenance diet on egg production and egg characteristics during the next laying season

Dietary treatments	ToNL weeks	HDEP (%)	IEWT (g)	AEWT (g)	MEST (mm)	EW (cm)	EL (cm)
Normal diet	1.170[b]	57.950	43.200	44.130[b]	0.54[a]	4.470	5.450
Maintenance diet	2.170[a]	58.880	43.600	46.560[a]	0.48[b]	4.320	5.630
SEM	0.289	1.035	1.265	0.961	0.01986	0.103	0.186
Layer diet introduction time							
Week 1 Early	1.330[b]	58.520	44.880[a]	45.400	0.52	4.480	5.580
Week 2 Early	2.000[a]	58.310	41.920[b]	45.300	0.50	4.300	5.500
SEM	0.289	1.035	1.265	0.961	0.020	0.103	0.186
Interaction							
Normal diet×week 1	1.000	59.620[ab]	44.900	44.730	0.56	4.530	5.530
Normal diet×week 2	1.330	56.270[b]	41.500	43.540	0.52	4.400	5.370
Maintenance diet×week 1	1.670	57.420[ab]	44.870	46.070	0.48	4.430	5.630
Maintenance diet×week 2	2.670	60.340[a]	42.330	47.050	0.47	4.200	5.630
SEM	0.408	1.463	1.789	1.359	0.028	0.145	0.263
p-value							
Dietary treatments	0.009	0.393	0.760	0.036	0.013	0.182	0.352
Layer diet introduction time	0.050	0.841	0.047	0.914	0.274	0.112	0.665
Interaction	0.282	0.016	0.741	0.290	0.426	0.640	0.665

Means with different superscripts in a column are significantly different, ToNL: Time of next laying, HDEP: Hen-day egg production, IEWT: Initial egg weight, AEWT: Average egg weight, MEST: Mean eggshell thickness, EW: Egg width, EL: Egg length and SEM: Standard error of means

diet introduction except for Platelets and mean corpuscular volume which recorded higher ($p<0.05$) values for normal layer diet than the maintenance diet. For all haematological parameters, significant interactions ($p>0.05$) were observed between the normal diet and the maintenance diet with the latter recording significantly higher platelets and mean corpuscular volume than the former suggesting that both diets and layer diet introduction times had similar effects on the haematological profile of the subjects.

There were no significant differences among dietary treatments, layer diet introduction times and their interactions. However, the normal layer diet recorded a numerically lower values for Lymph (8.17×10^9/L) compared to the maintenance diet (65.17×10^9/L) (Table 7), while the other parameters did not show statistical or numerical differences.

The lack of significant differences in the interactions indicates that the effects of the dietary treatments (normal diet and maintenance diet) were consistent across the early phases of week 1 and 2.

Effect of feeding maintenance diet during the lean season on biochemical characteristics: Significant differences ($p<0.05$) were observed for several parameters when the means of the normal diet were compared to the maintenance diet. The normal diet (ND) showed significantly higher

Table 6: Effect of feeding maintenance diet during lean season on haematological characteristics

Dietary treatments	RBC × 10⁶μL	WBC × 10⁶μL	HB g/dL	MCH pg	MCHC g/dL	HCT %	PLT × 10³μL	MCV fL
Normal diet	1.76	14.68	13.17	93.9	49.02	26.92	12.0[a]	195.0[a]
Maintenance diet	1.63	13.80	15.07	96.3	50.35	25.27	7.83[b]	182.6[b]
SEM	0.167	1.666	1.594	3.02	1.998	1.346	1.374	3.75
Layer diet introduction time								
Week 1 early	1.80	12.30[b]	14.95	94.2	49.96	26.35	9.67	191.9
Week 2 early	1.60	16.18[a]	13.28	96.0	49.42	25.83	10.17	185.6
SEM	0.167	1.666	1.594	3.02	1.998	1.346	1.374	3.75
Interaction								
Normal diet×week 1	1.93	12.30	13.33	93.16	48.33	27.63	12.00	199.6
Normal diet×week 2	1.58	17.07	13.00	94.69	49.72	26.20	12.00	190.3
Maintenance diet×week 1	1.66	12.30	16.57	95.27	51.59	25.07	7.33	184.3
Maintenance diet×week 2	1.61	15.30	13.57	97.23	49.72	25.47	8.33	180.8
SEM	0.236	2.356	2.254	4.27	2.825	1.904	1.944	5.30
p-value								
Dietary treatments	0.469	0.610	0.267	0.463	0.526	0.255	0.016	0.011
Layer diet introduction time	0.264	0.048	0.326	0.579	0.794	0.711	0.725	0.128
Interaction	0.394	0.610	0.427	0.945	0.361	0.515	0.725	0.459

Means with different superscripts in a column are significantly different, RBC: Red blood cells, WBC: White blood cells, HB: Haemaglobin, MCH-Mean corpuscular haemaglobin, MCHC: Mean corpuscular haemaglobin concentration, HCT: Haematocrit, PLT: Platelets, MCV: Mean corpuscular volume, SEM: Standard error of means

Table 7: Effect of feeding maintenance diet during the lean season on haematological characteristics

Dietary treatments	Lymph (%)	Neutrophils (%)	Monophils (%)	Basophils×10³ /μL	Eosino.×10³ /μL	T. Eosino. (%)
Normal layer diet	8.170	23.170	4.330	2.830	0.186	68.170
Maintenance diet	65.170	22.500	5.170	3.670	0.400	65.170
SEM	1.404	1.080	0.577	1.080	0.106	1.404
Layer diet introduction time						
Week 1 early	66.170	23.330	4.830	2.830	0.280	66.170
Week 2 early	67.170	22.330	4.670	3.670	0.310	67.170
SEM	1.404	1.080	0.577	1.080	0.106	1.404
Interaction						
Normal diet×week 1	67.000	24.000	4.000	3.000	0.220	67.000
Normal diet×week 2	69.330	22.330	4.670	2.670	0.150	69.330
Maintenance diet×week 1	65.330	22.670	5.670	2.670	0.350	65.330
Maintenance diet×week 2	65.000	22.330	4.670	4.670	0.460	65.000
SEM	1.986	1.522	0.816	1.528	0.150	1.986
p-value						
Dietary treatments	0.065	0.550	0.187	0.463	0.075	0.065
Layer diet introduction time	0.497	0.382	0.780	0.463	0.821	0.497
Interaction	0.370	0.554	0.187	0.312	0.427	0.370

Means with different superscripts in a column are significantly different. Lymph: Lymphocytes, Eosino: Eosinophils, T. Eosino: Total eosinophils, SEM: Standard error of means

(p<0.001) values for globulin (32.6 g/L), albumin (11.47 g/L), Total Protein (39.70 g/L) and total cholesterol (7.35 mmol/L) compared to globulin (20.2 g/L), albumin (9.90 g/L), total protein (30.63 g/L) and total cholesterol (4.05 mmol/L) for MD. However, the two diets had no significant differences in glucose, triglycerides, low and high-density lipoprotein (LDL and HDL). During the early phase of weeks 1 and 2, there were no significant differences (p>0.05) regarding the introduction of layer diets, with the exception of triglycerides (p<0.022) (Table 8), which showed a higher concentration of triglycerides (3.37 g/L) when the layer diet was introduced one week before egg laying.

Calcium levels (29.63mmol/L) were significantly higher (p<0.004) than 23.10 mmol/L recorded for the normal diet and Urea levels (1.97 mmol/L) were significantly higher than that recorded for the maintenance diet (1.52 mmol/L). However, the two diets were not significantly different (p>0.05) in terms of sodium, chloride, potassium and total bilirubin levels (Table 9). Neither diets nor layer diet introduction times had significant effects (p>0.05) on all parameters.

Effect of feeding maintenance diet during the lean season on feed cost and savings: The maintenance diet showed significantly higher values (p<0.001) for total feed intake after the introduction of the layer diet (TFIA) (918.7 g/bird) compared to 902 g/bird. Additionally, the cost per kilogram of feed before the introduction of the layer diet (C/KB) was significantly lower (1.84 GH¢) compared to the normal diet

Table 8: Effect of feeding maintenance diet during the lean season on biochemical characteristics

Dietary treatments	Glob (g/L)	Gluc (g/L)	Album (g/L)	T-Protein (g/L)	TG (mmol/L)	T Chol (mmol/L)	HDL (mmol/L)	LDL (mmol/L)
Normal diet	32.60[a]	13.970	11.470[a]	39.700[a]	2.530	7.350[a]	1.020	1.410
Maintenance diet	20.20[b]	12.770	9.900[b]	30.630[b]	1.700	4.050[b]	1.430	1.280
SEM	2.60	0.922	0.307	1.639	0.445	0.750	0.267	0.541
LDIT								
Week 1 early	26.50	13.750	10.970	33.330	2.320	5.520	1.350	1.400
Week 2 early	26.30	12.980	10.400	37.000	1.920	5.880	1.100	1.290
SEM	2.60	0.922	0.307	1.639	0.445	0.750	0.267	0.541
Interaction								
ND×week 1	34.47	14.270	11.970	38.330	3.370[a]	7.270	1.070	1.460
ND×week 2	30.80	13.670	10.970	41.070	1.700[ab]	7.430	0.970	1.360
MD×week 1	18.63	13.230	9.970	28.330	1.270[a]	3.770	1.630	1.350
MD×week 2	21.80	12.300	9.830	32.930	2.13[ab]	4.330	1.230	1.220
SEM	3.68	1.304	0.435	2.319	0.630	1.061	0.377	0.765
p-value								
DT	0.001	0.229	<0.001	<0.001	0.098	0.002	0.157	0.818
LDIT	0.926	0.430	0.102	0.056	0.395	0.638	0.376	0.839
Interaction	0.226	0.861	0.196	0.585	0.022	0.797	0.589	0.985

Means with different superscripts in a column are significantly different, LDIT: Layer Diet Introduction time, DT: Dietary Treatment, Glob: Globulin, Gluc: Glucose, Album: Albumin, TG: Triglycerol, T Chol: Total cholesterol, HDL: High-Density Lipoprotein and LDL: Low-density lipoprotein

Table 9: Effect of feeding maintenance diet on biochemical characteristics during the lean season

Dietary treatments	Ca (mmol/L)	Na (mmol/L)	Cl (mmol/L)	K (mmol/L)	Urea (mmol/L)	T-Bilirubin (µmol/L)
Normal diet	29.630[a]	132.80	109.330	2.550	1.9700[a]	23.700
Maintenance diet	23.100[b]	137.30	109.000	2.680	1.5200[b]	17.500
SEM	1.602	4.28	1.443	0.297	0.1546	3.830
Layer diet introduction time						
Week 1 early	26.920	137.80	108.830	2.770	1.7700	25.400[a]
Week 2 early	25.820	132.30	109.500	2.470	1.7200	15.700[b]
SEM	1.602	4.28	11.443	0.297	0.1546	3.830
Interaction						
Normal diet×week 1	30.630	135.70	109.000	2.430	2.0000	28.900
Normal diet×week 2	28.630	130.00	109.700	2.670	1.9300	18.500
Maintenance diet×week 1	23.200	140.00	108.700	3.100	1.5300	22.000
Maintenance diet×week 2	23.000	134.70	109.300	2.270	1.5000	13.000
SEM	2.266	6.05	2.041	0.420	0.2186	5.410
p-value						
Dietary treatments	0.004	0.324	0.823	0.666	0.0200	0.144
Layer diet Introduction time	0.512	0.235	0.656	0.342	0.7550	0.035
Interaction	0.590	0.970	1.000	0.110	0.9170	0.859

Means with different superscripts in a column are significantly different, Ca: Calcium, Na: Sodium and Cl: Chlorine K: potassium

(ND) (2.21 GH¢). Conversely, the cost of feed intake per bird (CFIB) was significantly higher (p<0.001) in the normal diet (13.97 GH¢) compared to the maintenance diet (11.87 GH¢). Compared to the early phase of introduction time (1 week to laying) (611.7 g/bird), the introduction time (2 weeks to laying) resulted in significantly higher total feed intake after introducing the new layer diet (1209 g/bird). Conversely, total feed intake before layer diet introduction (2 weeks to laying) resulted in significantly lower total feed intake before layer diet introduction (6045 g/bird) as compared to the early phase of introduction time (1 week to laying) (6729 g/bird). In a similar trend, the cost of total feed intake before the introduction of layer diet (CTFIB) recorded a significantly lower cost (12.23 GH¢) in the early phase of layer diet introduction (2 weeks before laying) as compared to 1 week before laying (13.61 GH¢). There were no significant (p>0.05) interactions among the dietary treatments and layer diet introduction times (Table 10).

DISCUSSION

Proximate composition of the study diets: The proximate composition of the experimental diets obtained from the present study was marginally higher than the recommended moisture level of poultry feed (12 %) as reported by Okoli *et al*.[12] and 11.17 % obtained by Naveed *et al*.[13]. The crude protein of the layer diets met the recommended level of 17%[14] and that of the maintenance diet was in the recommended range of 14-15%. The metabolizable energy of the layer diets fell marginally below the value of 2850 kcal/kg[15] but was in the recommended range of 2750-2900 kcal/kg[16,17].

Effect of feeding maintenance diet on Guinea hens in the lean (unproductive) season: Birds fed the maintenance diet have a higher daily feed intake due to the different nutrient

Table 10: Effect of feeding maintenance diet on feed cost and savings

Dietary Treatments and Feeding Period	TFIB (g/bird)	TFIA (g/bird)	C/KB (GH¢)	C/KA (GH¢)	CTFIB (GH¢)	CTFIA (GH¢)	TFC (GH¢)	FCS (%)
Normal diet	6321.0	902.00[b]	2.21	2.19	13.97[a]	1.980	15.95[a]	
Maintenance diet	6453.0	918.70[a]	1.84	2.19	11.87[b]	2.010	13.89[b]	12.92
SEM	22.2	3.32	-	-	0.047	0.010	0.054	
Layer diet introduction time								
Week 1 early	6729.0	611.70[b]	2.02	2.19	13.61[a]	1.340[b]	14.95	
Week 2 early	6045.0	1209.00[a]	2.02	2.19	12.23[b]	2.650[a]	14.88	0.5
SEM	22.2	3.32	-	-	0.047	0.007	0.054	
Interaction								
Normal diet×week 1	6640.0	603.70	2.21	2.19	14.68	1.320	16.00	
Normal diet×week 2	6002.0	1200.30	2.21	2.19	13.26	2.630	15.89	-
Maintenance diet×week 1	6818.0	619.80	1.84	2.19	12.55	1.360	13.90	
Maintenance diet×week 2	6088.0	1217.70	1.84	2.19	11.20	2.670	13.87	
SEM	31.5	4.69	-	-	0.067	0.010	0.076	
p-value								
Dietary treatments	<0.001	<0.001	-	-	<0.001	<0.001	<0.001	
Layer diet introduction time	<0.001	<0.001	-	-	<0.001	<0.001	0.238	
Interaction	0.076	0.859	-	-	0.484	0.859	0.525	

$1.00: GH¢12.00 as at the time of the study, Means with different superscripts in a column are significantly different, TFIB: Total feed intake before new layer diet, TFIA: Total feed intake after new layer diet, C/KB: Cost per kg of diet before introduction of layer diet, C/KA: Cost per kg of diet after introduction of layer diet, CTFIB: Cost of total feed intake before layer diet introduction, CTFIA: Cost of total feed intake after layer diet introduction, TFC: Total feed cost, FCS: Feed cost savings from maintenance feeding

levels in the maintenance diet, particularly metabolizable energy levels. As a compensatory mechanism to meet the body's energy requirements, feed intake is higher when dietary energy is lower than when it is higher[14,17,18]. The time of layer diet restoration did not affect the Daily Water Intake (DWI) and had no interaction effect. Body weight gain and average feed conversion ratio were not influenced by dietary treatments and time of layer diet restoration (week 1 and 2 to laying season) (Table 3). Body weight gain obtained across treatments was expectedly lower because the Guinea fowls had already attained full growth maturity (70 weeks old) and had laid eggs in the previous laying season. The relatively lower body weight gain observed is considered good because the heavier body weight of birds is negatively correlated with reproduction performance[19]. The recorded average feed conversion ratios were very high due to birds eating, not laying and not gaining substantial weight. Average feed conversion ratio is a ratio of feed intake and production output (body weight or egg mass) but in the absence of egg mass, it was calculated using body weight gain over the period, which resulted in higher values. This implies that the effect of the dietary treatments on the production parameters was consistent regardless of the specific time of layer diet restoration. Poorer average feed conversion ratios indicate the potential cost of feeding Guinea fowls during fallow periods in commercial intensive breeder farms and the need for strategic feeding for cost savings. Moreover, the higher water intake observed in the maintenance diet group is consistent with the well-established relationship between feed and water intake in poultry species[20]. As Guinea fowls consumed more feed due to the lower energy content of the maintenance diet, their water intake also increased proportionally to support the digestion process[21,22]. Notably, the interaction between dietary treatments and the time of layer diet restoration did not significantly impact the production parameters. While the maintenance diet resulted in higher feed intake, it did not lead to significant differences in body weight gain or feed conversion efficiency between the normal layer diet and maintenance diet groups during the lean season. This is likely due to the fact that Guinea fowls had already attained full maturity and laid eggs in the previous season, leading to reduced weight gain and productivity[23]. The high average feed conversion ratio recorded across treatments further supports the decreased production efficiency during the lean season[24].

Effect of maintenance diet feeding during lean season on production characteristic in the next laying season with restored layer diet: The lower intake of feed by Guinea hens that were fed the maintenance diet in the previous phase was due to the improved nutrition of the restored layer diet, which met the energy requirements. The lower daily feed intake of the maintenance diet group as compared to the normal layer diet group from the previous phase could be due to the adjustment process of the restored layer diet[25]. Final body weight remained consistent across all dietary treatments, restoration times of the layer diet and their interaction. Regarding the laying performance, egg quality and economics of feeding in layer diets this result contradicts with Belete *et al.*[26] but supported by Wise[27], who observed no significant changes in body weight and fat content of hen pheasants from mid-December until March (the onset of laying). At the end of the study, a significant effect was observed in the mean body weight, corroborated by the observation of Okyere *et al.*[28]. Dietary treatments and layer diet restoration times did not have any significant effects on interactions due to the birds' adaptive capacity and similar diets[29] and probably the relatively shorter differential in the restoration time[30]. This indicates that the maintenance diet fed to Guinea hens during the lean season had no adverse impact on the birds in the ensuing season. The higher body weight gain could be due to compensatory growth from the restoration of a layer diet, which provided the required nutrients other than the maintenance diet fed to the birds at the previous phase. The non-significant differences but numerically higher average feed conversion ratio was observed in the normal layer diet compared to the maintenance diet aligns with the results of Okyere *et al.*[28].

Effect of feeding maintenance diet in the lean season on egg production and characteristics in the next productive season: Compared with the normal layer diet group, the maintenance diet group had a significantly longer wait until the next laying season. This might have been due to the difference in nutritional levels in the diets fed to the Guinea hens during the lean season, which may have prompted the normal layer diet group to lay ahead of the maintenance diet group. High nutritional diets support layers to reduce the duration of the ensuing egg-laying season. Adequate nutrition during the lean season can positively impact the birds' reproductive physiology[31,32] and shorten the time required to start laying[33]. The number of days to egg laying affects egg size and egg weight such that longer days result in heavier and larger sizes and vice versa[34]. Many commercial layer farms have used this strategy to increase the number of days spent on egg laying to avoid peewee eggs by restricting feeding prior to egg laying[35]. The similar initial egg weight recorded indicates that after the initial onset of egg laying, subsequent egg sizes in the other laying seasons are not likely to be affected by egg-laying time. The non-significant ($p>0.05$) initial egg weight and the significant average egg weight from Guinea fowls fed the maintenance diet vividly indicate that maintenance diet feeding during the unproductive (lean) season of Guinea fowls is not likely to have an adverse effect on the egg size and weight in the subsequent laying season. The thicker eggshells of the Guinea fowls fed the normal layer diet are attributed to the level of calcium in the layer diet relative to that contained in the maintenance diet[36]. This allowed the birds to access higher calcium levels for eggshell formation. In the case of the new layer diet, the restoration time did not have any significant effect on the birds' calcium levels, as all birds gained similar levels of calcium from the same feed formula. This also suggests that increasing the calcium levels in the maintenance diet could lead to thicker eggshells in the ensuing laying season.

Higher levels of essential nutrients, such as proteins, vitamins and minerals, significantly promote poultry development, egg quality and laying frequency[37]. The non-significant differences in Hen-day egg production among dietary treatments indicate that enough nutrients were available from the diet to promote egg production. Similar results were obtained by Chung *et al.*[38] who fed vitamins C and E under heat stress to broiler breeders. Stable and consistent nutrition provided by the maintenance diet during the lean season and the nutritional variations in the layer diet fed to birds and smooth potential physiological adjustments during the transition to the next laying season might have contributed to the general non-significant effect on some measured parameters. The study suggests that a maintenance diet, when substituted 2- 3 weeks before the expected laying time, may lead to earlier laying times and heavier initial eggs and is consistent with the observation of Bain *et al.*[6] and Avila *et al.*[39].

Effect of feeding maintenance diet during the lean season on haematological characteristics: The absence of variations in most of the haematological parameters of Guinea fowls can be inferred and associated with the similarity in haematological parameters between the normal and maintenance diet groups, indicating that both diets did not adversely affect the subjects' overall health and well-being. Haematological parameters are essential indicators of an animal's health status and non-significant differences in values that are in the normal recommended range suggest that both diets supported healthy blood profiles[40,41]. These non-significant trends were also replicated in all parameters measured in the interactions. This indicates that the timing of introducing the normal diet did not significantly impact those parameters and their values remained relatively consistent across the different interactions. The Mean corpuscular volume and platelets were significantly ($p<0.05$) higher in Guinea hens fed the normal layer diet from the previous phase. To infer and associate scientific meaning from these results, the significantly higher platelet values in the normal diet at introduction time (weeks 1 and 2 to laying) suggest a potentially robust platelet response to the diet at this specific time point. Platelets are crucial components of the blood responsible for blood clotting and wound healing[42]. The observed platelet increase may indicate an adaptive response to the dietary composition during this period. Maintenance diets have lower mean corpuscular volume due to the difference in nutrients between normal layer diets and maintenance diets[43]. The normal and maintenance diets exhibited similar effects on the production characteristics during the early phases of restoration of the layer diet (weeks 1 and 2). However, it is essential to note that the lack of significant differences in the interactions does not necessarily mean that there were no differences between the dietary treatments. There might still be subtle variations in the measured parameters between the dietary treatments that could be relevant from a practical or biological perspective, even though they did not reach statistical significance.

Effect of feeding maintenance diet during the lean season on biochemical characteristics: Higher levels of globulin, albumin and total protein in the normal layer diets suggest that the normal diet provided a better balance of essential amino acids and proteins, contributing to higher globulin and albumin levels, crucial for various physiological functions, including immunity and nutrient transport[44]. At times of layer diet introduction (weeks 1 and 2 to laying), globulin and total protein levels significantly increased in the normal diet group, suggesting that the normal diet provided essential nutrients that promoted protein synthesis, leading to higher blood globulin and total protein concentrations. A range of physiological functions, including immune responses and tissue repair, may have been supported by these nutrients. The total protein levels were also higher in the normal diet group, indicating a more favourable protein intake than the maintenance diet. Total cholesterol and HDL (high-density lipoprotein) was also higher in the normal diets than the maintenance diet. Total cholesterol is an essential component of cell membranes and a precursor for various hormones[45]. The higher levels in the normal diet group may be due to the diet's composition, which contains more cholesterol-rich ingredients. High-density lipoprotein is considered "good cholesterol" as it helps remove excess cholesterol from the bloodstream[46]. The higher levels of high-density lipoproteins in the normal diet group suggest that this diet may promote better cardiovascular health[47] than the maintenance diet. The lack of variation observed between the two diets for glucose, triglycerides and LDL (low-density lipoprotein) implies that both diets had similar effects on blood glucose regulation and triglyceride levels. Low-density lipoprotein is often called "bad cholesterol"[48]. However, there were no significant differences between the two diets, indicating that low-density lipoprotein levels were not significantly affected by either diet. On the other hand, the relatively lower levels of globulins and total protein levels could be associated with the fact that the maintenance diet might have been designed to meet the basic nutritional requirements of the study subjects during the lean season, which might not have provided an abundance of nutrients for enhanced protein synthesis. Higher cholesterol levels observed for birds fed the normal diet during the layer introduction time (2 weeks before laying) may be related to higher amounts of cholesterol-rich ingredients in the normal diet that promoted cholesterol synthesis in the body.

The normal layer diet led to increased urea levels in the subjects, potentially due to variations in protein content or metabolism between the two diets[49]. The biochemical characteristics of the blood were not adversely affected by the feeding of the maintenance diet such that the production characteristics were impaired during the ensuing laying season by the Guinea hens.

Effect of feeding maintenance diet on feed cost and savings: Maintenance diet promotes feed consumption during unproductive periods, supporting the birds' energy levels and overall condition. A comparison of the cost per kilogram of diet before and after the maintenance diet's introduction demonstrates that the maintenance diet reduces feed costs during off-laying periods while providing adequate nutrition for birds[50].

Breeder farms must follow these practices to reduce overhead costs and ensure profitability during unproductive seasons. The cost-effectiveness of the maintenance diet highlights its potential significance in Guinea fowl production systems, where feed expenses often account for a significant percentage of overall costs[51]. A maintenance diet is cheaper than a normal layer diet due to the lower cost of protein and energy-supplying feed ingredients. In case feed intake is comparable to a normal diet, reducing these ingredients in the feed formulation will reduce feed costs. The feed intake of the maintenance diet did not differ significantly from the normal layer diet and that sustained the gains made from feeding the maintenance diet. Previous studies have demonstrated that timing plays a crucial role in the growth performance of birds and the notable increase in feed intake underscores the importance of strategic feed management[51]. Introducing the maintenance diet at the right phase could potentially optimise feed utilisation, improve bird productivity and reduce overall feed expenses[52] Therefore, Guinea fowl farmers may want to implement maintenance diets during unproductive (lean) seasons as a cost-saving measure.

CONCLUSION

As demonstrated in the present study, the lower feed costs associated with the maintenance diet unequivocally offer the improved profitability without adversely impacting the birds' performance. It is crucial to consider the timing of the introduction of layer diets meticulously. The substantial disparities in feed intake between the layer diet introduction time (week 1 and 2) undeniably indicate that introducing the diet earlier will undoubtedly enhance feed efficiency and improve economic outcomes. Feeding a maintenance diet (14-15% CP) during the lean season and switching to a layer diet two weeks before the next laying season is recommended. Simultaneously, considering the timing and introduction of a maintenance diet, there is an imperative need for further research on strategies that could indisputably promote all-year laying systems in Guinea fowls and support continuous production, which is essential for sustaining the industry year-round.

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