

Incubation and Early Growth Performances of Local Guinea Fowl (*Numida meleagris*) Fed on a Diet Supplemented with *Moringa oleifera* Leaf Meal in the Sudano-Guinean Zone of Cameroon

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Abstract

Background: Guinea fowl breeding is gaining more interest as a promising alternative in poultry production due to their high-quality meat and eggs for vulnerable community in Africa. However, guinea fowls are more often raised under a scavenging system with minimal housing and health monitoring, which may negatively hamper their productivity in term of reproduction and growth performance. **Aims:** This study aims to characterize and evaluate the hatching performances of guinea fowl eggs, and then, the early growth performances of keets post-hatch fed on experimental diet containing *Moringa oleifera* leaf powder in the Sudano-Guinean zone of Cameroon. **Materiel and methods:** A total of 510 eggs were collected from farm along three localities (Biou, Figuil and Batao) characterized, weighed and measured. They were then grouped into five egg weigh categories: [25 - 30[, [30 - 35[, [35 - 40[, [40 - 45[and [45 - 50[and incubated for 30 days. At the end of the incubation, unhatched eggs were candled to count unfertile eggs, and unhatched fertile eggs were separated through candling and breaking of unhatched eggs to count dead in shell embryos classified into 4 stages (very early, early, late and very late). Keets were collected at hatch as from 30 days of incubation from each group and weighed to determine their baseline weight post-hatch. Guinea fowl were weighed and monitored for 12 weeks to assess the effect of *Moringa*

oleifera leaf meal feed (MOLM) supplementation on growth traits performances. On a feed containing 3005.28 Kcal of metabolizable energy and 19% crude protein, the guinea fowl were fed *ad libitum* with four experimental diets: T0 (only basal diet), T1 (basal + 1% MOLM), T2 (basal + 2% MOLM) and T3 (basal + 3% MOLM). They were randomly assigned to keets group. Data collected included: egg characteristics (weight, height, large diameter and shape index), incubation performance (fertility rate, apparent and actual hatching rates, embryonic mortality rate, average hatching weight and percentage of viable guinea fowl). Feed intake, body weight, average weight gain and feed conversion ratio were recorded for growth performance. **Results:** Our results showed that, irrespective of location, egg weights ranged from 27.71 to 45.56 g, with an average of 37.81 ± 3.54 g. Eggs weighing between 35 and 45 g accounted for 77.25% of eggs collected overall. The effective hatching rate was 35.55%. The highest value was recorded at Figuil (41.61%) and the lowest (13.33%) at Batao. Candling gave fertility rates of 71.72%, 67.60% and 35.30% for Biou, Figuil and Batao respectively. The embryonic mortality rate was 36.86%, with the highest value (45.45%) at Biou and the lowest (30.60%) at Batao. Average hatchling weight was 22.84 ± 3.38 g. The viability rate was 61%. The 35 - 40 g category recorded the best effective hatching rate (19.72% at Biou and 22.92% at Figuil). Animals in treatment T1 had the best body weight (489.32 g), feed intake (219.92 g) and feed conversion ratio (3.6) compared to other treatments T0 (461.17 g, 213.72 g, 3.6), T2 (447 g, 220.80 g, 5) and T3 (470.45 g, 217.08 g, 3.7). **Conclusion:** This study shows that guinea fowl eggs collected at Biou and Figuil gave the best hatching performance; eggs weighing between 35 and 45 g are more suitable for better hatching. Guinea fowl eggs collected in village settings appear to have a low fertility rate. *Moringa oleifera* leaf powder can be used up to 3% with no adverse effect on guinea fowl production performance.

Keywords

Incubation, Local Guinea Fowl, Growth Performance, Sudano-Guinean Zone, Cameroon

1. Introduction

Indigenous poultry farming is very popular in the sub-Saharan region, sustaining the livelihood of millions of farmers and vulnerable communities [1]. In Cameroon, indigenous poultry farming is predominantly dominated by *Gallus Gallus* species [2]-[4]. Most of the research has been oriented towards predominant species of broiler, local chickens, to improve local chicken [5] [6]. Within vulnerable communities, poultry farming represents one of the few opportunities for food security, savings and investment [7]. Unfortunately, disease outbreak, climate change and global warming are among factors that decreased productivity of indigenous genetic resources in sub-Saharan countries and in Cameroon, hence, delaying their sustainable management initiatives, making them fragile in face of global changes and unsustainable for food security [4]. There is a need to look for non-conventional ani-

mal alternatives. In fact, non-conventional animal species can be justified by the fact that they can be adapted to harsh environmental condition and they can utilize natural resources that conventional species cannot, easy to manage, handle, feed, and thus be raised by smallholder farmers within household in Africa [8] [9]. In this regard, indigenous guinea fowl represent an important asset for diversifying animal protein origins but also for reducing pressure towards intensive chicken meat and egg production which is not affordable for many vulnerable families [7] [10].

In the Sudano-Guinean zone of Cameroon, the indigenous guinea fowl are considered as a non-conventional poultry species with great production potential and thus is a good candidate to increase availability of protein of animal origin [4]. Dongmo and collaborators have suggested that, based on morphometric analysis, indigenous guinea fowl could constitute a high potential food resource if provided appropriate breeding [11]. However, in Cameroon context, a large amount of guinea fowl eggs and meat are collected from the wild [4]. Henceforth, most of efforts towards production of indigenous guinea fowls remained in the scavenging rearing system with very scanty knowledge regarding their health care, nutrition, reproduction, housing, breeding and selection [2] [4] [7] [12]. Banla and collaborators also emphasized that most of the husbandry techniques adopted in the breeding of indigenous guinea fowls are copied from the common domestic chicken as they are similar [4]. It implies that, indigenous guinea fowl, may inherit most of constraints encountered in scavenging chicken farming. As a result, guinea fowl production has remained undeveloped for a long time.

In Cameroon, several studies have been carried out on breeding practice [2] morphobiometric characterization of guinea fowls [13], production performance [7] [14]. Research on eggs characteristics, early growth performance of guinea fowl keet are still very scanty. If properly managed and fed, guinea fowls could make a significant contribution to satisfying animal protein requirements and raising the standard of living of vulnerable population. The nutritional needs of guinea fowl are specific to the Sudano-Sahelian zone, where *Moringa oleifera* production and use is fairly widespread.

There are many unconventional food resources in the Sudano Guinean zone of Cameroon [15] [16], such as *Moringa oleifera*, reputed for its virtues and richness in nutrients, vitamins, minerals, essential amino acids, etc. Moringa has already been used in animal feed to improve growth performance in guinea pigs [17], quail [3] [18] [19] and the reproduction of laying hens [17] [20], but to our knowledge no work has been done on the use of *Moringa oleifera* on the production performance of guinea fowl. Henceforth, the present study aims to characterize guinea fowl eggs, evaluate the hatching rate, and to investigate the early growth performances of keets post-hatch fed on experimental diet containing *Moringa oleifera* leaf meal (MOLM) in the Sudano-Guinean zone of Cameroon.

2. Materials and Methods

2.1. Presentation of the Study Area

This investigation was carried out both in Figuil subdivision (North region) and

in Ngaoundere I subdivision (Adamaoua region).

Located between the 9th and 14th degrees North latitude and between the 8th and 13th degrees East longitude, Figuil belongs to the Sudano-Sahelian agro-ecological zone, with a relief alternating between plateaus, valleys and flood plains and mountain ranges that can reach altitudes of over 277 m. Figuil's climate is Soudano-Sahelian, characterized by higher temperatures than in the equatorial climate, with greater thermal amplitudes: 26.3°C in December versus 38.5°C in April. The average temperature is 28°C [21].

The town of Ngaoundere, located between the 6th and 8th degrees North latitude and between the 10th and 16th degrees East longitude (11th), is part of the agroecological zone known as the high Guinean savannahs, with an average altitude of 1000 m and mountains with peaks of almost 2300 m in altitude. The soils are generally fertile and suitable for agropastoral activities. The climate has two seasons: an 8-month rainy season from April to November and a 4-month dry season from December to March [22].

2.2. Ethical Approval

All animal care and protocol were carried out according to the guidelines (OIE ethical use of experimental animal) provided and supported by the University of Ngaoundere ethical review committee. There was constant monitoring of the adherence to the procedures and resource provision.

2.3. Experimental Animal

510 eggs were collected from three localities (Biou, Figuil and Batao), then weighed, measured and coded according to locality. They were then transported to Ngaoundere for incubation, under the same incubation conditions (duration, temperature, humidity). Incubation for 30 days, during which time we observed a temperature of 36.4 - 38.5°C, relative humidity of 60 - 80% [23] and manual turning at least twice a day. 72 keets hatched during incubation were randomly selected and monitored for 12 weeks (**Photo 1**).

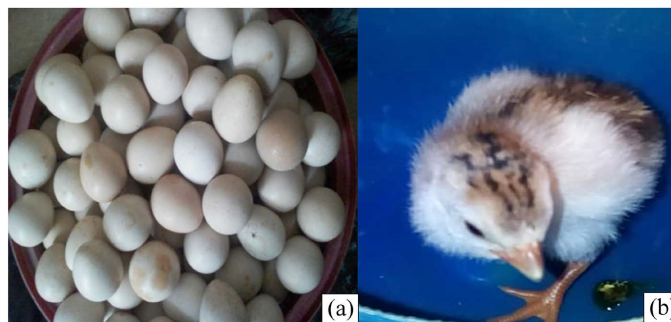


Photo 1. Animal material: local guinea fowl eggs (a) and day-old guinea fowl keet (b).

2.4. Plant Material Preparation

Fresh *Moringa oleifera* leaves were collected in Ngaoundéré before 08:00 in the

morning, then defoliated, washed and drained. They were then dried for 2 to 3 days in the shade until they became crumbly. They were then ground into flour using a pre-cleaned mortar, until an assimilable powder was obtained. The powder obtained was stored in a plastic bag in a dry place at room temperature until use.

2.5. Housing and Feeding

The centesimal composition and calculated chemical characteristics of feed are reported in **Table 1**.

Table 1. Centesimal composition of feed in the growth phase and calculated chemical characteristics.

Ingredients	Quantity (Kg)
Corn	62
Wheat bran	10.5
Soya	11
Peanuts cake	8
Fish meal	5
Shell Fish	1.8
Bone meal	0.5
Palm oil	1
Iodized salt	0.2
Total	100
Calculated chemical characteristics	
Protein content (%)	19
Metabolizable Energy (kcal/kg)	3005.28
Energy/Protein	158.17
Fat (%)	5.45
Calcium (%)	1.41
Phosphorus (%)	0.62
Lysine (%)	1.16
Methionine (%)	0.44

A total of 72 day-old guinea fowl keets were divided into 12 groups of 06 birds, so as to create batches similar in terms of average body weight (22.84 ± 2.39 g), and housed in cages (65 cm \times 50 cm) made of boards and low-mesh netting at a density of 12 birds/m². The guinea fowl were heated to 38°C for the first two weeks, then reduced by 2°C each week until room temperature was reached. On a feed containing 3005.28 Kcal of metabolizable energy and 19% crude protein, guinea fowl were fed *ad libitum* on four experimental diets (T0, T1, T2 and T3) with different rates of incorporation of *M. oleifera* leaf powder (0%, 1%, 2% and 3% respectively).

2.6. Experimental Set-Up and Trial Conduct

Each of the 4 experimental diets was randomly assigned to 3 batches in a completely randomized design to eliminate bias. The 72-guinea fowl were allocated to 12 groups of 6 birds of similar weight (22.84 ± 2.39 g), then were randomly assigned to 4 treatments (T0, T1, T2 and T3 corresponding to 0%, 1%, 2% and 3% levels of *Moringa oleifera* leaf powder incorporation), each treatment had three replicates of 6 birds each. The inclusion rates of 1%, 2%, and 3% for *Moringa oleifera* leaf powder (MOLM) diets were chosen based on their demonstrated effects on growth performance, meat quality, and overall health benefits of other avian species [3] [6] [18]. Water and feed were provided *ad libitum* throughout the trial. Birds were identified with leg bands and monitored individually for body weight gain. Birds in all cages benefited from the same rearing conditions (housing, feed and prophylaxis).

2.7. Data Collection

2.7.1. Egg Characteristics

Each egg was weighed, coded according to origin, grouped into 5 categories ([25 - 30[, [30 - 35[, [35 - 40[, [40 - 45[and [45 - 50[) at 5 g intervals and incubated for 30 days. An electronic balance with a 500 g capacity and 0.01 g accuracy was used to weigh the eggs. Then a digital caliper range of 15 cm and accuracy of 0.01 mm was used to measure height and large diameter of the eggs. The diameter and height data for each egg were used to calculate the shape index as follows:

$$\text{shape index} = \frac{\text{diameter (mm)}}{\text{height (mm)}}$$

2.7.2. Incubation Performance

At the end of the incubation period, data on fertility rates of egg, apparent and effective hatching rates and embryonic mortality rates were calculated for the different localities as follows:

$$\text{Fertility rate \%} = \frac{\text{Number of fertilized eggs}}{\text{Number of eggs incubated}} \times 100$$

$$\text{Reel hatching rate \%} = \frac{\text{Number of eggs hatched}}{\text{Number of fertilized eggs}} \times 100$$

$$\text{Embryo mortality rate} = \frac{\text{Number of eggs with a dead embryo}}{\text{Number of fertilized eggs}} \times 100$$

At the end of incubation, unhatched eggs were candled to determine unfertile and fertile eggs. Unhatched fertile eggs were broken to determine the embryonic mortality rate, classified into 4 different development stages as follows: very early (0 - 7 days), early (8 - 14 days), late (15 - 21 days) and very late (22 - 28 days).

The different incubation stages are described on (Photo 2).

2.7.3. Growth Performances

1) Average weight and percentage of viable keets after hatchings

Using an electronic balance with a capacity of 500 g and accuracy of 0.01 g, the

body weights of the keets after hatching were taken and the average weights were calculated. As the trial progressed, the viability rate was also calculated as the number of viable keets divided by the total number of keets after hatching.

$$\text{Percentage of viable keet} = \frac{\text{number of viable keet at end of trial (g)}}{\text{number of keet at the beginning of trial}}$$

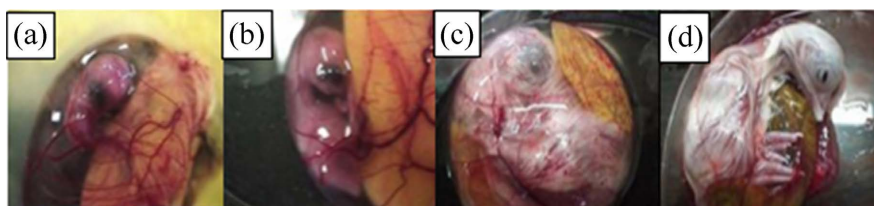


Photo 2. Different incubation stages used for embryonic mortality evaluation: Very early (a), early (b), late (c) and very late (d).

2) Feed intake

At the beginning of the week, feed was weighed and distributed daily. Each week, the remains from each processing unit were weighed. An electronic balance with a 5000 g capacity and 1 g accuracy was used for the various weighing operations. Weekly Feed intake was obtained by calculating the difference between the quantity of feed distributed during the week and the remain at the end of the same week.

3) Body weight and weight gain

At the start of the trial and every 7 days, the birds were weighed fasting in the morning using an electronic scale with a 2000 g capacity and 0.1 g accuracy. Every 7 days, the average weekly weight gain was calculated as the difference between two consecutive body weights.

4) Feed conversion ratio

Data on Feed intake (FI) for the week and average weekly weight gain (AWG) for the same period were used to calculate the FCR as follows:

$$\text{FCR} = \frac{\text{Feed Intake (g)}}{\text{Average Weight Gain (g)}}$$

2.8. Statistical Analysis

Data collected on egg characteristics, incubation performance and some growth parameters were subjected to one-way analysis of variance (ANOVA) (Locality and experimental diet) following the general linear model (GLM).

Mean values that differed significantly among and between rations were separated by Duncan's test at the 5% significance level [24]. Microsoft Excel 2016 and IBM SPSS Statistics 21.0 software were used.

3. Results

3.1. Eggs Characteristics

3.1.1. Variability of Egg Characteristics According to Locality

The variability of egg characteristics according to locality is highlighted in (Ta-

ble 2).

Table 2. Variability of egg characteristics according to locality.

Characteristics	Locality			Mean
	Batao	Figuil	Biou	
Weight (g)	36.83 ± 3.03 ^a	37.78 ± 2.71 ^b	38.80 ± 4.12 ^c	37.86 ± 3.51
Height (mm)	46.21 ± 1.76 ^a	46.84 ± 1.88 ^b	47.02 ± 1.89 ^b	46.70 ± 1.87
Large diameter (mm)	37.64 ± 1.02 ^a	37.83 ± 1.43 ^{ab}	38.18 ± 1.84 ^b	37.90 ± 1.51
Shape index	0.81 ± 0.02 ^a	0.81 ± 0.04 ^a	0.80 ± 0.05 ^a	0.81 ± 0.04

a, b, c: Means with same letter indices on the same row are not significantly different ($p > 0.05$).

Egg weights ranged from 36.83 ± 3.03 to 38.80 ± 4.1 g, with an average of 37.86 ± 3.51 g; the height and large diameter ranged from 46.21 ± 1.76 to 47.02 ± 1.89 mm with an average of 46.70 ± 1.87 mm and from 37.64 ± 1.02 to 38.18 ± 1.84 mm with an average of 37.90 ± 1.51 mm respectively, and the shape index varied from 0.80 ± 0.05 to 0.81 ± 0.04 with an average of 0.81 ± 0.04 (Table 2). After analysis, we note that Biou has the heaviest eggs compared with Batao and Figuil, which itself has heavier eggs than Batao. The same is true for height and large diameter. Biou has the smallest shape index eggs compared with Figuil and Batao, which are comparable.

3.1.2. Variability of Egg Characteristics According to Weight Categories

The variability of egg characteristics according to weight categories is shown on Table 3.

Table 3. Variability of egg characteristics according to weight categories.

Characteristics	Weight categories (g)				
	[25 - 30[[30 - 35[[35 - 40[[40 - 45[[45 - 50[
Weight (g)	28.85 ± 0.67 ^a	33.65 ± 0.19 ^b	37.41 ± 0.11 ^c	41.81 ± 0.18 ^d	46.83 ± 0.48 ^e
Height (mm)	43.03 ± 0.72 ^a	45.13 ± 0.21 ^b	46.57 ± 0.12 ^c	48.14 ± 0.19 ^d	49.89 ± 0.52 ^e
Large diameter (mm)	35.26 ± 0.63 ^a	36.90 ± 0.18 ^b	37.73 ± 0.1 ^b	39.05 ± 0.17 ^c	40.00 ± 0.45 ^c
Shape index	0.82 ± 0.022 ^a	0.81 ± 0.007 ^a	0.81 ± 0.004 ^a	0.81 ± 0.006 ^a	0.80 ± 0.016 ^a

a, b, c, d, e: on the same line, values with the same letter do not differ significantly ($p > 0.05$).

The results showed that egg weight, height and large diameter increased significantly ($p < 0.05$) with weight category. We note that the [25 - 30[category presented the highest shape index (0.82) as compared with other eggs categories [30 - 35[(0.81), [35 - 40[(0.81), [40 - 45[(0.81) and [45 - 50[(0.81).

3.1.3. Incubation Performances of Local Guinea Fowl Eggs

1) Variability in fertility rate of egg according to categories and locality

Figure 1 presents different fertility rates of eggs according to categories and locality.

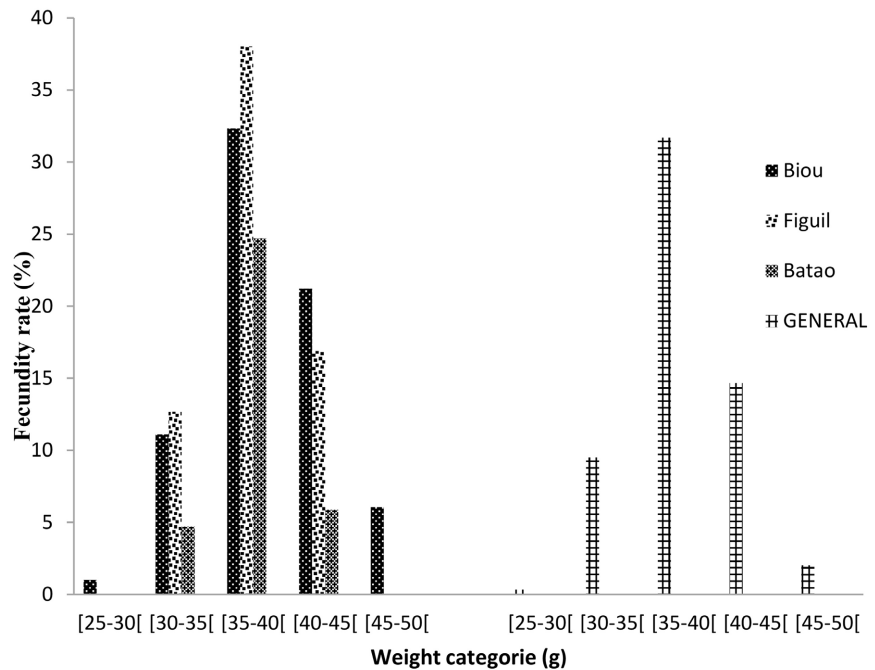


Figure 1. Egg fertility rates according to categories and locality.

With a total of 510 freshly incubated eggs, 31.69% were fertile in the 35 - 40 g category, followed by 40 - 45 (14.67%) and 30 - 35 (9.50%). Next came the 45 - 50 category (2.02%) and finally 25 - 30 (0.34%), as shown in **Figure 1**.

The results show that 38.02% of fertile eggs were recorded in Figuil, compared with 32.32% in Biou and 24.70% in Batao in the 35 - 40 egg weight category. Followed by the 40 - 45 category with 21.21%, 16.90% and 5.88% at Biou, Figuil and Batao respectively; then 30 - 35 with 12.67%, 11.11% and 4.70% at Figuil, Biou and Batao respectively. Finally, 45 - 50 (6.06%) and 25 - 30 (1.01%) in Biou.

2) Effective hatching rate of egg according to categories and locality

Figure 2 shows the effective hatching rate of egg according to categories and locality.

Taking into account fertile eggs only, the effective hatching rate was 17.54% and 9.95% in the 35 - 40 g and 40 - 45 g egg categories respectively. And 1.63% and 1.41% in the 30 - 35 g and 45 - 50 g categories respectively.

Taken by locality, it shows that: the categories of eggs weighing between 35 - 40 g recorded the best effective hatching rate with 22.92% in Figuil, 19.72% in Biou and 10% in Batao; followed by 40 - 45 g with 16.67%, 9.86% and 3.33% in Figuil, Biou and Batao respectively. Then the 45 - 50 g category with 4.22% in Biou. And finally, 2.82% in Biou and 2.08% Figuil in the 30 - 35 g category.

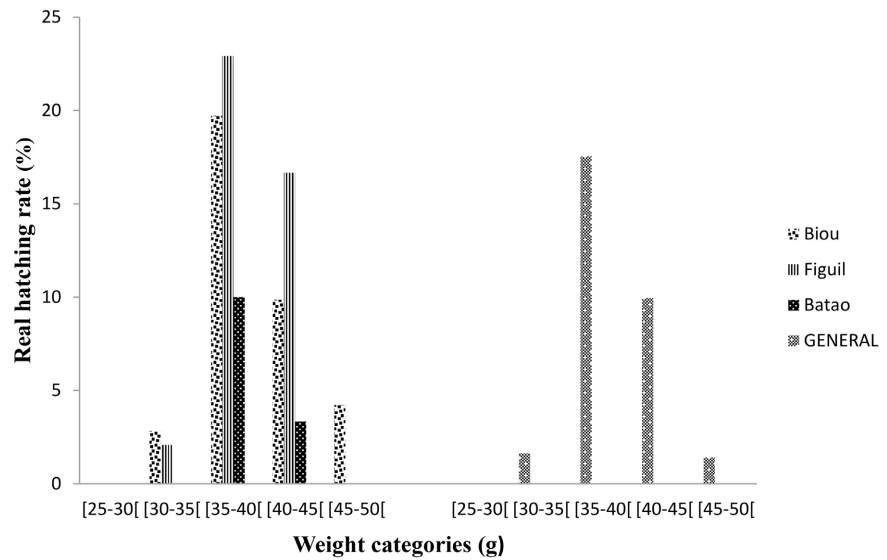


Figure 2. Effective hatching rate of egg according to categories and locality.

3) Embryonic mortality rate for egg

Figure 3 describes the embryonic mortality rate according to categories and stage of development in the different locality.

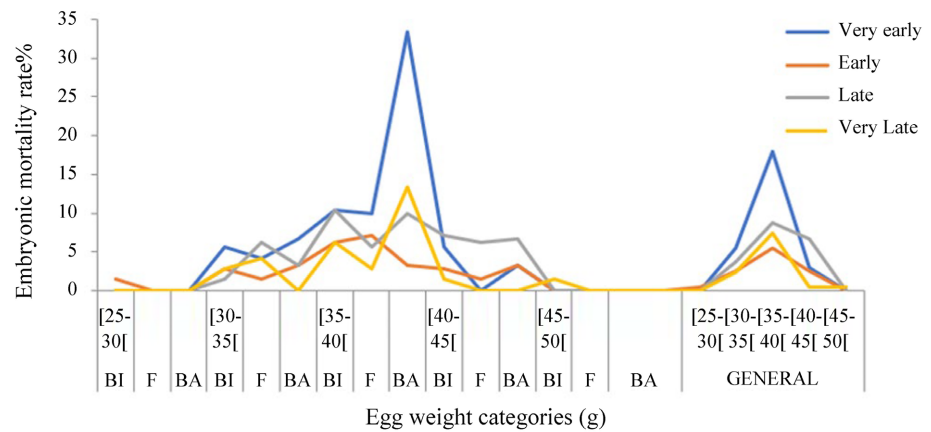


Figure 3. Embryo mortality rates as function of egg weight categories and stage of development in the locality. BI (Biou), F (Figuil) and Ba (Batao).

The results show in general that there was more very early mortality in the category of eggs weighing between 35 - 40 g (17.87%) and 30 - 35 g (5.49%), and late mortality between 35 - 40 g (8.68%) and 40 - 45 g (6.65%); and very late mortality between 35 - 40 g (7.47%). A value of 5.54% was recorded for early mortality rate within 35 - 40 g.

Taken by locality, the 35 - 40 g category recorded 33.33%, 10.42% and 9.86% very early mortality in Batao, Biou and Figuil respectively; 13.33%, 6.25% and 2.82% late mortality in Batao, Biou and Figuil respectively; 7.04% in Figuil, 6.25% in Biou and 3.33% in Batao early mortality. The 30 - 35 g category showed 6.67%

in Batao, 5.53% in Biou and 4.17% in Figuil of very early mortality; 3.33% in Batao, 2.82% in Biou and 1.41% in Figuil of early mortality; 6.25% in Figuil, 3.33% in Batao and 1.41% in Biou of late mortality; and 4.17% in Figuil and 2.82% in Biou of very late mortality. In the 40 - 45 g category, late mortality was recorded at 7.04% in Biou, 6.67% in Batao and 6.25% in Figuil; very early mortality at 5.63% in Biou and 3.33% in Batao; early mortality at 3.33% in Batao, 2.82% in Biou and 1.41% in Figuil. And 1.41% in Biou for very late mortality.

4) Average weight, rate of viable and non-viable keets after incubation phase

Table 4 highlights the average weight of guinea fowl keet after hatching.

Table 4. Average weight at keet after hatch according to locality.

Characteristics	Locality			
	Batao	Figuil	Biou	Mean
Weight of keet (g)	21.78 ± 6.03	22.81 ± 5.77	24.70 ± 4.12	22.84 ± 3.38

The average weight of keet after hatching for all the locality was 22.84 g ± 3.38 g. We also recorded 61% of viable guinea fowl and 39% of nonviable guinea fowl.

3.1.4. Growth Performance of the Guinea Fowl Fed on Different Experimental Diet

The growth performance variable of the guinea fowl keets fed on different experimental diet are shown on **Table 5**.

Table 5. Growth performance of the guinea fowl fed on different experimental diet.

Treatment group diets	Growth performance characteristics			
	Feed Intake (g)	Life Weight (g)	Weight Gain (g)	FCR
T0	213.72 ± 3.92 ^a	461.17 ± 20.71 ^a	37.40 ± 03.85 ^a	5.15 ± 0.54
T1	219.92 ± 4.06 ^a	489.32 ± 23.59 ^a	39.47 ± 10.88 ^a	5.41 ± 1.80
T2	220.80 ± 2.44 ^a	447.00 ± 35.07 ^a	33.80 ± 05.09 ^a	5.85 ± 1.06
T3	217.08 ± 2.94 ^a	470.45 ± 22.62 ^a	38.43 ± 03.88 ^a	5.57 ± 0.72

a: on the same column, value with the same letter do not differ significantly ($p > 0.05$). FCR: Feed Conversion Ratio.

The results show that feeding guinea fowl's keets on a diet containing *Moringa oleifera* leaf powder at different inclusion level did not significantly change ($p < 0.05$) growth performances between treatments. Although similar, treatment T0 (213.72 g) had a lower feed intake than treatments T1 (219.92 g), T2 (220.80 g) and T3 (217.08 g). Similarly, for body weight and average weekly weight gain, treatment T1 showed higher values 489.32 g and 39.47 g than the other treatments T0 (461.17 g and 37.40 g), T2 (447 g and 33.80 g) and T3 (470.45 g and 38.43 g). In terms of consumption index, treatment T0 showed a better consumption index

of 5.15 compared with treatments T1 (5.41), T2 (5.85) and T3 (5.57).

4. Discussion

Egg weights ranged from 27.71 to 45.56 g, with an average of 37.81 ± 3.54 g. This average is similar to the value 37.3 ± 4.1 obtained by Sanfo *et al.* investigations [25] in the northern Sudanian zone of Burkina Faso and to the value 37 ± 6.2 in dewormed guinea fowl and to the value 36.15 ± 6.5 g in non-dewormed guinea fowl reported by Hien *et al.* [26] in western part of Burkina Faso; it is lower than the 39.8 ± 0.08 g reported by Yamak *et al.* works [27] in India and the 40.37 ± 0.32 g recorded by Dzungwe *et al.* [28] in wetland Nigeria. Overall measurements increased with weight, with averages of 46.73 ± 1.80 mm for height and 37.77 ± 1.19 mm for large diameter. These averages obtained for height and large diameter are similar to 47.6 ± 2.4 mm and 37.3 ± 1.2 mm reported by Sanou trials [29] from the east of Ouagadougou in Burkina Faso, and, 48.6 ± 0.2 mm and 39 ± 0.2 mm noted by Dzungwe *et al.* [28] in Nigeria; lower than 52.3 ± 0.06 mm and 44.9 ± 0.3 mm according to Elergoglu *et al.* investigations [30] in Nigeria. The shape index ranged from 0.79 to 0.85 with an average of 0.75 ± 0.02 . This value is lower than 0.78 ± 0.54 (common) and 0.78 ± 0.52 (black) two improved guinea fowl breeds recorded by Obike *et al.* trials [31] in the dense tropical rainforest zone of Nigeria. But higher than 0.73 (French meat guinea fowl) and 0.74 (Polish domestic guinea fowl) found by Dzungwe *et al.* [28]. Several factors could exert significant effects on the characteristics of local guinea fowl eggs. Indeed, the variation in egg weight observed in this study could be explained by genetic difference, egg collection from layers of heterogeneous age and weight, and related to environmental factors [31]-[34]. The egg measurements and weights observed in this study are justified by the theory of Obike *et al.* [31] that egg measurements and weights are proportional to the weight of the animal. According to Oke *et al.* [32] show a high and positive correlation between the weight of the female guinea fowl and the weight of the egg laid. Shape index is an important factor in characterizing avian species and can be used as a selection criterion. It not only provides information on egg shape, but also measures the mechanical strength of eggs. And would suggest that guinea fowl eggs may be more resistant to breakage and environmental stress [31] [35] [36].

Fertility rates varied with egg weight category from 0.34% to 31.69%, with the majority of fertile eggs weighing between 35 and 40 g. The average rate of fertile eggs is 58.2% for all categories (71.71% in Biou, 67.60% in Figuil and 35.30% in Batao). It is similar to 58.46% reported by Yamak *et al.* [27]. It is lower than the 70.3% obtained by Sanfo *et al.* [37] and 97.1% reported by Dzungwe *et al.* [28]. There are a number of factors affecting the fertility of guinea fowl eggs. A sex ratio of two females to one male has been reported in Benin [38], while this parameter is three females to one male in traditional breeding in Burkina Faso [25] [39]. In the work of Boko [40] carried out on local guinea fowl in Nigeria, indicated that problems of sex ratio, with their monogamous sexual behavior [30] and maturity

of breeders are considered factors to be taken into account to optimize egg fertility, especially the onset of puberty and the level of hormones (gonadostimulis) [41].

In the present study, the average hatching rate overall was 30.53%. This average is lower than the 82.7% recorded by Sanfo *et al.* [37], to 58.46% noted by Yamak *et al.* [27]. The best effective hatching rate of eggs weighing between 35 - 40 g records 17.54% (with 22.92% in Figuil, 19.72% in Biou and 10% in Batao); 9.95% in 40 - 45 g (with 16.67%, 9.86% and 3.33% in Figuil, Biou and Batao respectively); and 0% in 25 - 30 g. These results by weight category are lower than those of 54.1% (25 - 30 g), 87.5% (35 - 40 g) and 90.7% (40 - 45 g) reported by Sanfo *et al.* [25]; by 20% (<39 g), 69.23% (39 - 42 g) and 58.85% (>42) reported by Moreki and Mothei [42] on local guinea fowl in Botswana; and by 79.89% (35 - 40 g), 86.33% (40 - 45 g), 90.12% (45 - 50 g) and 87.69% (50 - 55 g) recorded by Abudabos *et al.* [43] on native chickens in Saudi Arabia. This difference in hatchability is thought to be due to certain storage [27] [29] [44] and egg incubation factors [28]. Weight loss during egg storage is linked to the temperature and relative humidity of the environment, as well as to the length of storage. In the work of Khan *et al.* [44] on improved breed chickens (Rhode Island Red), at 16°C and 78% relative humidity, they recorded a loss of hatchability of 2.52% after 9 days' storage. While Sanou [29] records an average loss of 3.9% per day of storage after laying in local guinea fowl.

Overall, there was more embryonic mortality in the 35 - 40 g egg category than in the other categories, with 23.41% mortality (early and very early), the majority in Batao and Figuil; 8.68% late mortality, with a high rate in Biou; and 7.47% very late mortality, the majority in Batao. These averages are similar to 27% (early mortality) and 7.3% (late mortality) obtained by Sanfo *et al.* [45], higher than that of Sanfo *et al.* [25] and Yamak *et al.* [36] who report 1.65 - 7.9% (early mortality) and 4.6 - 5.71% (late mortality). But lower than the 48.3% early mortality and 17.6% late mortality recorded by Khan *et al.* [44]. Batao eggs showed low hatchability and high mortality during incubation. In the context of our study, embryonic mortality would be due to poor egg handling and storage conditions, temperature, humidity and/or ventilation. Indeed, a long storage period leads to water loss and albumen degradation [44]. These losses disrupt their physiological equilibrium and hence that of the embryo; similarly, fluctuating incubation temperature is said to be the result of unstable tension [27]-[29] in the work of Nwagu [46] cited by Boko [40] carried out on local guinea fowl in Nigeria, indicated that severe nutritional deficiencies in female guinea fowl, such as biotin, vitamin A and E, pantothenic acid are the cause of delayed development or mortality on the third day of incubation of guinea fowl (keet).

The average hatchling weight for all categories and localities was $22.84 \text{ g} \pm 3.38 \text{ g}$. This is similar to $23.5 \pm 2.5 \text{ g}$ found by Sanou [29] and 24.85 g obtained by Hien [39]. However, it is lower than the $25.6 \pm 2.6 \text{ g}$ reported by Sanfo *et al.* [25]. The significant effect of egg weight on guinea fowl weight is in line with the work of Ayorinde [47]. It confirms the importance of egg weight in improving the weight

productivity of guinea fowl, with more nutritional reserves available to the fetus [25]. According to Alkan *et al.* [48], hatchability and hatch weight of quail, and subsequent growth performance, are closely linked to egg weight. The importance of the egg's nutrient reserves is thought to favor better embryo development.

From hatching to 12 weeks (end of trial), we recorded a 39% rate of non-viable (dead) guinea fowl. This rate is similar to the 39.6% obtained by Sanou [29]. It is higher than the 18.9% reported by Dzungwe *et al.* [28] and the 16.5% recorded by Sanfo *et al.* [37] in guinea fowl, lower than the rates of 63% to 89% quoted by Bessin *et al.* [49], and those of 22% and 100%, respectively in controlled and real environments, according to Hien *et al.* [50]. The difference in reported mortality rates could be due to the conditions under which the guinea fowl are kept, such as the measures taken to avoid accidental drowning and the aggregation of the animals. The same applies to drowning, which is often fatal to guinea fowl, especially in cold weather [37]. This situation is compounded by guinea fowl's inability to thermoregulate and their chilly disposition. With regard to temperature, Bessin *et al.* [49] recommend 36°C to 40°C, with a drop to 32.2°C after 3 weeks, in brooding houses.

Guinea fowl feed intake showed a non-significant mean difference throughout the experiment from 34 to 318.87 g/week/subject. This is similar to the 44.95 to 46.74 g/day/subject reported by Savadogo [51] on the substitution of cowpea for soybean did not affect the feed intake of local guinea fowl at 03 months of age in Burkina Faso. The finding was that, as the rate of incorporation of *Moringa oleifera* leaf meal increased, feed intake decreased; such is the case here, which is similar to the results of Olugbemi *et al.* [52] who incorporated up to 20%, Gadzirayi *et al.* [53] who incorporated up to 100%, Abasse *et al.* [54] who incorporated up to 4%, of *M. oleifera* leaf powder meal on broiler performance. In contrast, studies by Tendokeng *et al.* [55] showed that incorporating up to 60% *Moringa oleifera* leaf meal into the finishing ration of broilers in substitution for soybean meal, had no negative effect on feed intake. The same is true with the investigations of Kakengi *et al.* [56], who found that high levels (15% and 20% respectively) significantly improved feed intake in laying hens. These observations of food consumption can be explained by the digestibility produced by the nutrients contained in leafy vegetables. In the case of moringa, it should be noted that its high nutritional quality has already been demonstrated in humans, particularly in sick and malnourished children [57] [58]. Moringa leaves are said to contain a very high concentration of vitamins A and C, a complex of B vitamins, iron, calcium, proteins, zinc and selenium [59].

In the present study, moringa leaf powder was used in proportions of 1, 2 and 3% incorporation. But these levels of incorporation did not induce a difference in body weight between these different treatments. At 12 weeks of age, body weights ranged from 447 ± 35.07 to 489.32 ± 23.59 g, which is similar to that reported by Savadogo [51], which ranged from 503.96 to 595.28 g at the same age when cowpea was incorporated in place of soya. A decrease in animal weight was observed

with increasing amounts of *M. oleifera* leaf meal in the experimental diets. These results are similar to those obtained by Tendongeng *et al.* [55], Olugbemi *et al.* [52] in broilers and Kana *et al.* [6] in laying hens up to 10%; which is contrary to those obtained by Mufwaya and Kiatoko [60] with moringa hay replacing palm kernel meal in broilers up to 10%. These results are lower than those obtained by Farougou *et al.* [61] in guinea fowl fed *Mucuna pruniens* seed meal as a substitute for palm kernel cake in broilers up to 10%. The weekly weight gain obtained (8.99 to 86.4 g/week) are better than those reported by Sanfo *et al.* (40.6 g/week) and similar to the Weight gain of 87.5 g/week reported by Halbouche *et al.* [62]. In addition, the peak of 96.2 g/week recorded in this experiment is better than that reported by Dahouda *et al.* [63] (61.67 g/week). T1 (basal diet + 1% MOLM) showed the best GMH, which does not corroborate the results of Tendongeng *et al.* [55] and Abasse *et al.* [54], who obtained the best GMH with T0 (only basal diet), but is similar to the results obtained by Bello [64] compared with the control treatment, which recorded the lowest GMH. This drop in body weight and weight gain with increasing moringa content is thought to be due to the anti-nutritional factors contained in moringa leaves, such as tannins and phytates, which are known to reduce the bioavailability of proteins, carbohydrates and minerals in the animal's intestine, and which can not only reduce the nutritional value of the feed but also zootechnical performance by reducing feed intake, particularly in poultry, and are also responsible for the low palatability of leaves, and consequently a drop in food consumption and growth in monogastric animals [65]-[67]. In their work, Sanfo *et al.* [25] [37] note that heterogeneity in growth is a guinea fowl characteristic, which is also due to the inbreeding observed in free-range farming.

The best feed conversion ratio (FCR) was found at T1 (basal + 1% MOLM), compared with the other treatments. These results are lower than those of Tendongeng *et al.* [55], Bello [64] and Kout *et al.* [18] who incorporated up to 2% moringa leaf powder in laying hens, broilers and Japanese quail respectively. It is higher than that reported at T0 (only basal diet), by Abasse *et al.*, 2017 in broilers. This is thought to be due to adequate utilization of the nutrients consumed in the feed ration [68] [69]. Furthermore, Berrama *et al.* [70] assert that high feed intake coupled with low weight gain for the same period leads to a decrease in the bird's ability to convert feed at the end of growth.

5. Conclusion

This study assessed the incubation and growth performance of local guinea fowl (*Numida meleagris*) in the Sudano-Guinean zone of Cameroon. It is showed that: the 35 - 40 g egg category was the most representative, with the highest values for height and large diameter noted in the 40 - 50 g category. The Biou locality recorded the best egg characteristics. The 35 - 40 g category recorded the highest incubation performance in Figuil and Batao. Guinea fowl eggs collected in village environments appear to have low fecundity and hatchability, and vary greatly from one locality to another. The low hatchability and fecundity rates of guinea

fowl eggs from village areas can be attributed to the variation of several interrelated factors, including nutritional deficiencies, management practices and environmental conditions, such as temperature and humidity. The use of 1% *Moringa oleifera* leaf powder improves the early growth performance (feed intake, body weight, weight gain and feed conversion ratio) of the indigenous guinea fowls keets. Findings from this study provide farmers with the appropriate range of egg weight (35 - 40 g) which is suitable for incubation, hatchability as well as the potential of the locally available resources that can be used in the low inputs system to enhance resilience and sustainability in local poultry farming.

Declaration of Authors Contributions

FDK and LFN, performed data curation and formal analysis; ANT, JP, FDK and HMW investigated, methodology, and wrote the original draft; FDK, ANT, JP, HWM, DM, HM, and ME writing reviewed and edited the manuscript. FDK and ME supervised, validated, and visualized the entire study. All the authors have read and approved the final version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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