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ASSOCIATION OF ANTHROPOMETRICAL INDEX, REPRODUCTIVE PARAMETERS AND REPRODUCTIVE HORMONAL LEVELS IN MALE GREATER CANE RAT (*THRYONOMYS SWINDERIANUS*)

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Abstract

Anthropometric parameters and their relationship with reproductive and hormonal parameters have been useful tools in predicting the effect of increased fat deposition on reproduction and general well-being in man. This study examined this interrelationship in the greater cane rat, a hystricomorphic herbivorous rodent that is currently undergoing domestication in parts of Africa. The body mass and Lee indices (BMI and LI), which are two most commonly used fat estimation parameters were characterized and their linear relationships with testicular and epididymal morphometric parameters as well as with serum concentrations of five sex hormones were analyzed in seventy-two sexually matured cane rats over a period of one year. Six animals, kidded and raised on a farm, with known ages and reproductive history were used each month. The experimental protocols entailed body measurements of weight, height and length; testicular and epididymal measurements of volume and weight; histology; and hormonal immunoassay of testosterone, estradiol, progesterone, luteinizing (LH) and follicle stimulating (FSH) hormones using their various kits. For the cane rat, the average testicular weight and volume were 1.43 ±0.40g and 1.33 ±0.26cm^3 and for epididymis, 0.33 ±0.03g and 0.23 ±0.03 cm^3, while the mean values for BMI and LI were 1.18±0.20g/cm^2 and 0.30±0.02g/cm respectively. With normal histo-architecture, no significant correlation exists between BMI/LI and testicular parameters, but a relationship exists between these indices and epididymal weight (BMI: r^2=0.38; LI: r^2=0.29). Also, of all the five hormones, only estradiol concentration has a low correlation with BMI/LI (r^2 = 0. 2). Knowledge of this interrelationship can help in breeding selection and aid in mitigating possible risk factors like obesity in the greater cane rat.

Key words: Greater cane rat, Anthropometric parameters, Hormones, Testicular parameter,

ASSOCIATION D'INDICE ANTHROPOMÉTRIQUE, DE PARAMÈTRES DE REPRODUCTION ET DE NIVEAUX D'HORMONES DE REPRODUCTION CHEZ LE GRAND AULACODE MÂLE (THRYONOMYS SWINDERIANUS)

Résumé

Les paramètres anthropométriques et leur relation avec les paramètres reproductifs et hormonaux ont été utilisés comme outils indispensables pour prédire l'effet d'une augmentation des dépôts adipeux sur la reproduction et le bien-être général de l'homme. Dans cette étude, nous avons examiné cette corrélation chez l'aulacode, un rongeur herbivore hystricomorphe actuellement en cours de domestication dans certaines parties de l'Afrique. L'indice de masse corporelle et l'indice de Lee (IMC et IL), qui sont les deux paramètres d'estimation de graisses les plus couramment utilisés, ont été caractérisés, et leurs relations linéaires avec les paramètres morphométriques testiculaires et épididymaires ainsi qu'avec les concentrations sériques de cinq hormones sexuelles ont été analysées chez soixante-douze aulacodes

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sexuellement matures sur une période d'un an. Six animaux, nés et élevés dans une ferme, ayant des âges et des antécédents de reproduction connus, ont été utilisés chaque mois. Les protocoles expérimentaux comportaient des mesures du poids, de la taille et de la longueur du corps ; des mesures du volume et du poids des testicules et de l'épididyme ; l'histologie ; et l'immunodosage hormonal de la testostérone, de l'estradiol, de la progestérone, des hormones lutéinisantes et folliculo-stimulantes à l'aide de leurs différents kits. Pour l'aulacode, le poids et le volume moyens des testicules étaient respectivement de 1,43 ± 0,40 g et 1,33 ± 0,26 cm^3, et pour l'épididyme ils étaient respectivement de 0,33 ± 0,03 g et 0,23 ± 0,03 cm^3, tandis que les valeurs moyennes de l'IMC et de l'IL étaient respectivement de 1,18 ± 0,20 g / cm^2 et 0,30 ± 0,02 g / cm. Avec une histo-architecture normale, on a relevé aucune corrélation significative entre l'IMC / l'IL et les paramètres testiculaires ; mais un lien existe entre ces indices et le poids de l'épididyme (IMC : r^2 = 0,38 ; IL : r^2 = 0,29). De plus, des cinq hormones, seule la concentration d'œstradiol a une faible corrélation avec l'IMC / IL (r^2 = 0,2). La connaissance de cette corrélation peut être utile dans la sélection des reproducteurs et contribuer à atténuer les facteurs de risque éventuels comme l'obésité chez l'aulacode.

Mots-clés : grand aulacode, paramètres anthropométriques, hormones, paramètre testiculaire

Introduction

The roles of reproductive hormones such as testosterone and estrogen in the regulation of male reproductive functions have been well established (O'Donnell *et al*., 2001; Balasinor *et al*., 2006; ASRM. 2015). According to Carreau (2011), spermatogenic processes, leading to the production and maturation of spermatozoa, are highly organized and coordinated events controlled by a well-regulated hormonal mechanism within which is the estrogen- androgen balance. The alteration of this endocrine balance has also been shown to disrupt or impair spermatogenesis, epithelial morphology of the epididymis and even the structure of the seminal vesicle in both humans and rodents (Li *et al*., 2001; Hess, 2003; Carreau and Hess, 2010, Walker *et al*., 2012).

Obesity, which is characterized by an excessive fat tissue relative to lean body mass, has been reported to be associated with changes in the male reproductive hormone profile causing alterations in the levels of testosterone and estrogens as well as sex-hormone binding globulin (SHBG) (Pasquali *et al*., 2007; Hofny *et al*., 2010). Although these hormonal abnormalities are apparent in all obese men and are more pronounced in infertile obese men (ASRM, 2015), the impact and import of these imbalances on testicular and epididymal functions can only be assessed by evaluating how changes in body fat vary with the estrogen- testosterone hormonal profiles and male reproductive parameters (MacDonald *et al*., 2010).

Anthropometrical indices such as body mass index (BMI), heights, weight, abdominal and thoracic circumferences are inexpensive and easily-calculated tools used in the estimation of body fat and the assessment of obesity, with the BMI being the most prevalent index of body fat (Ng and Shih-Wei, 2004). Although body mass and Lee (BMI/LI) indices have been extensively used to define obesity and its effects on male reproductive functions in the humans, its computation now provides valuable information on body fat deposition in livestock and rodents (Mendes *et al*., 2007; Novelli *et al*., 2007). Evaluating the interrelationship between BMI, reproductive parameters and hormonal profile has aided in elucidating the mechanism behind the pathological effects of increased body fat and obesity on male reproductive functions (Novelli *et al*., 2007; Bakh *et al*., 2010).

The greater cane rat (Thryonomys swinderianus), popularly known as Grasscutter, is a wild hystricomorphic rodent currently found only in Africa where it is vigorously hunted and exploited for its meat predominantly in the West Africa sub region (Adoun, 1993; Addo *et al*., 2007). It is currently undergoing domestication and captive rearing in this region and the current trend in its farming is towards increased stock levels and intensification of production practices (Adu *et al*., 2005). It is therefore pertinent to acquire knowledge about possible risk factors like the body fat

deposition that can affect the male reproductive function of this animal. In this work, using simple techniques, we evaluated the interrelationship amongst two anthropometric indices (BMI/LI), testicular and epididymal parameters as well as the estrogen-testosterone profile in the sexually active male greater cane rat.

Material and Methods

Animal management

A total of Seventy two (72) sexually matured adult male cane rats with an age range of 7-24months and a weight range of 1420-3040g, were used in this study. The study was carried out for twelve (12) calendar months with six (6) animals used each month. The animals were kidded and raised in a grasscutter Farm, with known reproductive and medical records. They were maintained on commercial cane rat feed and Elephant grass stems with water given ad libitum. All the animals had brownish perineal staining which is usually used as an index of sexual maturity in the male cane rat (Adu and Yeboah, 2003). Our protocols complied with the ethical guidelines of the Animal care Committee of the Federal University of Agriculture, Abeokuta, Nigeria.

Body measurements and Estimation of BMI and LI

The weight, height and length of each cane rat was taken after light inhalation anaethesia. Weights were taken using the Mettler's weighing balance; heights were measured from the scapular point to the ankle while the lengths were measured from the tip of the nose to the anus. These parameters were recorded against the known age of each animal. The body mass and Lee indices for each animal were calculated as recommended by Novelli *et al*., (2007):

BMI = body weight (g) divided by the square of the nose-to-anus length (cm).

Lee Index = cube root of body weight (g) divided by nose-to-anus length (cm).

Blood sampling and Tissue measurements

From each animal, blood samples were collected twice per day for seven times within a given month. Serum samples were separated from the collected blood for hormonal immunoassays. After all, each animal was transcardially perfused with Karnovsky's fixative and opened-up through a mid-ventral abdominal incision. The ischiatic arch was completely disarticulated to expose the reproductive organs and the testes and epididymidis were carefully dissected out individually. Epididymal and testicular weights were measured for each animal using a micro analytical balance while the epididymal and testicular volumes were estimated by the water displacement method. Samples from these tissues were then taken for histology.

Histology Procedure

Testicular and epididymal samples for the histology were further fixed in Karnovsky's fixative, dehydrated in a graded series of ethanol, cleared in xylene and paraffin-embedded. Five-micrometre-thick sections were cut and mounted on gelatinized slides, stained with haematoxylin and eosin (H&E) and examined with an Axioskop 2 plus, Carl Zeiss light microscope (Germany).

Hormonal Immunoassay

The serum levels for testosterone, estrogen, progesterone, luteinizing (LH) and follicle stimulating (FSH) hormones were assayed for each of the six animals in each month of the year using the Microplate Immunoenzymometric assay kits specific for each hormone. For testosterone, the DS-EIA-STERIOD-TESTOSTERONE-RT kit (Interco Diagnostic Ltd, UK) was used while for estrogen, ESTRADIOL-ELISA test kit (Fortress Diagnostics Ltd, UK) was employed. The progesterone kit used was the DS-EIA-STEROID-PROGESTERONE-RT (Interco Diagnostic Ltd, UK) while DS-EIA-GONADOTROPIN-LH (Interco Diagnostic Ltd, UK) and DS-EIA-GONADOTROPIN-FSH (Interco Diagnostic Ltd, UK) were used for the luteinizing and follicle stimulating

hormones respectively. The test procedure according to user instruction for each kit was duly followed. Briefly, 25µl of each of the Calibrators (serum reference for the hormone at graded concentrations), control serum and sample serum of each cane rats, were pipetted into appropriately labeled Anti-hormone-coated microtiter wells in duplicate. 10µl of the Conjugate (monoclonal anti-hormone-antibodies conjugated with horse radish peroxidase) was added to each well, swirled for 20-30 seconds to mix, covered and incubated for 60minutes at room temperature. The content of the microtiter wells were then decanted and blot-dried with absorbent tissue paper. To each well, 300µl of reconstituted washing solution (prepared by mixing the concentrated Washing Solution and distilled water at a ratio of 1:25 in a separate jar) was added, decanted and blot-dried. This washing was repeated four (4) additional times, after which 100µl of TMB-Substrate was pipetted into each well at timed intervals and incubated for 15-20 minutes at room temperature in a dark cupboard. The reaction was then stopped by the addition of 150µl of the Stopping reagent (0.2M sulphuric acid solution) into each well at timed intervals and the microtiter wells read on an ELISA reader (Elx 800, BioTek, England).

The serum concentration of the hormone in each sample was estimated on a 4-parameter calibrator curve plotted with the optic densities/Absorbance on the Y-axis and calibrator concentration on the X-axis. All the test validation criteria for each of the assays were met in this work in accordance with the kit manufacturers' instructions.

Statistical Analysis

Data were expressed as mean ± standard error. Pearson's correlation analysis was used to examine the relationships within and between data using Paleontological Statistics version 2.15 (PAST) data analysis tool. P-value □ 0.05 was considered statistically significant.

Results

The average testicular weight and volume in the sexually mature male greater cane rat was 1.43 ±0.40g and 1.33 ±0.26cm^3 while the average epididymal weight and volume were 0.33 ±0.03g and 0.23 ±0.03 cm^3 respectively (Table 1). Using fertile males with known reproductive history, positive relationships were observed between age and body parameters of weight, length and height in this population of greater cane rat (Table 2). A correlation was equally observed between both testicular and epididymal parameters and the animal heights (r^2=0.44; r^2=0.37) but

Table 1: The mean, standard deviation and range of Age, body parameters, gross testicular and epididymal morphometric data and anthropometric values in the male greater cane rat

	Mean	±SD	Range
Age (Months)	12.8	±6.15	7-24
Body weight (kg)	2.23	±0.40	1.42-3.04
Body length (cm)	43.6	±3.17	37-50.5
Height (cm)	16.36	±1.04	14.5-19
Testicular weight (g)	1.43	±0.40	0.84-2.57
Testicular volume (cm^3)	1.33	±0.26	1-2
Testicular diameter (cm)	1.10	±0.13	0.9-1.5
Epididymal weight (cm^3)	0.33	±0.03	0.40-0.33
Epididymal volume (cm^3)	0.23	±0.02	0.25-0.30
BMI (g/cm^2)	1.18	±0.20	0.88-1.70
Lee index (g/cm)	0.30	±0.02	0.27-0.35

Table 2: Correlation co-efficients between age, body measurements, testicular and epididymal morphometric as well as anthropometric parameters in the male greater cane rat

	Age (months)	Body weight (g)	Body length (cm)	Height (cm)	Testicular weight (g)	Testicular Volume (cm^3)	Epididymal Weight (g)	Epididymal Volume (cm^3)	BMI (g/cm^2)	Lee Index (g/cm)
Age (months)	1									
Body Weight (g)	0.57	1								
Body Length (cm)	0.34	0.56	1							
Height (cm)	-0.09	0.33	0.17	1						
Testicular Weight (g)	-0.18	0.01	-0.04	0.44	1					
Testicular Volume (cm^3)	-0.13	0.09	0.03	0.21	0.68	1				
Epididymal Weight (g)	0.08	0.16	-0.1	-0.08	0.55	0.27	1			
Epididymal Volume (cm^3)	-0.14	0.07	0.04	0.37	0.39	0.21	0.59	1		
BMI (g/cm^2)	0.34	0.61	-0.25	0.01	-0.04	0.01	0.38	0.08	1	
Lee index (g/cm)	0.09	0.27	-0.64	0.10	0.02	0.01	0.28	0.02	0.84	1

Figure 1: Line graphs showing the monthly variations of the mean serum levels of testosterone and progesterone concentrations in the greater cane rat.

Figure 2: Line graphs showing the monthly variations of the mean serum levels of luteinizing and follicle stimulating hormone concentrations in the greater cane rat.

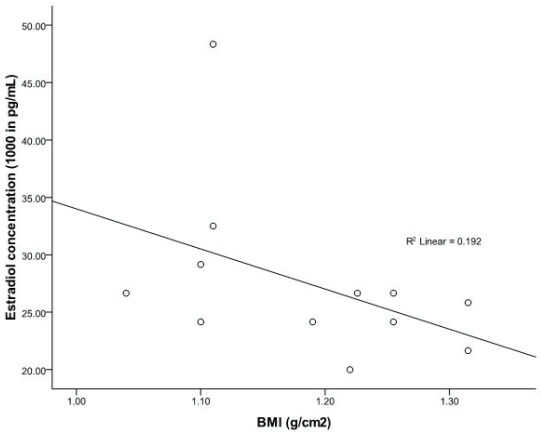

Figure 3: Scatter plot of the correlation between the body mass index and the serum estradiol concentration in the greater cane rat. Each plot represents the mean of six samples and shows the linear correlation co-efficient (R^2).

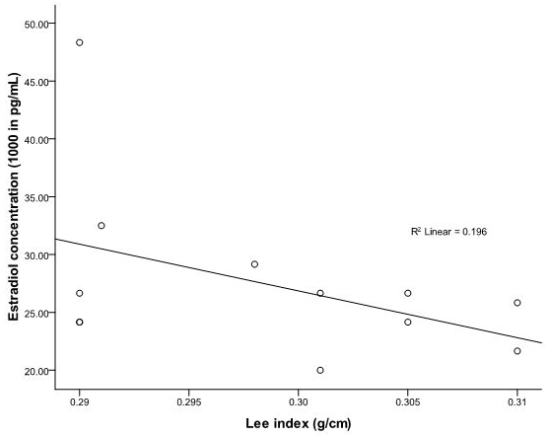

Figure 4: Scatter plot of the relationship between the Lee index and the serum estradiol concentration in the greater cane rat. Each plot represents the mean of six samples and shows the linear correlation co-efficient (R^2).

no significant relationships were observed between these parameters and the other body parameters (Table 2). Also, while there was no significant correlation between both anthropometric indices (BMI/LI) and testicular parameters, a relationship was observed between these indices and epididymal weight (BMI: r^2=0.38; LI: r^2=0.29) as well as a very strong relationship between BMI and LI (r^2=0.84) (Table 2). Of all the five hormones assayed, only testosterone and LH showed an increase in serum concentration between May-October which is the rainy season (Figure 1& 2). Whereas there was low correlation between BMI/LI and serum estradiol concentration (r^2 = 0. 2) (Fig. 3 & 4), no correlation was observed between these indices and the serum concentration of the other four hormones; testosterone, progesterone, LH and FSH concentrations. The histo-architecture of the testes and epididymis was typical indicative of normal functioning (Fig. 5& 6).

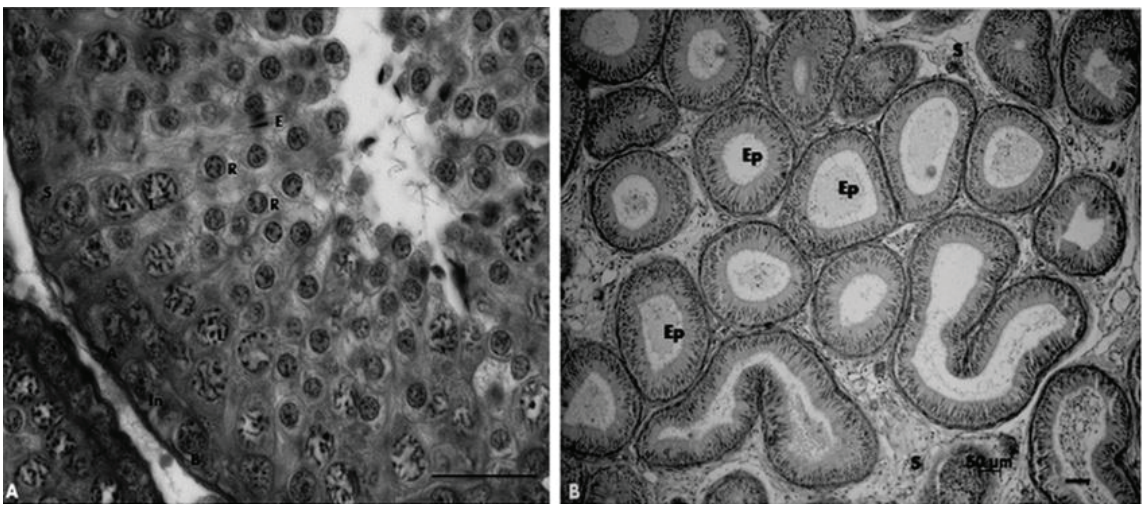

Figure 5: Normal histo-architecture of the Testes (A) and Epididymis (B) in the greater cane rat. (A) shows the spermatogenic cells; Spermatogonia (A, B, In), spermatocytes (L) spermatids (R, E) and Sertoli (S) cells while (B)shows epididymal tubules (Ep) and epididymal stroma (S). H&E. Scale bar: (A) =25µm; (B) =50µm

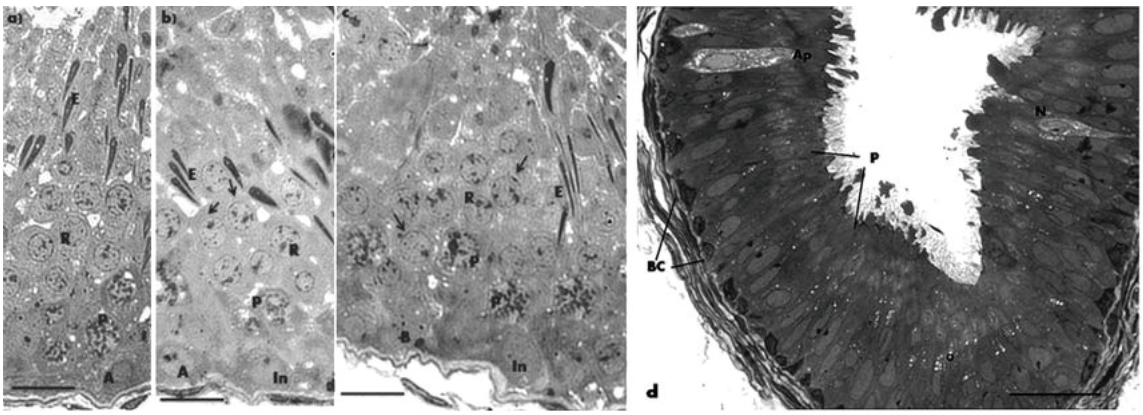

Figure 6: Normal histo-architecture of the Testes (a, b & c) and Epididymis (d) in the greater cane rat at higher magnification. (a, b & c) shows seminiferous tubules with the Spermatogonia (A, B & In), pachytene spermatocyte (P), elongated (E) and round (R) spermatids while (d) shows epididymal tubules with basal cells (BC), principal cells (P), Apical cells (Ap) and narrow cells (N). H&E. Scale bar: (a-c) =25µm; (d) =50µm

Discussion

This work established the interrelationships among anthropometric, gonadal, extra-gonadal and hormonal parameters in sexually and reproductively active male greater cane rats. Although these interrelationships, especially between BMI, semen/sperm qualities and sex hormones have been well studied in man but not much in animals (Bakh *et al*., 2010; Al-Ali *et al*., 2014), this information, with a focus on the organ morphometry, is necessary because of the current drive in the domestication and intensification of cane rat farming.

In the greater cane rat, the testicular and epididymal parameters did not correlate with the animals' weight and length but with the height. Testicular volume (and weight), which can be used to assess spermatogenesis and testicular functions, has been reported to have no significant correlation with height in young sexually active men (Innocent *et al*., 2016). The observation in the cane rat may not be unconnected with its ability to be able to withdraw its testis and epididymis from the scrotum into the inguinal and abdominal region under normal physiological conditions (Adebayo, 2015). Further studies are however on-going in this subject area.

Anthropometric indices are ratios of linear body measurements used to estimate body fat and define obesity in man, animals and birds (Pala *et al*., 2005; Mendes *et al*., 2007; Engeland *et al*., 2007). They can also indicate nutritional status and well being as well as predict risk factors in certain disease conditions (Tylor *et al*., 2000). In sexually mature men, the reports on the relationship between BMI and testicular parameters have not been consistent (Lim *et al*., 2009; Kiridi *et al*., 2011). In fact the report of innocent *et al*. (2016) showed differential associations of the right and left testes with BMI. Our work characterized the body mass and Lee indices (BMI/LI) and showed no correlation between both indices and testicular parameters but a relationship with epididymal weight in the greater cane rat. To the best of our knowledge, this is the first report that characterizes these anthropometric parameters in the cane rat. While no immediate biological explanation could yet be inferred as to the relationship between BMI/LI and epididymal weight, the observation is consistent with both BMI and LI.

The observed increase in the testosterone and LH levels during the rainy season might be attributable to the seasonal breeding trait in the male cane rat. Although cane rats can breed all year round (Opara, 2010), sexual activity tends to increase among the wild

cane rat during the rainy season because of increased food availability (Adebayo, 2015). In the same vein, changes in the hormonal profile especially of testosterone and estrogen, is a common factor that plays a role in the adverse effect of obesity on human male reproduction (Hofny *et al*. 2010; ASRM, 2015). According to Al-Ali *et al*. (2014) and ASRM (2015), in obese men there is reduced total and bio-available testosterone simultaneously combined with decreased LH pulse amplitude. Concomitantly, there are increased estrogen levels consequent to the inhibition of estrogen negative feed-back mechanism due to enhanced adipose-derived aromatase activity. With the observed hormonal profiles and their relationship with BMI/LI in the cane rat, it can be inferred that the mechanism by which obesity may affect male reproduction in this rat might be similar to that in man. It can therefore be said that higher BMI beyond the estimated values can alter hormonal balance which might affect reproductive performance in the male cane rat.

In conclusion, the interrelationships amongst the anthropometric, reproductive and hormonal parameters provided in this work will not only help in breeding selection but also aid in mitigating the possible risk factors like obesity in the greater cane rat.

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Statement of animal rights: The experimental protocols followed the ethical guidelines of the Animal care Committee of the Federal University of Agriculture, Abeokuta, Nigeria.

Conflict of interest statement: The authors declare no conflict of interests.

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COMPARATIVE SURVIVABILITY AND FERTILITY POTENTIALS OF OVINE SPERMATOZOA STORED IN EGG YOLK CITRATE AND MIXED VEGETATIVE EXTENDERS AT ROOM TEMPERATURE.

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Abstract

Proper semen extension is essential for successful artificial insemination and increased livestock production thereby helping in bridging the imbalance between livestock production and the high demand for animal protein in the developing world. Eight healthy multiparous non gravid West African Dwarf (WAD) ewes and two sexually matured rams intensively managed on grass, fed concentrate and water (ad libitum) were used in this study. Three diluents prepared using standard procedures were tested as extenders. Two were mixtures of 10% pawpaw juice and 90% coconut milk citrate (P_1C_9) and 30% pawpaw juice and 70% coconut milk citrate (P_3C_7). The third diluent (Standard Egg-yolk citrate) served as a control. Oestrus was synchronised in all the ewes by two intramuscular injections of 5mg $PGF_2\propto$ seven days apart. Semen collection, evaluation and extension using the three diluents were carried out by standard methods. Artificial inseminations, using semen extended with the better of the two test diluents (P_1C_9) and egg-yolk citrate (EYC) at 6 hours post extension were carried out. Conception was monitored using a portable ultrasound machine. At three, four, five and six hours post extension, P_3C_7 (64.00±1.41, 52.80±1.16, 41.00±0.71, 31.60±0.68 respectively) had significantly ($p< 0.05$) low motility score (%) compared to P_1C_9 (71.20±0.86, 61.00±1.48, 52.80±1.28, 44.60±1.21 respectively) and EYC (76.00±1.14, 69.00±1.30, 61.40±0.75, 49.20±0.86 respectively). The EYC and P_1C_9 ewes both recorded 50% conception rates. In conclusion, a mixture of 10% pawpaw juice and 90%coconut milk-citrate was as effective as EYC and could be optimally used as an extender for ram semen stored at room temperature for up-to 6 hours

POTENTIELS DE SURVIABILITÉ ET DE FERTILITÉ DE SPERMATOZOÏDES D'OVINS STOCKÉS DANS DU CITRATE DE JAUNE D'ŒUF ET UN MÉLANGE DE DILUEURS VÉGÉTAUX À LA TEMPÉRATURE AMBIANTE

Résumé

Un milieu de conservation approprié du sperme est essentiel à la réussite d'une insémination artificielle et à une augmentation de la production animale, contribuant ainsi à combler le déséquilibre entre la production animale et la forte demande de protéines animales dans les pays en développement. La présente étude a utilisé huit brebis de race naine Djallonké d'Afrique de l'Ouest, en bonne santé, multipares et non gravides, et deux béliers sexuellement matures gérés en système intensif, nourris à l'herbe et recevant des concentrés et de l'eau (ad libitum). Trois diluants préparés en utilisant des procédures standard ont été testés comme agents de conservation du sperme. Deux des diluants étaient des mélanges de 10% de jus de papaye et 90% de citrate de lait de coco (P_1C_9) et 30% de jus de papaye et 70% de citrate de lait de coco (P_3C_7). Le troisième diluant (citrate de jaune d'œuf standard) a servi de témoin. L'œstrus a été synchronisé chez toutes les brebis au moyen de deux injections intramusculaires de 5 mg de $PGF_2\propto$ à sept jours d'intervalle. Le prélèvement, l'évaluation et la conservation du sperme à l'aide des trois diluants ont été

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effectuées au moyen de méthodes standard. Des inséminations artificielles, utilisant du sperme dilué avec le meilleur des deux diluants d'essai (P_1C_9) et du citrate de jaune d'œuf (EYC) 6 heures après la dilution ont été effectuées. La conception a été contrôlée à l'aide d'une machine à ultrasons portable. Trois, quatre, cinq et six heures après la dilution, le diluant P_3C_7 (respectivement 64,00 ± 1,41, 52,80 ± 1,16, 41,00 ± 0,71, 31,60 ± 0,68) avait significativement un score do motilité significativement ($p < 0,05$) faible (%) par rapport au P_1C_9 (respectivement 71,20 ± 0,86, 61.00±1.48, 52,80 ± 1,28, 44,60 ± 1,21) et à l'EYC (respectivement 76,00 ± 1,14, 69,00 ± 1,30, 61,40 ± 0,75, 49,20 ± 0,86). Les brebis à l'EYC et au P_1C_9 ont toutes enregistré des taux de conception de 50%. En conclusion, un mélange à 10% de jus de papaye et à 90% de lait de coco-citrate était aussi efficace que l'EYC et pourrait être utilisé de manière optimale comme dilueur de sperme de bélier conservé à température ambiante jusqu'à 6 heures.

Introduction

Inefficiency in reproduction has been the costly and limiting constraint to animal production (Campbell *et al*., 2003; Imasuen and Otoikhian, 2006) resulting in a great imbalance between livestock production and the high demand for animal protein needed to nourish the expanding population in developing countries like Nigeria (Ibe, 2004). The panacea is adoption of assisted reproduction techniques which help to enhance reproduction. Assisted Reproduction Techniques is defined as a direct or indirect artificial manipulation of the reproduction of a livestock herd for increase in livestock productivity (Al-Merestani *et al*., 2003). It comprises of modern reproductive tools of which oestrus synchronization is primary as it provides a model for the secondary reproductive tools such as semen extension, artificial insemination, oocyte transfer and embryo collection and transfer (Al-Merestani *et al*., 2003).

Oestrus synchronization is concerned with the manipulation of either the luteal or the follicular phase of the oestrous cycle. Synchronization of oestrus in animals serves as a model to supercharge animal production and is indeed one of the techniques being used in this era of Assisted Reproductive Technologies (ART) (Jordan, 2005). There are several routes of administration of these biologically active agents and several types of synchronization scheme combinations. Agents successfully used by some researchers in ewes have been Gonadotropin Releasing Hormone (GnRH), Prostaglandin $F_2\propto$ ($PGF_2\propto$) (Ataman and Aköz, 2006) and intravaginal devices impregnated with progesterone or synthetic progestagen (Karaca *et al*., 2009).

To meet the needs of artificial insemination, many diluents known as extenders have been used for extension. An extender is the aqueous solution used to increase the volume of the semen while the functional characteristics and the fertility rate of the spermatozoa are preserved (Salamon and Maxwell, 2006). Among the extenders that have been used by some workers are the standard egg yolk, coconut milk and pawpaw juice. Over the years, extenders have improved from the simplest salt and sugar solutions used by Russians as early as 1914 (Geoffrey *et al*., 1992) to the more advanced Tris Skimmed Milk and Egg yolk-citrate diluents (Sinha *et al*.,1991). Sule (1996) , using coconut milk citrate diluent indicated that semen of bucks extended in this diluent at 28°C would have to be used for artificial insemination within 3-4 hours post dilution to obtain an appreciable motility and hence a good conception rate. Also, Oloye *et al*. (2008), working on 80% coconut milk citrate concluded that sperm motility could be maintained at 66% for 2 hours and at 8% at 6hours post extension. Ajala *et al*. (2010) working with a graded mixture of pawpaw juice and egg yolk concluded that semen could be extended with pawpaw juice for a maximum period of 72 hours stored at 5°C.

The fertility rate from inseminating with a particular extended semen is mainly measured with conception rate (Wang *et al*., 1997). Diluents also keep a check on the contamination of the medium and protect semen from microbial growth. Liquid extended semen produces a higher conception rate with a relatively less number of sperm cells (Anzar *et al*., 2003). Examples include egg yolk- phosphate

(Phillips *et al*., 1940), skim milk (Almquist *et al*., 1962) and orange juice (Bonadonna *et al*., 1962). This study evaluated the conception rate following artificial insemination of West African dwarf ewes with egg yolk citrate extended semen and a graded mixture of pawpaw juice – coconut milk extended semen at room temperature

Materials and Methods

Experimental Animals and management

Eight apparently healthy multiparous West African Dwarf (WAD) ewes of mean age 1.63±0.26 years and two sexually mature rams of mean age 2.05±0.25 years were used. The ewes, randomly grouped into two (of four ewes per group) and rams were all treated prophylactically and parenterally with Ivermectin (1ml/50 kg body weight, Kepromec®, kepro B.V., Holland), multi-vitamin (1ml/5kg body weight, kepro B.V., Holland) and Cypermethrin 0.5% (50mg/kg, Pour on®, Kepro B.V., Holland). The animals were managed intensively in a clean, well-ventilated wooden pen, fed with feed concentrate and grasses and served clean water ad libitum. Ethical approval for the experiment was obtained from the ethical committee of the College of Veterinary Medicine, Federal University of Agriculture Abeokuta, Nigeria.

Preparation of 2.9% sodium citrate buffer

2.9grams of sodium citrate was added up to make 100ml of distilled water. It was thoroughly stirred until the solute was completely dissolved in the solvent.

Preparation of media

Pawpaw juice: fresh ripe pawpaw fruit was rinsed with water and the edible part was carefully removed using a clean knife. It was cut into small pieces and then blended with a clean blender. It was then sieved and the juice was collected into a clean beaker.

Coconut milk: fresh coconut fruit was cracked and the edible part was carefully removed with a clean knife. The edible portion was cut into small pieces, grated using a clean grater and its milk was squeezed out into a clean beaker using a sterile sieve. The milk was then centrifuged at 1000rev/min for 15mins after which the coconut milk was carefully sucked up from under the topmost oily layer using a sterile pipette and collected into clean sample bottles.

Diluents: The Pawpaw juice and Coconut milk were mixed at a proportion of 10%: 90%, and 30%:70%. To each mixture was added freshly prepared sodium citrate at a proportion of 80% sodium citrate to 20% mixture leading to the constitution of two diluents (P_1C_9 and P_3C_7 respectively). Penicillin-streptomycin (1000 µl/ml) was thereafter added to each of the diluents. Five aliquots (5ml) of each diluent were constituted.

Egg yolk-citrate diluent: Sterilised fresh egg was crack-opened at the tip using a clean knife and the albumen carefully separated from the egg yolk. The egg yolk was collected into a beaker to which prepared sodium citrate buffer solution was added at a ratio of 20% of egg yolk to 80% of sodium citrate. This mixture was thoroughly mixed to form a homogenous mixture.. Penicillin-streptomycin (1000 µl/ml) was then added to the mixture. Five aliquots of 5ml were constituted.

Semen collection and Evaluation

Semen collection was done aseptically by the Electro-ejaculation method from the two mature rams (Noakes *et al*., 2001). The ejaculate was collected into a clean insulated graduated semen collection tube, through a funnel held by an assistant. Semen evaluation was done as promptly as possible post collection as described by Rodriguez-Martinez and Barth (2007) for qualitative and quantitative parameters.

Semen Volume: The volume of semen collected was measured using a graduated collection tube.

pH Evaluation: The pH of the diluents was measured using a digital pH meter

Individual Motility: Using a dropping pipette, a drop of semen was placed on the warm slide, two drops of sodium citrate buffer were added, and a cover slide was placed and the slide was examined under x40 magnification using a light microscope. The motility estimate was done by taking estimates from four different apexes of the angle and finding the average.

Sperm Concentration: Neubauer haemocytometer was used to determine the sperm concentration using the method described by Zemjanis, (1970)

Sperm Morphology: The morphology of the spermatozoa was evaluated using Eosin-Nigrosin stain as described by Zemjanis (1970)
Extension and Storage

1 drop of the collected semen was added to the five aliquots of each of the three constituted diluents ((P_1C_9, P_3C_7 and EYC) at a dilution ratio of 37.5:1 (Oyeyemi *et al*., 2010) at room temperature and semen evaluation was done at 0,1,2,3,4,5,6 and 24 hours post-extension.

Extended Semen Evaluation

Evaluation was done as described above (Rodriguez-Martinez and Barth, 2007). The pawpaw juice-coconut milk diluent that gave the better semen parameter scores of the two that were evaluated was noted for subsequent use for artificial insemination alongside the EYC extended semen.

Estrus Synchronization Protocol

Oestrus was synchronised in all the eight multiparous experimental ewes by injecting twice 5mg $PGF_{2}\propto$ (Lutalyse®; Pharmacia & Upjohn) seven days apart as described by Leigh *et al*., (2010). The following pointers to the elicitation of oestrus were monitored: standing heat, vigorous tail twitching, reddening of the vulva, serous vulvar discharges and mounting among pen mates.

Artificial Insemination

After adequate restraint of the ewes, 2ml of freshly collected and extended ejaculate sample containing 10^7 sperm cells was slowly introduced into the cervix of each ewe at 6 hours post extension using an insemination catheter guided by a small ruminant speculum (Ajala *et al*., 1997). EYC ewes (n=4) were inseminated with EYC- extended semen evaluated at 6 hours. The remaining four ewes were inseminated with P_1C_9 (the better of the two pawpaw juice-coconut milk diluents) - extended semen evaluated at 6 hours

Pregnancy Diagnosis

Ewes were subjected to ultrasonography scan for confirmation of pregnancy using a portable ultrasound machine Kaixin KX2000® with a 3.5MHz transabdominal transducer at day 48 post insemination

Statistical Analysis

Descriptive statistical analysis was used. The Mean and standard error of the mean were calculated for motility, concentration, percentage morphological abnormalities (Steele, 1996). Conception rate was expressed in percentages and was calculated as the percentage of inseminations that resulted in pregnancy

(Conception rate=number of ewes that conceived /number exposed to A.I. x 100)

Differences of means were compared using one-way Analysis of Variance (ANOVA). Tukey multiple comparison was used to separate significant mean scores where appropriate. All statistical analysis was performed using SPSS

17.0 software (SPSS Inc., Chicago IL., USA). A p value less than 0.05 was considered significant.

Results

Vital parameters including rectal temperature, heart rate, respiratory rate and pulse rate of the experimental rams fell within the normal range (Table 1). The mean weight of the eight WAD ewes was 21.75 ±0.88 kg, while their mean age was 1.63±0.26 year. The mean weight of the two rams was 24.50 ±1.5 kg while their mean age was 2.05 ±0.25 years (Table 1). The mean scrotal circumference of the rams used was 23.25±0.35cm while mean ejaculate volume in five collections was 0.60 ± 0.10 ml (Table 2). The semen colour observed varied from a homogenous milky to creamy white fluid. The mean pre-extended motility of the spermatozoa was 91.40 ± 1.03% with a concentration of 216.00 ±22.94 ^{x} 10^{6} spermatozoa per ml and morphological abnormalities of 28.33±4.00% (Table 2). The pH means of the diluents P_1C_9, P_3C_7 and Egg yolk were 6.09 ± 0.02, 6.00 ± 0.11 and 6.10 ±0.04 while their mean after sodium citrate was added were 6.62 ± 0.09, 6.60 ± 0.24 and 6.76 ± 0.13 respectively (Table 3).

At zero hour post extension, there were no significant differences in the spermatozoa motility scores in all the diluents ($p > 0.05$) (Fig 1)

At one hour, two hours and twenty four hours post extension, Egg Yolk citrate (EYC) (88.20±0.97, 82.40±0.68 and 6.60±1.03) had a significantly higher motility score (%) compared to P_1C_9 (82.20±1.16, 76.80±1.28 and 2.60±0.68) and P_3C_7 (79.20±1.11, 73.40±0.93 and 0.80±0.37), respectively at $p<0.05$ whereas the two test diluents had no significantly different motility scores at $p>0.05$ (Fig1)

At three hours, four hours, five hours and six hours, P_3C_7 (64.00±1.41, 52.80±1.16, 41.00±0.71 and 31.60±0.68, respectively) had significantly lower motility scores (%) compared to P_1C_9 (71.20±0.86, 61.00±1.48 52.80±1.28, and 44.60±1.21, respectively) and EYC (76.00±1.14, 69.00±1.30, 61.40±0.75 and 49.20±0.86, respectively) at $p<0.05$. Also at these intervals, the P_1C_9 motility score was significantly lower compared to EYC at $p<0.05$ (Fig.1).

Table 1: Vital Parameters for the Experimental Animals (Rams)

Parameters	*Normal values	Ram 01	Ram 02	Mean ± SEM
Age (year)	-	1.8	2.3	2.05 ±0.25
Weight (Kg)	-	23	26	24.50 ±1.50
Temperature (°C)	38.0-39.6	39.0	39.4	39.20 ±0.20
Heartrate (bpm)	70-80	79	76	77.50 ±1.50
Respiratory rate (bpm)	16-34	24	22	22.00 ±1.00
Pulse rate (ppm)	70-90	77	74	75.00 ±2.00

**Khan et. al. (2010)*

Table 2: Mean (±SEM) scrotal circumference, semen volume, colour, sperm and motility concentration of the rams and morphological abnormalities

Parameter	Mean±SEM
Scrotal circumference (cm)	23.25 ±0.35
Semen volume (ml)	0.60±0.10
Semen colour	Milky to Creamy white
Semen concentration (106cell/ml)	216.000 ±22.935
Semen motility (%)	91.40 ± 1.03
Morphological abnormality (%)	28.33±4.00

Table 3: Means pH values of diluents

Diluents	MEAN±SEM of p values
Sodium citrate	8.01
Coconut milk	5.93±0.13
Pawpaw juice	5.39±0.19
P_1C_9	6.09±0.02
P_3C_7	6.00±011
Egg-yolk	6.10±0.04
P_1C_9 + Na citrate	6.62±0.09
P_3C_7 + Na citrate	6.60±0.24
Egg-yolk +Na citrate	6.76±0.13
*Ram Semen	5.9-7.3

*(Source: Singh, 2005)

Table 4: Percentage mean spermatozoa morphological abnormality and progressive motility of diluents at six hours

	P_1C_9	P_3C_7	EYC
Percentage Morphological abnormalities	22.21±2.99	19.84±3.78	20.29±3.47
Percentage Mean progressive Motility	$44.60±1.21^{ac}$	$31.60±0.68^{bc}$	$49.20±0.86^{ab}$

Table 5: Oestrus synchronisation responses of the eight ewes

Mean Synchronisation success rate (%)	Mean Synchronisation -oestrus onset interval (Hours)	Mean oestrus duration (Hours)
95.00 ±1.89	60.00 ±4.54	72.00 ±9.07

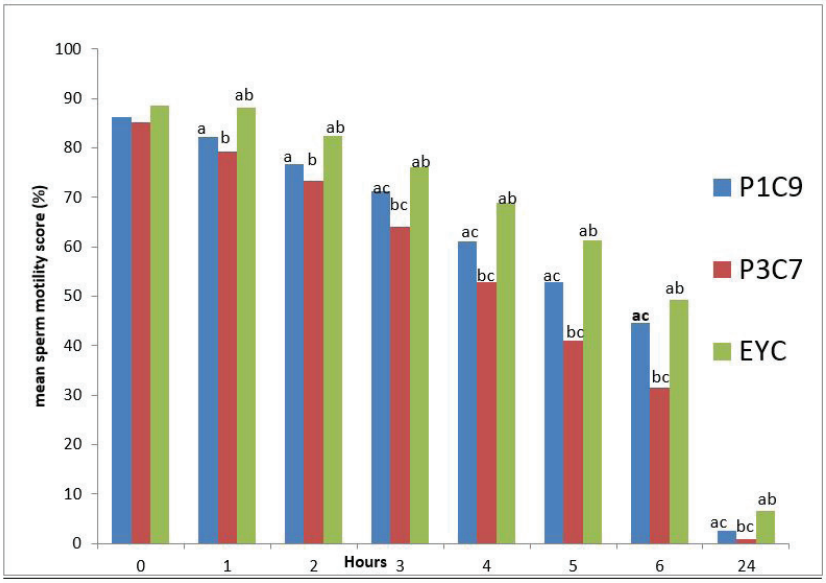

Figure 1: The changes in sperm motility of ram semen in different diluents at different hours. Values with same superscript within the same hour group are significantly different at $p<0.05$

Legends: *P_1C_9- pawpaw (10 mls) + Coconut (90 mls); P_3C_7- pawpaw (30 mls) + Coconut (70 mls); EYC- Egg yolk citrate*

There was a progressive reduction in motility values (%) from zero hour to twenty four hours in all the diluents being 86.80±1.66, 85.20±1.77 and 88.60±1.57 at zero hour for P_1C_9, P_3C_7 and EYC respectively and reduced to 2.60±0.68, 0.80±0.37 and 6.60±1.03 at 24 hours post extension respectively (Fig.1).

The mean percentage spermatozoa morphological abnormalities in diluents P_1C_9, P_3C_7 and EYC, six hours post extension, were 22.21±2.99%, 19.84±3.78% and 20.29±3.47% respectively, there was no significant difference ($p>0.05$) in the abnormalities in all the diluents (Table 4).

The oestrus synchronisation success rate in all the ewes was 95±1.89%, mean synchronisation - oestrus onset interval was 60.00 ±4.54 hours while mean oestrus duration was 72.00 ±9.07 hours (Table 5).

Both P_1C_9 and EYC ewe groups recorded a 50% conception rate.

Discussion

The vital parameters of the experimental animals in this study were within the normal ranges showing that the animals were clinically normal (Merck manual 2010). The mean scrotal circumference obtained in this study was 23.25±0.35 cm, which was in agreement with the work of Oyeyemi *et al*. (2009) who reported 23.80 ± 0.45 cm. The mean ejaculate volume collected in five trials was 0.60 ± 0.10 ml which fell within the range of 0.3-1.0 ml reported by Oyeyemi *et al*. (2009) but it was slightly lower than 0.65 ml reported by Marai *et al*. (2008). Variations observed may be due to methods of semen collection, season of the year, breed, age, body weight of animals, scrotal circumference and frequency of semen harvest which are known to affect the ejaculate volume in rams (Iheukwumere *et al*. 1990). The semen colour observed in the five collections varied from a homogenous milky to creamy white fluid which was in concordance with the findings of Moss *et al*. (1979) and Oyeyemi *et al*. (2009). The mean pH value of egg yolk citrate (7.06 ± 0.09), pawpaw juice (5.39 ± 0.19) and coconut milk (5.93 ± 0.13) in this work were slightly different from the findings of Fayomi and Oyeyemi (2010) (6.90, 5.22 and 6.06, respectively). The pH of coconut milk largely influenced the pH of diluents P_1C_9 and P_3C_7 with the pH increasing from diluents P_3C_7 to P_1C_9 as the coconut milk constituent of the diluents increased (Fayomi and Oyeyemi, 2010).

The mean pre- extended motility of the spermatozoa (91.40± 1.03%) fell within the range of 80-92% obtained by Hossian (2013). Also a mean pre-extended concentration of 0.22 ±22.94 $\times 10^9$ spermatozoa per ml was within the normal range of 200 to more than 1,000 million spermatozoa/ml reported by Rodriguez-Martinez and Barth (2007).

At zero hour post extension, a slight reduction in spermatozoa motility score was observed when comparing the three diluents with the mean pre extended motility. However, there were no significant differences in all the diluents within this hour. This slight reduction was also reported by Fayomi and Oyeyemi (2010) who worked on tomato juice citrate, pawpaw juice citrate, coconut milk citrate and egg yolk citrate. The authors attributed the pronounced reduction to a rapid pH change. The pH change in this study was not pronounced hence the reduction observed in this work could probably be related to difference in energy levels of pre and post extended semen.

At one hour and two hours post extension, EYC had a significantly higher motility score compared ($p< 0.05$) to the two test diluents. However, both test diluents at these hours had motility scores that could support fertility meaning that P_1C_9 and P_3C_7 can thrive very well with the standard EYC at these hours.

At three hours, four hours, five hours and six hours post extension, there were significant higher motility scores ($p< 0.05$) comparing P_1C_9 with P_3C_7. This showed that P_1C_9 was better test diluents compared to P_3C_7 at these hours. This could be attributed to higher constituent of coconut milk in P_1C_9 compared to P_3C_7, hence making available more energy source.

P_1C_9 and EYC groups, at six hours post extension, had motility scores and morphological abnormalities that met the minimum standards of 30% motility score (Schoenian, 2012, Robert and Walter 2007) and 30% morphological abnormalities (Schoenian, 2012) required for the ram. This could be attributed to favourable pH and the fat content in these diluents which could be metabolized providing an energy source (Fayomi and Oyeyemi, 2010). These motility scores recorded at six hours were higher than the 8% reported by Oloye *et al*. (2008) who used coconut milk citrate at room temperature. However, the motility scores were lower than the 60% recorded by Fayomi and Oyeyemi (2010) using coconut milk (attributable to better storage under refrigeration) but higher than 0% reported using pawpaw juice at 5°c.

There was no significant difference ($p<0.05$) in the morphological abnormalities of all the test diluents compared with EYC at six hours. At this time, the morphological abnormalities in all the diluents were below the value (30%) considered as standard, which conferred good fertility status on the extended semen.

At twenty-four hours post extension, EYC and P_1C_9 had low motility scores but there was no significant difference ($p<0.05$) in the motility score of all the diluents which was in contrast with the observation of Ajala *et al*. (1997) who worked with pawpaw juice. This low motility score at twenty four hours might be due to the depletion of the energy supply of the extender coupled with the environmental temperature.

This study showed that successful oestrus synchronization was achieved using prostaglandin $F^2\propto$. Occurrence of oestrus was 95% compared to 94% reported by Ott *et al*. 1980. According to the report of Leigh *et al*. (2010) the ewes will be in oestrus between 72-96 hours following the second injection of Lutalyse which was in concordance with the onset of oestrus in this study with mean duration of 72 hours.

The success of artificial insemination obtained in the study based on inseminating the ewes twice between 48 and 96 hours after two Lutalyse injections was good (50%). However, it has been reported (Leigh and Ajibade, 2010), that better success rate in artificial insemination is achieved by depositing semen at the bifurcation of the uterine body than at other locations such as the cervix as was done in the present study.

The conception rate result might not be solely due to the properties of the two test diluents since there are several factors that influence fertilization in assisted reproduction such as handling, storage, male factors and female factors.

The test diluent P_1C_9 had a motility score, percentage morphological abnormalities and conception rate close to those of the standard egg yolk citrate, which presumably, contributed to the stability observed with it. Furthermore, they both provided a medium with a pH that fell within the range (5.9-7.3) considered optimum for survivability of ram spermatozoa (Singh, 2005).

Conclusion

This work showed that a combination of pawpaw juice and coconut milk at the mixture rate of 10:90 gave motility values close to the standard egg yolk citrate within the same time interval and also compared well with EYC with regards to conception rate. Therefore, P_1C_9 could be recommended as an extender for ram semen stored for 6 hours at room temperature for optimal productivity

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EVALUATION OF FOUR CLASSICAL NON-LINEAR MODELS TO DESCRIBE THE GROWTH CURVE OF FUNAAB-ALPHA CHICKENS

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Abstract

The study assessed four non-linear models (Gompertz, Logistic, Bertalanffy and Richards) to describe the growth performance of FUNAAB-Alpha chickens (FAC). Three hundred (300) FAC chicks of both sexes were raised from day old until the 20th week of age. Body weight records were taken weekly and the NLIN procedure of SAS^® was used to fit the four non-linear growth models. For all the models, parameter A (or asymptotic weight) ranged from 2050.8 to 3716.6g for the male and 1591.7 to 3330g for the female chickens respectively, while Parameter B, the scaling parameter (constant of integration) ranged from 0.7541 to 15.441. Similarly, Parameter K (maturity index) ranged from 0.0463 to 0.2002. Parameter A was highest for the Bertalanffy model while the Logistic model estimated the highest values for Parameter B and Parameter K. For all the models fitted, age at inflection point ranged between 13.30 and 17.63 weeks for male chickens and 14.23 and 19.94 weeks for female chickens, while the corresponding body weights at inflection point ranged between 754 and 1528g and 586 and 1261g for male and female chickens respectively. Using the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) as the goodness-of-fit criteria, the Bertalanffy and Gompertz growth models were selected as the best fit models for evaluating the growth of FAC.

Keywords: Non-linear models, Growth curve parameters, FUNAAB-Alpha chickens, Point of Inflection, Relative growth rate.

ÉVALUATION DE QUATRE MODÈLES NON-LINÉAIRES CLASSIQUES POUR DÉCRIRE LA COURBE DE CROISSANCE DES POULETS FUNAAB-ALPHA

Résumé

La présente étude a évalué quatre modèles non linéaires (Gompertz, Logistic, Bertalanffy et Richards) pour décrire les performances de croissance des poulets FUNAAB-Alpha (FAC). Trois cents (300) poussins FAC des deux sexes ont été élevés du 1er jour jusqu'à la 20ème semaine. Les poids corporels ont été enregistrés chaque semaine, et la procédure NLIN de SAS^® a été utilisée pour ajuster les quatre modèles de croissance non linéaires. Pour tous les modèles, le paramètre A (ou poids asymptotique) variait respectivement de 2050,8 à 3716,6 g pour les mâles et de 1591,7 à 3330 g pour les femelles, tandis que le paramètre B, le paramètre de mise à l'échelle (constante d'intégration), variait de 0,7541 à 15,441. De même, le paramètre K (indice de maturité) variait de 0,0463 à 0,2002. Le paramètre A était le plus élevé pour le modèle de Bertalanffy tandis que le modèle Logistic a estimé les valeurs les plus élevées pour le paramètre B et le paramètre K. Pour tous les modèles ajustés, l'âge au point d'inflexion variait entre 13,30 et 17,63 semaines pour les poulets mâles et 14,23 et 19,94 semaines pour les femelles, tandis que le poids corporel correspondant au point d'inflexion variait entre 754 et 1528 g et 586 et 1261 g respectivement pour les poulets mâles et les femelles. En utilisant le critère d'information d'Akaike (AIC) et le critère d'information bayésien (BIC) comme critères d'adéquation, les modèles de croissance de Bertalanffy et Gompertz ont été sélectionnés comme les meilleurs modèles d'ajustement pour l'évaluation de la croissance des FAC.

Mots-clés : Modèles non linéaires, Paramètres de courbe de croissance, Poulets FUNAAB-Alpha, Point d'inflexion, Taux de croissance relatif.

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Introduction

The Nigerian indigenous chickens are quite varied in shape, form, size, colour and feathering (Odubote, 1994). They have been characterized along genetic lines of feather morphology pattern and plumage colour, feather distribution pattern, body structure and colour variants (Ajayi, 2010) and according to body size (Momoh *et al*., 2007). These authors reported wide variations in the plumage colour, body size, matured body weight and many other morphological traits of these chickens. However, they all asserted that the Nigerian indigenous chicken is generally a light breed, and a good scavenger with high adaptive fitness to the prevailing climatic conditions. Despite this, their productivity has been reported to be generally lower than their exotic or crossbred counterparts (Nwosu and Asuquo, 1985; Odubote, 1994; Ajayi, 2010). Nwosu and Asuquo (1985) described them as small bodied, slow growing, poor feed converters, poor layers and poor meat birds. Odubote (1994) highlighted their small body size, slow growth rate, and low mature body weight as constraints to taking up their production as a viable business enterprise. These shortcomings led to intensification of efforts by various researchers towards the genetic improvement of these local breeds through crossbreeding with exotic breeds. (Akinokun and Dettmers, 1977; Nwosu and Omeje 1982; Adedokun and Sonaiya, 2002 and Adebambo *et al*., 2010).

Many indigenous chickens in some parts of the world have experienced tremendous improvement in productivity in terms of feed conversion efficiency, average daily gain, final body weight and egg production due to sustained genetic improvement and crossbreeding programmes. These improved indigenous breeds include the Giriraja breed of India, Fayoumi breed of Egypt, Desi breed of Bangladesh, Horro breed of Ethiopia, FUNAAB-Alpha chicken of Nigeria and the Kari breed of Kenya. FUNAAB – Alpha chickens (FAC) have been described as a multicoloured breed of chickens developed for the rural poor under the village scavenging system (Adebambo *et al*., 2018). They are described as an improved, indigenous, tropically adapted and dual-purpose breed developed through crossbreeding and intensive selection over twelve generations for improved meat and egg production without sacrificing adaptation to the tropical environment characterized by heat stress and infectious diseases (Adebambo, 2015).

According to Adebambo (2015), the development of FAC started in 1994 with initial characterization of indigenous genetic materials sourced all over Southwestern Nigeria. These included the frizzled feathered, naked neck, normal feathered and the dwarf skeletal variants. These selected indigenous chickens were then crossed with Giriraja, an improved breed native to India. The crossbred chickens were thereafter backcrossed to the indigenous chickens to obtain a bodyweight of 1.6-2.1Kg at 20 weeks of age in 3 generations of crossbreeding using artificial insemination. These chickens are currently 37.5 to 62.5% indigenous in their bloodline (Adebambo, 2015).

Growth is a complex composite of economic traits that can be simply defined as an increase in body size per time unit (Al-Samarai, 2015). It is a fundamental characteristic of all living organisms that can be expressed as an increase in the entire body weight or any part of an animal as it approaches mature body size (Narinc *et al*., 2010). Poultry species generally show a determinate growth pattern which is analogous to the growth of mammals. They show a sigmoidal pattern of growth where live weight increases with time to reach a predetermined adult size when reared under the ideal environmental conditions and provided with adequate nutrients required for the optimum growth and development of tissues. The rate of live weight gain increases during approximately the first third of growth, remains relatively constant during the middle third and decreases to reach a plateau in live weight at maturity (Taylor and Murray, 1987). Many factors affect the growth of poultry species. These include those related to genetics, sex, nutrition and environment. Growth parameters such as mature body

weight, feed efficiency, average daily gain, initial body weight and feed conversion rate are of particular significance in poultry production for evaluating and comparing the productivity of different genotypes, predicting feed requirements, growth rates and response to selection (Ngeno *et al*., 2011 and Aggrey, 2002).

One of the most important and popular ways of evaluating and predicting the body growth of mammals is by growth curve analysis from an individual animal's growth data. The most common models applied to describe growth are non-linear differential equations that estimate various parameters with biological interpretations that are related to the initial body weight, growth rate, and matured body weight (Mello *et al*., 2015). Evaluation of growth using non-linear models enables the detection of some other important phenomena such as sexual dimorphism allowing for management techniques to be devised in accordance to the requirements of each sex (Galeano-vasco *et al*., 2014). Since the trajectory of growth of poultry species can be modified by selection (Aggrey, 2002), adequate knowledge on body growth has strategic importance for genetic improvement. Similarly, adequate knowledge of the growth parameters could be useful as they may be used to provide estimates of the daily feed requirements or to evaluate the influence of the environmental conditions on the weight gain of the animal (Ngeno *et al*., 2010).

Several growth models have been developed in poultry research to describe the nonlinear and sigmoidal relationship between growth and time. These nonlinear models fitted curves that can relate the age of the bird with its weight, characterize the different phases of growth of the bird, allow the estimation of the animal's growth rate, the age at which the animal stops growing and when it reaches sexual maturity (Galeano-Vasco *et al*., 2014). Growth curves for poultry generally have the following characteristics: an accelerating phase of growth from hatching, a point of inflection in the growth curve at which the growth rate is maximum, a phase where growth rate is decelerating, and an asymptotic or mature weight (Wilson, 1977). According to Teleken *et al*. (2017), different growth functions can be grouped into three main categories; those with a diminishing returns behaviour (such as the Brody model), those with a fixed inflection point (such as the Gompertz, Logistic and von Bertalanffy models) and those with a flexible point of inflexion (such as the Richards model). The Logistic model has its inflexion point fixed at 50% of the asymptotic weight, the Gompertz model has its point of inflexion at 37% of the mature body weight while the von Bertalanffy model exhibits its inflection point at approximately 30% of the mature weight. However, the Brody model, with a diminishing returns behavior, does not exhibit an inflection point. The Richards model exhibits a variable point of inflexion and therefore represents a summary of other growth functions as they could be specified by the shape parameter. These models are very useful as, besides incorporation in genetic improvement programmes, they can also be used to predict feed requirements and optimal slaughter age (Knizetova *et al*., 1991).

The objective of this study, therefore, was to evaluate four non-linear models (Gompertz, Logistic, Bertalanffy and Richards) to describe the growth performance of FUNAAB-Alpha chickens (FAC) reared under a deep litter system.

Materials and Methods

Experimental location

This experiment was conducted at the Poultry Unit of the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Osun State Nigeria. The farm is located at Longitude $04^{0}33'$E and Latitude $07^{0}28'$N at an altitude of 224m above sea level.

Experimental birds

Three hundred (300) day-old chicks of FUNAAB-Alpha chickens (FAC) were obtained from the Hatchery Unit of the Federal University of Agriculture, Abeokuta (FUNAAB). They were brooded for two weeks. An adequate temperature of 40°C - 45°C was provided during brooding using electric bulbs

and a gas burner as the source of heat. The chicks were transferred to deep litter pen at the end of the fourth week.

Housing

The deep litter pen, contained thirty cells each of 1.5m × 1.5m dimension, was made of wood and wire netting while the floor was made of concrete. The bushes around the building were cleared, the pen was properly fumigated and wood shavings were thoroughly spread on the concrete floor before the birds were transferred.

Nutrition

Feeders and drinkers were provided for each cell in the deep litter pen. The chickens were fed starter ration containing 20% crude protein (CP) and 2800 Kcal/Kg of metabolizable energy from day old until the fifth week and were thereafter fed with grower ration containing 18% CP and 2900 Kcal/Kg until the twentieth week when the experiment was terminated. Clean water was provided ad-libitum. The feed was placed in a standard and specialized feeding tray that was red in colour to attract the chicks to the feed while water was provided in a specialized 2.5 litre plastic drinker placed upside down for proper water dispensation and to avoid water spillage.

Health management

Proper hygiene was ensured all the time. Bio-security was guaranteed by barring visitors and strangers from entering the pen while a foot dip was provided at the entrance which was replaced daily. Drinkers and feeders were thoroughly washed and cleaned daily while left-over feeds and water were removed in order to prevent the build-up of parasites and pathogens. The litter was kept dry at all times. The chicks were vaccinated against Newcastle disease on the 10th day and other medications were administered when due, following the standard practice in poultry management.

Data collection

Each bird was weighed weekly using a sensitive digital weighing scale (Model SF-400) with a maximum capacity of 10 Kg and a sensitivity of 1g throughout the conduct of this experiment. The bodyweight records were taken early in the morning before feeding following FAO guidelines (FAO, 2012).

Data analysis

Four classical non-linear growth models; von Bertalanffy, Richards, Gompertz and Logistic models were fitted to the bodyweight records using the NLIN procedure of SAS^® according to the equations presented in Table I using the Marquardt iterative option (Marquardt, 1963). And the most appropriate model(s) was selected using the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC).

Table I: Non-linear growth model equations

Model	Equation	Inflection time	Weight at inflection	Relative growth rate
Gompertz	$W_{(t=A*\exp(-B*\exp(-K*t))}$	A/e	$\ln^{(B)}/_{k}$	$k\ (^{A-W(t)}/_{A})$
Logistic	$W_{t=A/(1+B*\exp(-k*t))}$	A/2	$\ln^{(B)}/_{k}$	$k*\log\ (^{A}/_{(W(t)})$
Bertalanffy	$W_{t=A\ (1-B*e^{(-K*t)}\ )^{3}}$	8/(27) (A)	$^{1}/_{k}$ ln.3(B)	$3k[(^{A}/_{(W(t)})(^{1}/_{3})-1]$
Richards	1+B*exp(-k*t)^(1/d)	A/(d+1)^(1/d)	$^{1}/_{k}$*ln |d/B|	$dk[(^{A}/_{(W(t)})(^{1}/_{d})-1]$

Where W_t= body weight at t weeks of age; t=bird's age in weeks; A=asymptotic weight or mature weight; B=scaling parameter (constant of integration); k=maturity index; d= shape parameter for Richard's model which allows a variable point of inflection.

Results and Discussion

Table II shows the estimated growth model parameters for male and female FUNAAB-Alpha chickens (FAC) reared intensively under a deep litter system using Gompertz, Logistic, Bertalanffy and Richard's growth functions. For all the models, Parameter (A) which is the asymptotic weight ranged from 2050.8 to 3716.6g for the male and 1591.7 to 3330g for the female chickens respectively while Parameter (B), the scaling parameter (constant of integration) ranged from 0.7541 to 15.441. Likewise, Parameter K, which is the maturity index ranged from 0.0463-0.2002. The Bertalanffy model estimated the highest asymptotic weight while the Logistic model estimated the least. The asymptotic weight estimated in this study by the Gompertz model was consistent with the findings of Zhao *et al*. (2015) and Al-Samarai (2015) on some improved indigenous chickens of China and meat-type chickens of Iraq respectively but higher than the values obtained by Aggrey (2002), Osei-Amponsah *et al*. (2014) and Ngeno *et al*. (2010) for Athens-Canadian chickens and local chickens in Ghana and Kenya respectively. The values of parameter A obtained for the Logistic model were consistent with the values reported by Aggrey (2002) and Al-Samarai (2015) but lower than the values reported by Eleroglu *et al*. (2014) for some Turkish indigenous chickens. The Parameter A values obtained for the Richard's model in this study were consistent with the findings of Aggrey (2002) but higher than those reported by Rizzi *et al*.(2013) and Osei-Amponah *et al*.(2014) for chickens in Italy and Ghana respectively. The variations in the asymptotic weight of these chickens could be attributable to genetic differences, the system of management and the prevailing climatic conditions of the environment in which these chickens were raised as well as the various interactions which ultimately influence the growth trajectory.

Table II: Estimated growth model parameters for FUNAAB-Alpha chickens

	Male				Female			
Model	**A**	**B**	**K**	**D**	**A**	**B**	**K**	**D**
Gompertz	3056.3	3.5503	0.0860	-	2521.0	3.5813	0.080	-
Logistic	2050.8	15.441	0.2002	-	1591.7	15.718	0.1964	-
Bertalanffy	3716.6	0.7541	0.0463	-	3330.6	0.7672	0.0417	-
Richards	3056.2	2.521	0.150	0.343	2520.9	2.852	0.147	0.352

Where A, B, K and D are the asymptotic weight, the scaling parameter, maturity index and the shape parameter for Richards' model respectively

Table III showed the body weight and age at inflection point for FAC as estimated by the Gompertz, Logistic, Bertalanffy and Richard's models. For all the models fitted, age at inflection point for FAC ranged between 13.30 and 17.63 weeks for male chickens and 14.23-19.94 weeks for female chickens while the corresponding body weight at inflection point ranged between 754 and 1528 g and 586 and 1261 g for male and female chickens respectively. For both sexes, the Gompertz model estimated the highest body weight at inflection while the Logistic model estimated the least. Similarly, the Richard's model predicted the earliest age at inflection point while the Bertalanffy model estimated the highest age at inflection. For all the models, the males had higher body weights at inflection than females. However, the females had higher ages at the inflection point than the corresponding males for all the models.

Table III: Body weight (g) and age (weeks) at inflection point

	Male		Female	
Model	**T_i (weeks)**	**W_i(g)**	**T_i (weeks)**	**W_i(g)**
Gompertz	14.73	1528	15.95	1261
Logistic	13.67	754	14.03	586
Bertalanffy	17.63	1101	19.94	987
Richards	13.30	1294	14.23	1070

Where T_i is the age (weeks) and W_i is the body weight (g) at inflection point.

The goodness-of-fit tests for the Gompertz, Logistic, Bertalanffy and Richard's growth models are presented in Table IV. These included the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). The lower the values of AIC and BIC, the better fit is the data (Kaps and Lamberson, 2004). For both sexes, the Bertalanffy model had the lowest AIC and BIC and was adjudged the best fit model followed by the Gompertz model, the Richard's model and the Logistic model in that order. This is in agreement with the conclusions of Aworetan and Oseni (2018), Eleroglu *et al*.(2014), Ngeno *et al*.(2010) and Osei-Amponsah *et al*.(2014) who reported the Bertalanffy as the best fit nonlinear model for some indigenous chickens in Nigeria, Turkey, Kenya and Ghana respectively, while Darmani *et al*.(2003) selected the flexible Richard's model as the best fit. The lesser fit of the Richard's model observed in this study may be due to the extra parameter in the model, for which it was penalized by the model selection criteria. It has also been reported as inadequate in providing good fit to data patterns and observation (Meng *et al*., 1997). Aggrey (2002) suggested that the addition of the fourth parameter may represent an over-parametarization of the growth model.

Table IV: Best fit model selection criteria using Goodness-of-Fit tests

	Male		Female	
Model	AIC	BIC	AIC	BIC
Gompertz	50.42	61.528	44.46	55.102
Logistic	53.23	64.488	47.10	58.342
Bertalanffy	49.42	60.122	44.21	54.154
Richards	50.42	61.778	46.76	57.813

Where AIC and BIC are Akaike Information Criterion and Bayesian Information Criterion and Bayesian Information Criterion respectively.

Table V shows the correlation coefficients among the model parameters. High and negative correlation coefficients ($r < -0.90$) were observed between parameters A (asymptotic weight) and K (maturity index), for both male and female chickens for all the models. There were high positive correlations between parameters B and K, for the Logistic and Richards' models, for both male and female chickens. For the Gompertz model, a negative correlation was observed for the male while a positive correlation was observed for the female. The correlation coefficients between parameter A (asymptotic weight) and B (constant of integration), ranged from -0.933 to 0.735 for all models. For the Richards' model, there were highly negative correlations ($r < -0.90$) between these parameters for both male and female chickens, which indicated that chickens with a higher constant of integration had lower asymptotic weight and vice-versa. A positive correlation was observed between these parameters based on the Bertalanffy model which implied that high asymptotic weight is associated with higher values of the constant of integration. The high negative

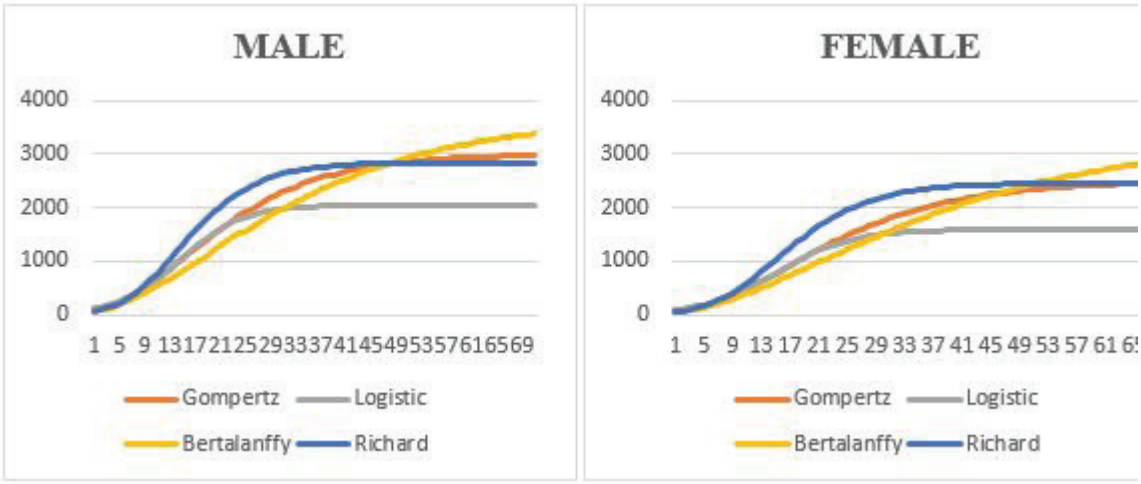
correlation coefficients between parameters A and K indicated that the higher the value of the maturity index, the lower is the value of the asymptotic weight. This might be due to the fact that chickens with a higher maturity index reached the point of inflection faster as observed with the Logistic model with the highest maturity index value. As noted by Aggrey (2002), the position of the inflection point strongly influences the growth rate and the mature body weight, meaning that the faster the inflection point was reached the lower the value of the mature body weight. This is in agreement with the findings of Al-Samarai (2015) and Ngeno *et al.* (2010) who reported pronounced negative correlation coefficients between parameters A and K.

Table V: Correlation coefficients among model parameters for nonlinear models

Male				Female			
Gompertz	**Logistic**	**Bertalanffy**	**Richards**	**Gompertz**	**Logistic**	**Bertalanffy**	**Richards**
			Parameter A and B				
0.00266	-0.176	0.406	-0.918	0.263	-0.106	0.735	-0.933
			Parameter A and K				
-0.981	-0.915	-0.993	-0.981	0.982	-0.918	-0.995	-0.983
			Parameter B and K				
-0.181	0.533	0.309	0.962	0.0931	0.467	-0.669	0.986

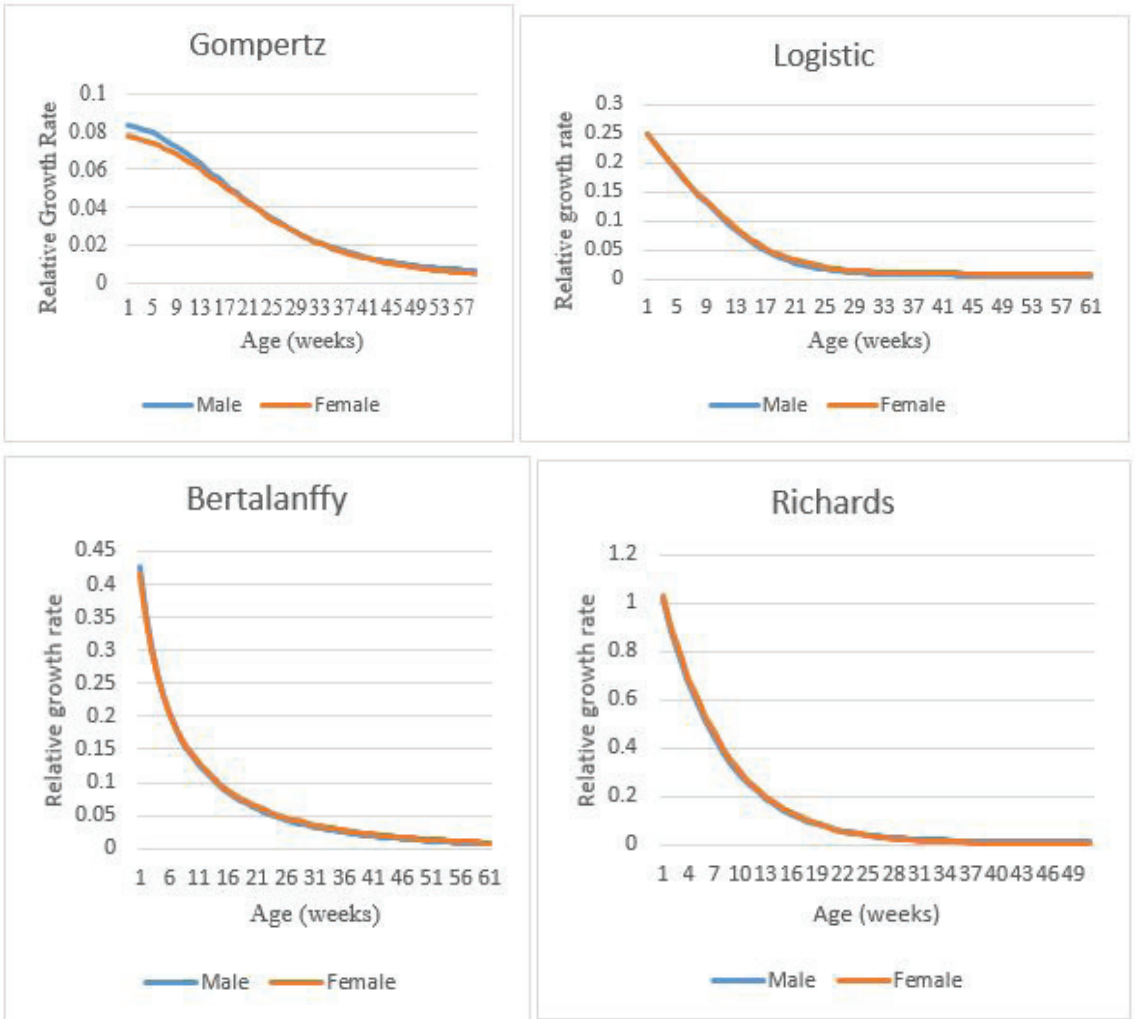
A=asymptotic weight or mature weight; B=scaling parameter (constant of integration); and k=maturity index

Graphical representations of the growth rate patterns of FAC are depicted in Figures 1a and 1b. The growth curves showed the non-linear dependency of body weight on age. Body weight increased with age but at different rates which differed slightly from one model to the other.



Figures 1a and 1b: Growth curves for FAC predicted by the Richards, Gompertz, Logistic and Bertalanffy growth models

The relative growth rate patterns for FAC raised under a deep litter system across sex, feather morphology and distribution as estimated by the Gompertz, Logistic, Bertalanffy and Richards' models respectively are presented in Figures 2a to 2d. . Based on all nonlinear models fitted, the initial relative growth rate was observed to be at a maximum and it decreased exponentially until the curve flattened out indicating that the relative growth rate was almost zero after the point of inflection had been reached. The relative growth rate decreased at a lower rate from 0 to 8 weeks. However, the rate of decrease was exponential after the inflection point was reached until maturity age was reached. The highest values of relative growth were obtained for the Bertalanffy (0.36-0.45), followed by the Logistic (0.22-0.25), Richard's (0.09-0.12) and Gompertz (0.075-0.085) models in that order for both male and female chickens respectively. This was in agreement with the observations of Eleroglu *et al*., (2014) that the relative growth rate is always highest at day old and it decreases until it reaches zero or even negative value at which point the animal stops growing.



Figures 2a-d: Relative growth rate for FUNAAB-Alpha chickens raised under a deep litter system based on Gompertz, Logistic, Bertalanffy and Richards' model

Conclusion

The present study generated growth curves and growth parameters such as asymptotic weight (A), maturity index (K) and the constant of integration (B) for FAC. Among the non-linear models fitted, Bertalanffy and Gompertz models were found to be the best fit models for describing the growth performance of FAC.

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GENOTYPIC AND SEASONAL VARIABILITY ON THE REPRODUCTIVE PERFORMANCE OF TWO STRAINS OF HYBRID LAYERS IN SOUTHWEST NIGERIA

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Abstract

The egg-laying or layer strain is of high nutrient and of good economic importance to the society at large due mainly to its egg production traits and also for its meat. The exotic layer strains have been able to adapt to the climatic and environmental conditions of the southern part of Nigeria. Non-the-less, challenges are still being faced in its rearing and production especially during extreme climatic conditions. Previous research found that changes in the seasonal environment had significant effects on egg fertility, hatchability of total set eggs and hatchability of fertile eggs. This study aimed at determining the effects of genotype and season on two exotic layer chicken strains. A total of one thousand five hundred (1500) layers per strain were used for the evaluation of their reproductive performances. Each strain included one hundred and twenty cocks (120) for random mating. It was observed that there were significant differences ($P<0.05$) in the values obtained for the different seasons. The late wet season had a higher significant difference ($P<0.05$) in values of the percent fertile (78.12±0.51), percent hatched (72.36±0.74) and percent hatchability (92.92±0.36) than other seasons. the percent hatchability (90.60±0.48), total hatched (67.68±0.98), percent fertility (74.80±0.72), were highly significant ($P<0.05$) in Brown dominant than the Hyline brown strain of laying Chicken with percent hatchability (88.38±0.49), total hatched (63.01±0.92) and percent fertility (71.02±0.71). In conclusion, it was discovered that the Brown dominant layer chicken strain had a better performance in the fertility and hatchability than the Hyline brown chicken layer and the late wet season was observed to be more favourable to percentages hatched, fertility and hatchability. The Brown dominant strain is preferable for brown layer production and also, the late wet season should therefore be targeted for optimal production of layers in southwest Nigeria.

Keywords: Reproductive, performance, Brown, dominant, Hyline, Hatchability, Fertility, Strain, Season

EFFETS DE LA VARIABILITÉ GÉNOTYPIQUE ET SAISONNIÈRE SUR LA PERFORMANCE DE REPRODUCTION DE DEUX SOUCHES DE PONDEUSES HYBRIDES DANS LE SUD-OUEST DU NIGÉRIA

Résumé

La souche de poule pondeuse est très nutritive et revêt une importance économique pour la société dans son ensemble, principalement en raison de ses caractéristiques de production d'œufs et de sa viande. Les souches de pondeuses exotiques ont pu s'adapter aux conditions climatiques et environnementales de la partie sud du Nigéria. Néanmoins, des défis restent à relever dans leur élevage et production, en particulier dans des conditions climatiques extrêmes. Des recherches antérieures ont révélé que les changements de l'environnement saisonnier avaient des effets importants sur la fertilité des œufs, la capacité d'éclosion des œufs pondus au total et le taux d'éclosion des œufs fertiles. Cette étude visait à déterminer les effets du génotype et de la saison sur deux souches de poulets exotiques. Au total, mille cinq cent (1500) pondeuses par souche ont été utilisées pour l'évaluation de leurs performances reproductives. Chaque souche comprenait cent vingt coqs (120) pour un accouplement aléatoire. Des

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différences significatives (P <0,05) ont été notées au niveau des valeurs obtenues pour les différentes saisons. La fin de la saison humide a eu une différence significative plus élevée (P <0,05) au niveau des valeurs du pourcentage de fertilité (78,12 ± 0,51), du pourcentage d'œufs éclos (72,36 ± 0,74) et du pourcentage de capacité d'éclosion (92,92 ± 0,36) par rapport aux autres saisons. Le pourcentage d'éclosion (90,60 ± 0,48), le total d'œufs éclos (67,68 ± 0,98), le pourcentage de fertilité (74,80 ± 0,72) étaient significativement (P <0,05) élevés chez la souche dominante Brown par rapport à la souche Hyline Brown de pondeuses aux performances suivantes : pourcentage d'éclosion (88,38 ± 0,49), total éclos (63,01 ± 0,92), pourcentage de fertilité (71,02 ± 0,71). En conclusion, il a été découvert que la souche de pondeuse dominante Brown avait une meilleure performance en matière de fertilité et d'éclosion par rapport à la pondeuse Hyline Brown, et la fin de la saison humide s'est avérée plus favorable aux pourcentages d'œufs éclos, de fertilité et d'éclosion. La souche dominante Brown est préférable pour la production de pondeuses brunes ; en outre, la fin de la saison humide devrait donc être ciblée pour une production optimale de pondeuses dans le sud-ouest du Nigeria.

Mots-clés : Reproductif, performance, Brown, dominant, Hyline, éclosion, fertilité, souche, saison

Introduction

The egg-laying or layer strain is of high nutrient and economic importance to the society at large due mainly to its egg production traits and also for its meat. The commercial layer is best known for table egg production because of the high level of genetic improvement in its laying performance and thorough management input (Ogbu, 2012). Hyline brown parent stock is expected to attain the weight of 1450 – 1530g with a feed intake of 81 – 85 g/day per bird at 18 weeks of age (Hyline, 2014). The Brown dominant strain is colour-sexed through silver-red S/s alleles of Silver gene. Brown dominant pullet at 18 weeks of age, with an average feed consumption of 79 g/day, is able to attain a body weight of 1450 to 1500g provided good management procedures and practices are adhered to (SochĹŻrek, 2008). At laying period, its livability is 95 – 97%.

Climate change is a natural process that takes place simultaneously on various time scales, in relation to the variation over time of the global climate or local climates, which may be the results of both natural forces and human activities (FAO, 2009). The exotic layer strains have been able to adapt to the climatic and environmental conditions of the southern part of Nigeria, non-the-less, challenges are still faced in its rearing and production especially during extreme climatic conditions. These challenges include; the effects of heat stress that has resulted in increased mortality of the birds, susceptibility to infections and diseases, drop in daily egg production, decrease in hatchability and fertility among others.

Heat stress has negative effects on both hatchability and fertility in poultry production. Previous research demonstrated that high environmental temperatures commonly called heat stress adversely affected egg production, fertility (McDaniel *et al*., 1995; Obidi *et al*., 2008) and hatchability (Lourens *et al*., 2005) of breeders. This was in line with other research work that showed that changes in the seasonal environment had significant effects on egg fertility (Aggarwal, 1987; Pruthi and Aggarwal, 1987; Das and Ali, 1999), hatchability of total set eggs (Farooq *et al*., 2003; Chowdhury *et al*., 2004), and hatchability of fertile eggs (Kalita *et al*., 1985; Sreenivasaiah and Joshi, 1987) in poultry and ducks.

Nigeria, like the rest of West Africa and other tropical lands, has only two seasons. These are the dry and the rainy seasons (Oguntunji *et al*., 2008). The Nigeria season has also been further divided into four by many researchers as; January – March being Late Dry season, April – June being Early Wet season, July – September being Late Wet season, October – December being Early Dry season (Adedeji *et al*., 2006). The seasonal variability is prevalent in the entire landscape of Nigeria including the southwest region. The seasons are therefore targeted by poultry farmers during their production cycle to maximise performance.

The objective of this study was to

determine the effects of genotype and season on two exotic layer chicken strains; Brown dominant and Hyline brown, and to compare their performances in the different seasons of the year.

Materials and Methods

Experimental Site

The study was carried out in a poultry breeding farm, located in Igboora, Oyo State, South-Western, Nigeria. Igboora is a town situated 80 km North of Lagos State with coordinates 7°26'10" N and 3°17'34" E. The vegetation of the area is typical of a Sahel savannah with two main seasons consisting the rainy and dry seasons.

Experimental Birds

Two strains of hybrid layers were used for this study; Brown dominant and Hyline brown. The birds were housed separately per genotype in a deep litter system of the production unit of the farm. Small wooden cages were provided in the pen for egg collection.

Egg collection, incubation and management

A total of one thousand five hundred (1500) layers per strain were used for the evaluation of their reproductive performances. Each strain included onehundred and twenty (120) cocks for random mating. Egg collection started when the layers were thirty (30) weeks old. Four hundred (400) eggs per strain (Brown dominant and Hyline brown) were collected for incubation per week (nine weeks per season) throughout the duration of the study. The four seasons under consideration were early wet, late wet, early dry and late dry. A total of three thousand six hundred (3600) hatchable eggs per strain were collected per season from the Breeder farm in Oyo state. The eggs were grouped to differentiate between batches and stored in the cold room at a temperature of 17°C prior to setting in the incubator. Before setting in the incubator, the eggs were sorted, arranged into trays and then aligned into trolleys. The eggs were positioned in the trays with the broad ends up to allow for ease of gas exchange (CO2 and O2) between the eggs and the environment. The trolleys were then moved to the fumigation chamber where the eggs were fumigated using formaldehyde (40%) and potassium permanganate crystals at a ratio of 2:1.

The hatchery unit is automated with a two stage incubation system, comprising the setters and the hatchers. After 18 days of incubation in the setter, the eggs spent a further 3 days in the hatcher. The temperature in the setters was set at 99.5°F and the relative humidity at 83.0% while the hatchers were set to a temperature of 98.5°F and 85.0% relative humidity. The ambient temperature was kept cool with air-conditioners installed in the incubator rooms. The setters allowed for the turning of the eggs at 60° hourly, sprinkling of humidified water, provision of heat to keep the air warm, the inflow of chilled water from the chiller to regulate the temperatur, and a damper to allow for the exchange of air between the inside of the incubator and the environment.

Candling of the eggs was carried out to determine the percentage fertility of the eggs on the 7th and 18th days of incubation. During the process, the eggs were separated into three groups; Fertile, Infertile and Dead-in-germ eggs, while records were taken on weekly basis.

After the candling operation, the fertile eggs were transferred into the hatchers in preparation for hatching. After hatching the chicks were grouped into three during counting and boxing and documented as follows: the normal chicks also termed real chicks, the reject chicks (abnormal chicks) and the dead-in-shell. Chicks which were under sized, poorly feathered, parrot beaked, blind, lame, and those with poorly absorbed yoke were considered and counted as rejects.

Estimation of percentage fertility, hatchability of fertile eggs, hatchability of set eggs and dead in shell

The percentage fertility, infertility, hatched, dead-in-Shell and hatchability were estimated using the formulae below:

$$\text{Fertility (\%)} = \frac{\text{Number of fertile eggs}}{\text{Total number of eggs set}} \times 100\%$$

$$\text{Infertility (\%)} = \frac{\text{Number of infertile eggs}}{\text{Total number of eggs set}} \times 100\%$$

$$\text{Hatchability (\%)} = \frac{\text{Number of eggs hatched out}}{\text{Total number of fertile eggs}} \times 100\%$$

$$\text{Hatched (\%)} = \frac{\text{Number of eggs hatched out}}{\text{Total number of eggs set}} \times 100\%$$

$$\text{Dead-in-Shell (\%)} = \frac{\text{Number of Dead-in-Shell}}{\text{Total number of fertile eggs}} \times 100\%$$

Statistical analysis

Data obtained were analysed using the General Linear Model of SAS (2009). After the removal of non-significant interactions, the following model was used:

$$Y_{ij} = \mu + S_i + T_j + \varepsilon_{ij}$$

Where, Yij = an observation of the trait (%Fertility, %Hatchability etc.),
μ = Overall mean
S_i = Effect of Strain (Brown dominant, Hyline brown)
T_j = Effect of Season (Early wet, Late wet, Early dry, Late dry)
ε_{ij} = Random error

The significant differences among treatments were determined by Least Significant Difference (LSD) test.

Statement on the welfare of the animals

Ethical approval:

The experiment was conducted following the code of ethics for animal experimentation with prior approval by the University's Animal Ethics Committee.

Table 1: Effect of genotype on reproductive performance of both Brown dominant and Hyline brown strains of laying Chicken

Parameters	Brown dominant	Hyline brown
%Infertile	25.20±0.73[b]	28.99±0.71[a]
%Fertile	74.80±0.72[a]	71.02±0.71[b]
%Hatched	67.68±0.98[a]	63.01±0.92[b]
%D.I.S.	9.40±0.48[b]	11.62±0.49[a]
%Hatchability	90.60±0.48[a]	88.38±0.49[b]

[a,b] – means on the same row having different superscripts are significantly ($p<0.05$) different, D.I.S. – Dead in shell

Table 2: Effect of season on reproductive performance of both Brown dominant and Hyline brown strains of laying Chicken

Parameters	Late Dry	Early Wet	Late Wet	Early Dry
%Infertile	31.68±0.58[a]	27.43±0.92[b]	21.88±0.51[c]	27.39±1.01[b]
%Fertile	68.33±0.58[c]	72.58±0.91[b]	78.12±0.51[a]	72.62±1.01[b]
%Hatched	59.37±0.75[c]	65.55±1.10[b]	72.36±0.74[a]	64.12±1.32[b]
%D.I.S.	12.96±0.59[a]	10.09±0.56[c]	7.09±0.36[c]	11.91±0.61[a]
%Hatchability	87.04±0.59[c]	89.91±0.56[b]	92.92±0.36[a]	88.09±0.61[c]

[a,b,c] – means on the same row having different superscripts are significantly ($p<0.05$) different, D.I.S. – Dead in shell

Results

The effect of genotype on the reproductive performance of both layer birds

The effect of strain on the reproductive performance of both Brown dominant and Hyline brown is presented in Table 1. The result shows that the percent hatchability (90.60±0.48), total hatched (67.68±0.98), percent fertility (74.80±0.72), were significantly higher (P<0.05) in Brown dominant compared to Hyline brown strain of laying Chicken. However, the percent infertile (28.99±0.71) and percent dead-in-shell (11.62±0.49) were significantly higher (P<0.05) in Hyline brown than in Brown dominant.

The effect of season on the reproductive performance of both layer birds

The effect of season on the reproductive performance of both Brown dominant and Hyline brown is presented in Table 2. It was observed that there were significant differences (P<0.05) in seasonal variability. The late wet season was significantly higher (P<0.05) in values for the percent fertile (78.12±0.51), percent hatched (72.36±0.74) and percent hatchability (92.92±0.36) than other seasons. This was closely followed by the early wet season.

Discussion

The effect of genotype was highly significant as found in this study. The Brown dominant strain had a better reproductive performance in the percentage hatchability, fertility and hatched when compared to the Hyline brown which on the other hand had a significantly higher percentage in the total infertile, rejected chicks and dead-in-shell. This is in line with the works of Sola-Ojo and Ayorinde (2011) and Ndofor-Foleng (2015) whose results recorded significant effect of genotype on fertility and hatchability. The significance effect of genotype recorded in this study could have also be as a result of the acclimatization of the Brown dominant to the Nigerian environment since they have been used for production in the research farm for a longer period than the Hyline brown which were recently introduced into Nigeria from the United Kingdom to supplement the production of brown chicks in the breeder farm. It has been reported by Dauda *et al*. (2006) that the Nigerian climatic environment is characterised by high temperature and relative humidity typical of tropical regions which could negatively affect the physiological functions of birds.

The effect of season on reproductive performances of Brown dominant and Hyline brown was significant in the percent infertile, percent fertile, percent dead-in-shell, percent hatched and percent hatchability. The highest significant differences found in the percent fertile, percent hatched and percent hatchability productions were in the late wet season. This was closely followed by the early wet season. The percent infertile and percent dead-in-shell were highest in the early dry and late dry seasons. This could be as a result of the influence of season on fertility and hatchability (Olawumi, 2007) which made the lower temperature and favourable condition of the weather experienced during the wet season to give advantage to the reproductive performances of the layers while the harsh and hot environmental condition as a result of the dry season had a negative influence on the layers. The lower hatchability percentage recorded in the early and late dry seasons could be as a result of development of the embryo prior to incubation due to high environmental temperature which also weakens it. Jesuyon and Oseni (2015) reported that the best fertility and hatchability results were obtained in Black Nera and Isa Brown genotypes during the late wet season respectively. Also, earlier reports had also lay claim on the fact that reproductive performance of poultry was influenced by season. This is supported by Elsayed (2009) who reported that fertility in Ostrich was influenced by the season of production. Roy *et al*. (2003) also reported that season had significant effect on the fertility and hatchability of White Leghorn eggs. Similarly, Gonźalez-Redondo (2006) reported that laying date had influence

on the fertility and hatchability of red-legged Partridge (Alectoris rufa) eggs. This influence of season was also similar to the results obtained in the study for Brown dominant and Hyline brown layers.

The results revealed that genotype had significant effect on the reproductive performance as the Brown dominant chicken layer strain had a better performance in the fertility and hatchability than the Hyline brown chicken layer. It was also found from the study that season had significant effect on the reproductive performance of both strains of laying birds. The late wet season was observed to be more favourable to percentage hatched, percentage fertility and percentage hatchability. On the other hand, the late dry season had more impact on the percentage infertile and percentage dead-in-shell. It is therefore recommended that the Brown dominant strain is preferred for brown layer egg production in tropical condition and also that the late wet season should be targeted for optimal production of layers in southwest Nigeria.

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Conflict of interest statement

There is no conflict of interest with any individual or organization regarding the materials discussed in the manuscript.

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THE ROLE OF LIVESTOCK PRODUCTION IN ADDRESSING POVERTY AND HUNGER IN A CHANGING ENVIRONMENT: CASE STUDY OF ZAMBIA

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Abstract

Eradication of hunger and extreme poverty are two sides of the same challenge facing the human race in recent times amidst growing population and adverse climate change. The paper reviewed the significance of livestock as a solution and an avenue to boost smallholder farmer productivity and income, well-being of the people and the national economy. It highlighted the strategies to increase livestock production and products through intensification, diversification and reduction in wastes and losses; and the roles to be played by the farmers and the government through the Ministry of Fisheries and Livestock. Impact of climate change on livestock and possible Climate Smart Agriculture (CSA) practices to be employed were reviewed and this include micro level activities, income related responses, institutional changes (policies) and technological development. The paper also brought to the fore, the business opportunities that comes with CSA activities. The significance of government policies and regulations in providing adaptation and mitigation measures were equally stressed for successful cushioning of the negative impact of climate change.

Keywords: Livestock, Climate Smart Agriculture, Policies, Adaptation, Mitigation,

LE RÔLE DE LA PRODUCTION ANIMALE DANS LA LUTTE CONTRE LA PAUVRETÉ ET LA FAIM DANS UN ENVIRONNEMENT ÉVOLUTIF : ÉTUDE DE CAS DE LA ZAMBIE

Résumé

L'éradication de la faim et de l'extrême pauvreté sont les deux faces du même problème auquel la race humaine est confrontée ces derniers temps, dans un contexte de croissance démographique et de changement climatique défavorables. Le document a passé en revue l'importance de l'élevage en tant que solution au problème et moyen de stimuler la productivité et les revenus des petits exploitants, le bien-être des populations et l'économie nationale. Il a mis en évidence les stratégies visant à accroître l'élevage et les produits d'élevage par l'intensification, la diversification et la réduction des gaspillages et des pertes ; et les rôles que doivent jouer les éleveurs et le gouvernement par le biais du Ministère de la pêche et de l'élevage. L'impact du changement climatique sur l'élevage et les éventuelles pratiques d'élevage adapté au climat (CSA : climate smart agriculture) auxquelles il faut recourir ont été examinés, notamment les activités au niveau micro, les interventions liées au revenu, les changements institutionnels (politiques) et le développement de technologies. Le document a également mis en évidence les opportunités commerciales engendrées par les activités CSA. L'importance des politiques et réglementations gouvernementales dans la fourniture de mesures d'adaptation et d'atténuation a également été soulignée pour l'amortissement réussi de l'impact négatif du changement climatique.

Mots-clés : élevage, agriculture adaptée au climat, politiques, adaptation, atténuation

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Background

Eradication of hunger and extreme poverty is perhaps one of the greatest challenges facing the human race in recent times. This is coming on the heels of negative impact of climate change which poses serious immediate and long-term threats to the efforts of achieving sustainable development with striking negative effects on food security and rural development. The United Nations captured the scenario in the laudable Sustainable Development Goal (SDG) 1, on ending poverty in all its forms everywhere and SDG 2 to end hunger, achieve food security, improved nutrition and promote sustainable agriculture.

The targets set for ending hunger include food availability, accessibility, stability and utilization. It entails, that all people (in particular, the poor and people in vulnerable situations, including infants) at all times, have access (physical, social and economic) to safe and nutritious food (that meets their dietary needs for an active and healthy life). It means provision of balanced nutrients, diet diversity and having enough to eat (sufficient food) all year round. On the other hand, poverty was described as more than lack of income or resources but that it includes lack of basic services, such as education, hunger, social discrimination and exclusion, and lack of participation in decision making. The above is typical of a number of developing countries in Africa with increasing population growth rates which puts pressure on the economy and food security of most developing countries.

Zambia's population as at the 2010 census was 13,092,666, according to the Central Statistical Office (CSO, 2014), and has been growing at an average of 3.07 % ever since. The World Bank (2015) projected that the population will hit 23,576,214, which is almost double by 2030. The CSO (2014) further reported that the poverty levels in Zambia remains unacceptably high with 54% living below the poverty line. It was further reported that 76.4% live in poverty in the rural areas compared to 23.4% in the urban areas while income disparity stands at 69%. It could be seen immediately that the problem of hunger and poverty are intrinsically linked and complex with roots in social, economic, cultural and food production factors.

It is, however, ironical that smallholder farmers who are mostly rural based and contribute close to about 75% food production in Zambia are the same group mostly prone to hunger and poverty. It is known that Agriculture sector in Zambia employs 67% of the labour force and remains the main source of income and employment for both rural men and women. The sector provides livelihood for more than 50% of the population (CSO 2014) but contributes a paltry 8.5% of the national GDP in 2015 despite the huge potential. Diao *et al* (2010) stated that in the early stages of development, the growth of the agricultural sector is key for achieving development objectives. The authors further asserted that as a developing country, growth in the agricultural sector is the clearest avenue through which sustainable economic growth and poverty reduction can be achieved.

In Zambia, poverty and vulnerability are largely a rural phenomenon and are associated with primarily rain-fed smallholder agricultural system, which is extremely vulnerable to climate change related risks. For over 70% of the smallholder and rural farmers, especially those in low rainfall and drought prone areas, most of them women and youth, droughts and floods can impose severe economic and social stress on the households. The climatic changes can erode incomes, severely threaten food security and weaken the very foundation upon which small-holder households build assets and capabilities to reduce risk and increase resilience to climate change.

IAPRI (2016a) depicted the Zambia farm structure in an illustration with data from crop forecast survey for 2016 as comprising smallholder farmers cultivating between 0-2Ha farmland constitute 71.5% and those with 2-5ha another 23.8%. The smallholder farmers mostly depend on rain fed agriculture and farm input support programme of the government which until recently was maize seeds and fertilizers. This has made the budget of the Farmers Input

Support Programme (FISP) and Food Reserve Agency (FRA) to be as high as 58% of budget for the Ministry of Agriculture. The Ministry was likened at one time by concerned persons to be the "Ministry of Maize". Various reports showed the programmes to be ineffective at boosting productivity and reducing rural poverty (Mason *et al* 2013). This prompted the government to begin the diversification programme to such crops as soybeans, cowpeas, cassava and rice among others; and livestock.

One of the outstanding characteristics of the smallholder farmer is the fact that each smallholder farmer keeps at least one species of livestock. Livestock keeping is widely practiced in rural areas of Zambia. Smallholder farmers hold the bulk of the livestock population (about 80%). This stems from the ability to utilize a broad range of feed resources and adapt to marginal conditions which present an opportunity for income generation among the resource poor households and food security to a certain extent. Surveys in the past have shown that approximately 45-47% of the rural population own livestock.

The Department of Livestock Department reported in its 2015 Annual Report that over two million households were captured as cattle raising households and the dairy industry provides the equivalent of over 800,000 jobs largely in informal, self-employment. It is estimated that total formal jobs available to the Zambian workforce totalled over one million in 2015. IAPRI (2016b) also noted in the Rural Agricultural Livelihood Survey (RALS) for 2015, that Fisheries and Livestock account for 8.6% of smallholder income and on average account for 21.6 of the smallholder productive assets. Incidentally, dairy farming, one of the most rewarding agri-business activities in Zambia, is driven mainly by small scale farmers who contribute about 60% of the total milk production in the country (ZDA, 2011). The report further stated that the total output of the Zambia dairy industry was around 70 million litres per annum, having increased by over 100% within a period of five years due to the growing demand.

The rising demand for animal proteins is driving a significant change in livestock markets for small holder farmers. Policies and investments that support greater commercialization by Smallholder livestock farmers hold significant income growth and poverty reduction potential. Development agencies (Heifer International, SNV Netherlands Development Organization, World Vision and Oxfam among others) have over the years recognized livestock as a veritable avenue to overcome malnutrition, alleviate poverty through alternative source of income and bring about changes in livelihood of poor rural people and thus bring about the much-needed development. Heifer International in its 2015 Annual report observed that Zambian households that received animals via the Pass on the Gift (Dairy Cow) model had increased their diet diversity via direct consumption (1/3 more of dairy; increased expenditure on more food groups. Heifer International (2015) further reported decrease in poverty from 78% to 59% for those below $1.25 for dairy recipients and increased sense of security and improvement in welfare.

Strategies to increase livestock production for enhanced food security and income

The main strategies to increase livestock production and products are threefold: the need to expand the livestock production base, intensification of production and curtaining of "post-harvest losses". Livestock production can be enhanced in Zambia through expansion of animals farmed and animal farms established and develop more interest in other livestock species such as ducks, geese, guinea fowls, pigeons, quails, rabbits, guinea pig and other rodents. It is interesting to also note that the Food and Agricultural Organization (FAO) and other Institutions have been working on topics pertaining to use of insects as food and feed in many countries worldwide. This should not be surprising given that some insects such as locusts, termites, grasshoppers, caterpillars and crickets are eaten by sections of the Zambian

population when in season. It is also instructive that FAO has since added insects (bees) to the list of domesticated animals.

Equally important is the need for intensification of production by moving away from extensive system of production and thus increase productivity per animal per unit area. This can be achieved by provision of housing, improved husbandry practices and animal health care. Intensification of food production is already taking root in the poultry, dairy and pig sectors. It has been reported by FAO (2004) that mortality (through predators, stealing) can be reduced by provision of housing by as much as 20% and another 25% through improved management practices like feeding and health care.

Another critical area of enhancing livestock production is the area of curtailing "post-harvest losses". Generally, livestock products (meat, milk, eggs) are mostly perishable without immediate storage, adequate processing and packaging. It arises as a result of damage, wastage, contamination and deterioration. It has been noted that postharvest wastes or losses from farm to market or households account for 30-40% of total production but this could be reduced by as much as 10% by good storage and quick processing.

Importance of Livestock in combating hunger and alleviating poverty

The significance of livestock in the lives of the individual farmer and community cannot be over emphasized given the multi-functional roles it continues to perform.

Food Supply: Livestock provides food in various and diverse forms as meat and meat products (from beef cattle, dairy cattle, sheep, goat, pig, poultry), eggs (from poultry -chickens, duck, geese) milk and milk products (from dairy cattle and goat). Animals convert low-biological-value protein foods that are less palatable and less nutrient dense to high-biological-value foods that are highly palatable and nutrient dense for humans.

Food and Nutritional security: Poor people survive largely on diets based on starchy foods that fail to meet all their nutritional needs. However, the more people earn, the higher their consumption of nutrient-rich animal-source food. Consumption of meat and milk, driven by population increase, urbanization and rising incomes in developing countries, helps to meet balanced diet requirement.

Improvement of human health: Animal sourced food match particularly well with the nutrients needed by people to support normal development, physiological functioning, and overall good health. Consumption of even small amounts of animal-source foods has been shown to contribute substantially to ensuring dietary adequacy, preventing under-nutrition and nutritional deficiencies. Consumption of adequate amounts of micronutrients, such as those that can be found in animal-source foods, is associated with more competent immune systems and better immune responses (Keusch and Farthing, 1986).

Income Generation: Livestock helps in generating cash incomes from various aspects of the production system such as sales of animals and their food products; sale of animal by-products – hides and skins; provision of services along the animal source food chains- slaughter houses, markets, transporters, processors; provision of traction services such as oxen; sale and supply of manure and through gainful employment in production.

Means of Finance: Income from livestock sales and activities help to raise money to buy staple food and meet cash needs. It thus acts as means of finance, self-insurance, store of wealth and risk management tool.

Employment: In addition to directly providing cash-generating opportunities for livestock keepers, farm animals also create significant numbers of jobs and small business opportunities, many of them in rural areas where other income opportunities are limited. Livestock value chains represent a large and

growing employment sector. They include farm-level production, input, and service industries to farmers; transportation of livestock and their products; and processing and marketing.

Livestock manure as organic fertilizer: Livestock dung and droppings do serve as a source of fertilizer (organic) and act as soil conditioner to degraded farmland

Livestock as a source of energy (draught power, fuel and biogas generation): Livestock as a source of energy for tillage (draught animal power) and fuel (biogas generation from dung).

Livestock as Assets and leveler in society: Livestock are often the most important asset in poor rural households. Access to and control and ownership of assets are regarded as being critical aspects of well-being (Sherraden, 1991). Accumulation of livestock has been identified in some studies as the tipping point that allows poor households to invest in land or small businesses, diversify their incomes, and become less poor and vulnerable, all of which tend to enhance food and nutritional security (Ellis and Freeman, 2004). Furthermore, livestock assets such as poultry and small ruminants are more often owned, reared and income controlled by the women.

Livestock Underpinning Smallholder Agriculture: Livestock contribute to this staple food production by providing manure, contributing to land preparation, and providing ready cash to buy planting materials or fertilizer or to hire labor for planting, weeding, or harvesting. Livestock contributions can thus increase the area of land cultivated, the yields and productivity achieved, the feed produced from crop residues, and, through enhanced nutrient recycling, the sustainability of those farming systems. It is estimated that globally livestock manure supplies up to 12% of gross nitrogen input for cropping and up to 23% in mixed crop–livestock systems in developing countries (Liu *et al*., 2010).

The role of the Department of Livestock Development of the Ministry of Fisheries and Livestock

The Department of Livestock Development (DLD, 2015) reported that the livestock sector in Zambia contributes about 3.2% towards the National Gross Domestic Product while RALS (2012) noted that about 6% of smallholder household income, sales and consumption were from the livestock sector. Meanwhile, FAO (2015) stated that per capita meat consumption in Zambia is 7.8 kg per person per year which is about half that of the average for Africa. Admittedly, the livestock statistics in Zambia are inconsistent due to lack of proper census (livestock census proper was done in the 1970s). Despite this shortcoming, the livestock numbers are quite significant and there is enormous potential to grow these numbers to a large extent. Tables 1 and 2 shows the Livestock population and Livestock products respectively.

It should be observed from the Tables that there is consistent growth in the livestock population and livestock products over the years despite the challenges facing the livestock industry.

The government having recognized the importance of livestock to smallholder farmers and potential contribution to livelihood of the people and meeting food security, decided to pay closer attention to the livestock sector which led to the creation of the Ministry of Fisheries and Livestock in 2015. It must be mentioned that hitherto, the Department of Livestock Development (DLD) was established under the Ministry of Agriculture and Livestock Development in the year 2010 with lofty objectives of developing the sector.

Table 1: Livestock Population: 2008 -2016

Livestock	2008	2009	2010	2011	2012	2013	2014	2015	2016*	GR 2014-2015	2015 - 2016
Cattle	2,457,563	2,315,327	3,038,000	3,837,880	3,932,269	4,026,658	4,319,277	4,624,220	4,984,909	7.5	7.8
Sheep	80,541	83,524	88,507	91,490	95,473	101,456	115,338	131,300	149,420	13.8	13.8
Goats	746,143	758,501	1,380,100	2,067,858	1,839,650	3,023,585	3,538,785	4,095,000	4,823,910	17.0	17.8
Pigs	583,036	655,919	700,802	832,685	910,568	1,098,951	1,533,402	2,146,762	3,048,403	40.0	42.0
Poultry	73,290,635	74,700,661	75,928,130	78,585,623	86,745,351	122,605,273	146,055,266	174,470,000	212,853,400	19.5	22.0

- *Second National Agricultural Policy 2016 and Ministry of Fisheries and Livestock 2016 as cited in IAPRI 2016a*
- **Projection*

Table 2: Livestock Products 2010 -2015

	2008	2009	2010	2011	2012	2013	2014	2015	Growth Rate 2014-29015
Milk (MT)	160,881	170,000	215,000	306,000	370,000	452,000	463,000	524,000	13.2
Eggs (000,000)	125,000	226,000	326,000	429,000	529,547	630,112	1,058,000	1,216,700	15
Hides	203,989	226,654	238,584	245,987	278,219	289,025	303,174	313,785	3.5
Beef	20,865,095	22,235,586	23,129,471	25,874,903	29,375,668	30,474284	3,800,000	4,104,000	8.0
Pork	1,311,575	137,071,000	288,767,500	328,752,000	332,039,520	383,378,816	408,751,305	439,407,653	7.5
Poultry	1,701,265	1,809,857	1,846,793	5,274,563	1,580,529	3,409,572	3,818,227	4,352,779	14

Source: DLD (2015)

The DLD has made significant strides in the development of livestock infrastructures such as Livestock service centres, Artificial Insemination centres, and livestock breeding centres across the country. It, however, continues to grapple with poor staffing levels and poor funding.The department only received K24.5 million against budget *al*location of K96.5 million. It further highlighted challenges in the sector which has to do with breeding stock, financing, poor road infrastructures, lack of processing facilities, high energy costs, shortage and high cost of feedstock, absence of input support, inadequate and inappropriate research, poor extension support, poor organisation of marketing services and high number of levies on livestock and livestock products. IAPRI (2016a) also reported other challenges as weak policy framework for fisheries and livestock, inability to undertake a livestock census and regular annual statistical surveys, high prevalence of livestock diseases, low productivity of local livestock breeds and ineffective extension services resulting in low adoption rates of simple husbandry practices.

The Climate change concept

In tackling and proffering solutions to the above challenges, it will be prudent to holistically look at the livestock sector in light of the global climate challenge. The United Nations Framework Convention on Climate Change (UNFCCC), described climate change as a change climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. This definition highlights the variability in weather pattern over a long period of time and human activity as main causative agent.

It is widely recognized that climate change constitutes a significant and serious threat to sustainable development of any country including Zambia. Evidence shows that Zambia has over the years experienced droughts and dry spells, seasonal and flash floods and extreme temperature with varying frequency and intensity. This has impacted adversely on food and water, energy and livelihoods of communities. Uncertain climate patterns have several implications for the rural populations who derive their livelihoods from farming and related enterprises

Challenges of Climate change in Zambia:

Zambia is divided into three major agro-ecological regions, namely Regions I,II and III based on climatological and soil characteristics. The agro-ecological map of Zambia is as shown in Figure 1 below

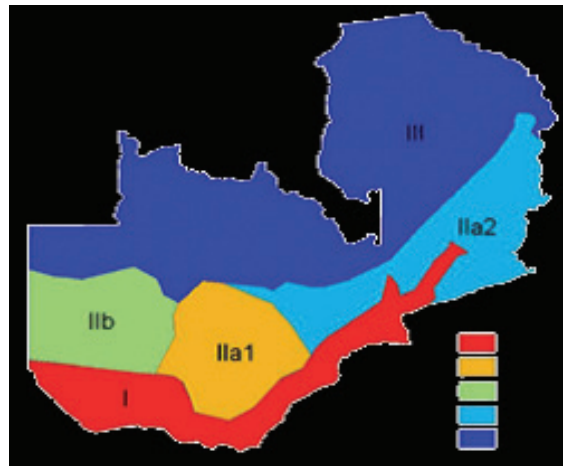

Figure 1: Zambia Agro-Ecological Regions (AER) I, IIa, IIb and III

ZaAS 2013 noted that Agro-Ecological Regions (AERs) has been used in Zambia for policy and adaptive management purposes since its development in the late 1970's and early 1980's without climate change consideration. It further observed in their study that Zambian agriculture is highly vulnerable to climate change and yields will continue to be low unless policy measures are climate proofed. From the data made available by the Zambia Meteorology Department (ZMD, 2013), the temperature rise averages 0.30C per decade in the first three decades (1950-1980) but from 1950-2010, the increase is approximately 0.60C per decade for the six decades under review.This shows that the country is becoming warmer with time. Average temperatures have

increased but precipitation levels have reduced.

The pattern of rainfall has changed with a trend of late onset and early cessation of rainy season. There is an observed declining rainfall pattern across Zambia with the Southwest Region (largely AER I) receiving less rain compared to other AERs of the country. This rainfall trend has shown a sharp decline especially starting in the 1980s and shows that the country is getting drier but more pronounced in the Southwestern regions of the country which also experience higher frequency of climate extreme events (droughts and flash floods). These changes have serious implications for natural systems and farming systems and AERs in general. These changes are similar to global reported trends

Additionally, extreme climate events have become increasingly frequent, with direct consequence to annual production rates. Uncertain climate patterns have several implications for the rural populations who derive their livelihoods from farming and related enterprises. Agriculture in Zambia is largely (98%) rainfed and thus extremely vulnerable to increasing temperatures, droughts, and floods. Smallholder farmers are especially hard hit by these changes, often confronted with livestock losses, crop failures, related income and livelihood losses and consequent food insecurity. It was estimated that as a result of climate change, the country's loss in agriculture GDP is approximately US$430 million per year, thus emphasizing the fact that poverty and food insecurity will be magnified under climate change scenario. The study concluded that in the face of climate change scenarios, the assumptions underpinning the AERs may not hold and its effectiveness as an adaptation tool in agriculture is questionable.

Climate Change and Livestock

According to FAO 2016, the direct impact of climate change on livestock production range from extreme climatic events (such as drought and floods) to thermal stress and reduced yields or water availability; it also affects indirectly through impacts on forage productivity and quality and on animal diseases, modifying the patterns of affected areas and livestock vulnerability simultaneous. The sum total of the diverse effects on the livestock is morbidity and eventual mortality if severe thus threatening food security and nutrition. See Table 3.

Table 3: Climate change effects on livestock keepers and production.

	Animals	**Forages and feed crops**	**Labour force and capital**
Variability in rainfall	• Shortages in drinking & servicing water • Diseases - Increased pathogens, parasites & vectors. - Changed distribution & transmission. - New diseases	• Decreased yields • Decreased forage quality • Changes in pasture composition (species, communities) • Changes in production system (e.g. from mixed crop-livestock to rangelands)	• Altered human health & resources allocation to livestock • Decreased productivity • Migration • Conflict for resources
Temperature	• Heat stress - Decreased feed intake & livestock yields	• Decreased yields • Decreased forage quality • Change in pasture composition	

	Animals	Forages and feed crops	Labour force and capital
	- Decreased conception rates - Altered metabolism & increased mortality • Diseases - Increased pathogens, parasites & vectors - Decreased resistance of livestock • New diseases • Domestic biodiversity loss		
CO2 in the atmosphere		• Partial stomata closure & reduced transpiration • Change in pasture composition	

Source: FAO 2016 FAO's work on climate change: Livestock and climate change

What is the Way Out: Climate Smart Agriculture (CSA)?

Enhancing food security while preserving the natural resource base and vital ecosystem services requires the transition to agricultural production systems that are more productive, use inputs more efficiently, have greater stability in their outputs, and are more resilient to climate risks, shocks, and long-term variability are the corner stone of Climate Smart Agriculture. Climate-smart agriculture requires a major shift in the way land, water, soil nutrients, and genetic resources are managed to ensure that these resources are used more efficiently. Making this shift requires considerable changes in technical approaches. It must be borne in mind that while the concept is new and still evolving, many of the practices that make up CSA already exist worldwide and are currently used by farmers to cope with various production risks.

The CSA concept is understood as an approach that advocates for the generation of more productive farming systems to help ensure present and future food security, increased adaptation to climate change and variations, and reduced agricultural greenhouse gas emissions. CSA initiatives aims to achieve food security (sustainably increase productivity, enhance resilience, reduce emissions) and broader agricultural development goals under a changing climate and increasing food demand.

Some of the CSA options may be able to reduce the negative impacts of livestock on climate change (Mitigation) while at the same time increasing household food security, income and or system resilience (Adaptation). This paper will focus on livestock production adaptation measures while not demeaning mitigation issues. Nevertheless, it should be mentioned that livestock has been implicated in greenhouse gasses (GHG) emissions as high as 14.5% of all human caused GHG. Main sources of emissions are feed production, feed processing and methane from ruminants' digestion. However, the good news is that wider adoption of existing best practices and technologies in animal breeding, animal feeding, health and husbandry, and manure management could help to make the livestock sector to be more resilient and cut its emissions by as much

as 30% (FAO 2013). These CSA practises are equally intertwined and complex.

Kurukulasuriya and Rosenthal (2003), provided a typology of adaptation options to climate change to include four major components namely:

- Micro-level adaptation options: Including farm production adjustments such as diversification and intensification of crop and livestock production; changing land use and irrigation; and altering the timing of operations
- Income related responses: that are potentially effective adaptation measures to climate change such as Crop, livestock and flood instance schemes, credit schemes and income diversification opportunities
- Institutional changes: Including pricing policy adjustments such as removal or putting in place of subsidies, development of income stabilization options, agricultural policy including agricultural support and insurance programs; improvements in agricultural markets and the promotional of inter-regional trade in agriculture
- Technological developments: such as the development and promotion of new crop varieties and livestock feeds, improvements in water and soil management and improved animal health technology.

It must be highlighted that CSA practices and technologies are also avenues for creating businesses and business linkages thus increasing capacity to create income streams and enhance household food security and reduce poverty. Some of the CSA practices and technologies are listed in Table 4. It would be noted from the table, that while the livestock farmer has an obligation to make behavioural and managerial changes to the farm management practices, the government holds the key to significant transformation by introduction of favourable policies.

Table 4: CSA Adaptation options to climate change in light of challenges

	CSA Practices and Technologies	**Gap filled**
Micro level Adaptation	• Shifts in species, breeds and/ or production system (e.g. small ruminants, poultry) • Diversification of livestock- rabbits, ducks, geese, pigeons, quails • Intensification of livestock production through housing • Plant New and Improved fodder and pasture management • Crop livestock integration • Water resources management (e.g. boreholes, dams) • Cooling (indoor systems) or provide shade (e.g. trees) • Weather information services	Improved livestock development outcomes
Income related responses	• Livestock indexed Insurance • Creation of livestock Credit schemes • Cash transfers • Subsidies on inputs especially on drugs	Strengthened resilience of poor and vulnerable livestock keeping communities

	CSA Practices and Technologies	Gap filled
Institutional changes (Policies)	• Development of Livestock development Policy • Development of Animal breeding policy • Development of Livestock Extension services • Deliberate policy for Livestock Financing and subsidy • Price stabilisation schemes for Livestock • Livestock Value chain market development • Promote local and regional trade • Develop Gender mainstreaming Schemes	Create conducive environment for livestock production to thrive Reconversion (in the context of national/regional production zoning) Institutional changes (e.g. trade, conflict resolution, income stabilization programs)
Technological development	• Breed animals for resistance to drought, heat and harsh environments • Develop local breeds for Improved performance • Breed feed crops & forage resistance to drought and heat • Improve use of Artificial Insemination • Improve Technology for Collection, Storage, Processing and Packaging of livestock products • Disease control & animal health through dip tanks, vaccination campaigns • Manure management	Improve resource use efficiency in small scale livestock production systems Reduced wastage through storage, processing and packaging Reduce morbidity and mortality

Government Policies:

NASAC (2017) noted that since food security and adequate nutrition are essential for national development, health, productivity and well-being, the scope of food security and nutrition policy cuts across all sectors of government, demanding strong coordination mechanisms that are informed by a comprehensive policy framework. It further noted to achieve the SDGs, the AU Agenda 2063 vision and the Malabo Declaration targets, the pace and impact of development programmes will need to improve. It concluded by stating that ensuring future sustainable food security and nutrition and sustainable development requires attention on how to improve production across the full range of agricultural products, shaping more efficient food systems that ensure improved nutrition and health as well as effective monitoring and evaluation systems supported by an appropriate institutional architecture to create continual policy review, reform and implementation.

It is very evident that Government has a lot at stake to do to drive the livestock production in the country. Policies and regulations must therefore be put in place and recommended to boost the sector given its importance. To achieve this, the policies must be directional, consistent and devoid of discordant tunes

Government Policies and Climate Change

ZaAS (2015) had recommended that climate change adaptation strategies should be incorporated into the existing strategies in the National Agricultural Policy rather than developing a separate climate change policy for the sector. It is gratifying to note that in the recently launched Second National Agricultural policy 2016, Climate change was given prominence in at least four out of the ten objectives. The National Policy on Climate Change that was launched recently also has components related to Agriculture. Furthermore, recent ppronouncement by the Honourable Minister of General Education, to make Agricultural Science a compulsory subject in Schools is commendable and should be implemented. Perhaps it is time to also resuscitate Agricultural Youth clubs in all Secondary schools.

Government Policies and Livestock Budget:
The 2016 Zambia National budget allocation revealed that Fisheries and Livestock sector received 23% of the Agriculture budget compared to 3% in the 2015 budget. This represented a significant shift in the importance attached to the livestock and fisheries sector and should be supported. It must also be pointed out that despite the low budget allocation in 2015, the release of funding was less than 25%. It is however, a matter of concern that the budget allocation to Agriculture (Fisheries and Livestock sector inclusive) was lower in 2016 compared to 2015. This is an indication of decreasing importance of the agriculture sector within the economy. There is a largely positive connection between government policy and budget allocation. In the year 2017, the government made a declaration that livestock census will be conducted. This was an expensive exercise and represented a bold step which will go a long away in addressing the challenges (gaps and inadequacies) with livestock data in the country. It was also an indication of the desire of government to reposition the livestock sector going by the dictum 'whatever you can measure, you can develop'

Government Subsidies and Market

It is a fact that two main reasons for the continuous crops bumper harvest in the country are the farm input support (FISP or eVoucher) and ready market provided by the Government through the FRA. Farmers do respond positively to markets access. It would be good if similar policies and programmes are also extended to the Livestock sector. The government will also need to address the high cost of livestock drugs and the recent hike in fees of veterinary charges as this may stifle the development of the livestock sector.

Conclusion

Livestock has a significant role to play in addressing poverty and hunger as the rising demand for animal protein therefore presents an opportunity for smallholder livestock farmer to earn more income to improve on their livelihood and or expand their herd or flock. This potential opportunity is, however, threatened by climate change as the direct impact on livestock production could lead to morbidity and eventual mortality. It is therefore important that smallholder livestock farmers start practicing Climate Smart Agriculture to mitigate against the adverse effects. Government has a big role to play through enactment and review of policies to address micro level adaptations, institutional changes and technological development.

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PRINCIPAL COMPONENT ANALYSIS AND REPEATABILITY ESTIMATE OF EGG PRODUCTION TRAITS IN NIGERIAN INDIGENOUS CHICKENS DIVERGENTLY SELECTED FOR ANTIBODY RESPONSE TO SHEEP RED BLOOD CELLS (SRBC)

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Abstract

A study of the principal component analysis and repeatability on egg production traits was carried out in Nigerian indigenous chickens. The internal and external qualities of eggs of of three different genotypes (normal feather, naked neck and frizzle feather) of Nigerian indigenous chickens were determined using a sample of 500 eggs. From the results, there were no significant ($p>0.05$) differences in the any of the internal and external characteristics of the eggs of the birds with the genotypes. Associations recorded for the egg traits of the normal feather birds ranged from -0.25 to 0.68. Strong association for the egg traits recorded for the naked neck birds was between egg weight and egg thickness ($r = 0.66$, $p<0.05$), egg weight and albumen weight ($r = 0.71$, $p<0.05$), egg thickness and yolk breadth ($r = 0.63$, $p<0.05$) and the association between egg thickness and yolk breadth ($r = 0.71$, $p<0.05$). Strong associations for the frizzle feather birds was recorded for egg weight and albumen weight ($r = 0.63$, $p<0.05$), egg length and egg thickness ($r = 0.76$, $p<0.05$), egg length and yolk weight ($r = 0.85$, $p<0.05$) and the association between yolk height and albumen weight ($r = 0.68$, $p<0.05$). The communalities which represent estimates of the variance in each variable accounted for by the components ranged from 0.249 – 0.819, 0.428 – 0.997 and 0.946 – 0.997 in Nigerian indigenous normal feathered, naked neck and frizzle feathered chickens respectively. Repeatability estimates were significant ($p>0.05$) but generally low with egg weight recording 0.064 ± 0.037, egg length recording 0.024 ± 0.018 and egg thickness recording 0.010 ± 0.013. In conclusion the internal and external egg characteristics of the genotypes were similar, but association of traits differed between the genotypes.

Key words: Egg, Principal Component, Repeatability, Stepwise regression, Nigerian

ANALYSE DES PRINCIPALES COMPOSANTES ET ESTIMATION DE LA RÉPÉTABILITÉ DES CARACTÉRISTIQUES DE PRODUCTION D'ŒUFS CHEZ LES POULETS AUTOCHTONES NIGÉRIENS SÉLECTIONNÉS DE MANIÈRE DIVERGENTE POUR LA RÉPONSE ANTICORPS AUX ERYTHROCYTES DE MOUTON (SRBC)

Résumé

Une étude de l'analyse des principales composantes et de la répétabilité des caractères de production d'œufs a été réalisée chez des poulets indigènes nigérians. Les qualités internes et externes des œufs de trois génotypes différents (plumage normal, cou nu et plumage frisé) de poulets indigènes nigérians ont été déterminées en utilisant un échantillon de 500 œufs. Les résultats ont révélé qu'il n'y avait aucune différence significative ($p> 0,05$) dans les caractéristiques internes et externes des œufs des oiseaux ayant ces génotypes. Les associations enregistrées pour les caractéristiques des œufs des oiseaux au plumage normal variaient de -0,25 à 0,68. Une forte association pour les caractéristiques des œufs enregistrés pour les oiseaux à cou nu se situait entre le poids des œufs et l'épaisseur des œufs ($r = 0,66$, $p <0,05$), le poids des œufs et le poids de l'albumine ($r = 0,71$, $p <0,05$), l'épaisseur des œufs et la largeur du jaune ($r = 0,63$, $p <0,05$) et l'association entre l'épaisseur de l'œuf et la largeur du jaune ($r = 0,71$, $p <0,05$). De fortes associations pour les oiseaux au plumage frisé ont été enregistrées pour le poids des œufs et le

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poids de l'albumine (r = 0,63, p <0,05), la longueur et l'épaisseur des œufs (r = 0,76, p <0,05), la longueur des œufs et le poids du jaune (r = 0,85, p <0,05) et l'association entre la hauteur du jaune et le poids de l'albumine (r = 0,68, p <0,05). Les points communs qui représentent les estimations de la variance dans chaque variable expliquée par les composantes variaient respectivement entre 0,249 et 0,819 ; 0,428 et 0,997 et 0,946 et 0,997 chez les poulets au plumage normal, les poulets au cou nu et les poulets au plumage frisé. Les estimations de répétabilité étaient significatives (p> 0,05) mais généralement faibles avec un poids d'œuf enregistré de 0,064 ± 0,037, une longueur d'œuf enregistré de 0,024 ± 0,018 et une épaisseur d'œuf enregistré de 0,010 ± 0,013. En conclusion, les caractéristiques internes et externes des œufs des génotypes étaient similaires, mais l'association des caractères était différente entre les génotypes.

Mots-clés : Œuf, principale composante, répétabilité, régression séquentielle, nigérian

Introduction

Nigeria has rich chicken genetic resources and also has a large number of livestock in the nation, yet the animal protein intake per person per day still falls below the minimum requirement level recommended by the United Nation (UN)/Food and Agricultural Organization (FAO) (Ayodele and Ajani, 1999). The above underscores the need to improve the level of animal protein production in Nigeria.

Nigerian indigenous chickens have proven to be hardy and able to survive in extreme weather conditions (Adebambo *et al*., 1999; Ajayi, 2010; Mengesha, 2012). However, they have been characterized with small body size, small body weight, small egg size and low productivity. Studies relating to the development of the local chicken as a potential layer have shown appreciable improvement in egg production traits under improved management (Nwosu *et al*., 1979; Adebambo *et al*., 1999; Momoh *et al*., 2007).

The Nigeria local chicken though often described as "a low producer" possess great potentials of a good layer (Nwosu and Omeje, 1985; Momoh *et al*., 2007). Incidentally, the rich genetic diversity of these chickens has not been harnessed and developed through a pure breeding strategy. Muchadeyi *et al*. (2007) and Halima *et al*. (2009) indicated that there are large phenotypic and possibly genetic variances existing within the indigenous breeds and variances; and suggested the application of genetics and selection breeding towards improving the local breeds/ecotypes. For optimum production of local chicken, therefore, there is need for genetic improvement.

The egg production of the local chicken is a result of many genes acting on a large number of biochemical processes, which in turn control a range of anatomical and physiological traits. With appropriate environmental conditions (nutrition, light, ambient temperature, water, sound, health, etc.). The many genes controlling all the processes associated with egg production can act to allow the chicken to express fully its genetic potentials (Fairfull and Gowe, 1990). Altering and improving the environment, physiological situation or manipulation of these birds though contribute immensely towards improvement of their production qualities, the possibility remains that variation in their productivity exists after optimum non-hereditary conditions have been established.

Growth rate and egg production under conventional system of rearing in the villages are very low. This is generally due to the insufficient feed supply and problem of disease and social behaviour (Ibe, 1998). Poultry management in Nigeria has been improving significantly with rapidly increasing production. However, one of the major constraints facing the Nigerian poultry industry today is lack of indigenous parent breeding stock (Ndofor-Foleng *et al*., 2006). A streamlined production of local chicken could be an option for alternative income generation and diversification of the agricultural production base of the nation. Local chickens may appear less productive when compared to specialized exotic breeds but they are highly productive in their use of

local feed resources, adaptable to the harsh variable and extreme weather and climatic conditions making them more sustainable in the long term.

Repeatability is a measure of the similarity of successive measurement of a single trait in an individual (correlation) over time or space, is a measure of an individual's ability to repeat its ranking in a population of successive records (Falconer, 1989; Ibe, 1995), and is a concept closely related to heritability (Falconer, 1989). Variance with repeatability includes additive, dominant and epistatic genetic portions, since the genes or gene combination do not change when they influence the successive expression of the same traits in the individuals.

There has been limited information on the repeatability and eigen-vector indices of egg production traits in Nigerian indigenous chicken. Consequently, the little breeding experimental programs on chicken rely heavily on estimates obtained from exotic populations. There is therefore, need to improve egg production traits and their indices (size, width and weight) in Nigerian indigenous chickens as compared to the exotic birds. Hence, this research aims to evaluate the repeatability and Eigen–vector indices in egg production traits in Nigerian indigenous chicken and also to develop a stepwise regression model to predict egg weight using internal and external egg qualities.

Materials and methods

A total of 179 eggs were sampled from 82 birds comprising 36 normal feathered, 11 frizzled feathered and 10 naked neck from the 2nd generation of Nigeria indigenous chickens which has been divergently selected for high and low antibody response to Sheep Red Blood Cell (SRBC) were used for the research. Eggs were collected daily for 4 months from each pen and marked for proper identification. The 2nd Generation birds were mated using Artificial Insemination. The experiment birds were raised under the intensive system of management on deep litters. Adequate sanitation and vaccination programs were adhered to prevent occurrence of diseases. Mortality was disposed and infected hens were culled. Marek's vaccine was administered at day old from hatchery. They were brooded for four weeks before being transferred to the grower's pen. Clean water was supplied adequately throughout the research. Data was collected on the following egg production traits.

Weight of first egg (WFE): the weight of the first egg laid by each hen were obtained soon after lay using an electronic balance scale having a sensitivity of 0.01g

Egg weight (EW): This was taken on individual egg on daily basis from each layer with the aid of an electronic balance scale having a sensitivity of 0.01g. The average egg weights obtained from individual hens for each week of lay for each population or the short-term period of study were used in the data analysis.

Body weight: the weight of the chicken was determined by measuring it with a sensitive scale. It is measure in grams (g).

Egg width: the diameter of the egg was determined with the use of a Vernier caliper. It was measured in centimeters (cm).

Egg length: the length of the egg was determined with the use of Vernier caliper. It was measured in centimeters (cm).

The data collected on the egg production traits monitored was subjected to descriptive statistics using All analyses were done in SPSS (2001). The effect of major gene on egg traits was evaluated using one-way analysis of variance. The model is given below.

$$Y_{ij} = \mu + A_i + e_{ij}$$

Where;
Y_{ij} = The observed value of the eggs.
μ= overall mean.
A_i = effect of ith major gene (i=frizzled, normal and naked neck)

e_{ij} = Random residual error

Repeatability estimates was obtained using the model

$$R = \frac{\sigma^2_B}{\sigma^2_b + \sigma^2_E}$$

Where
R = Repeatability using paternal half-sib correlation.
σ^2_B = Variance component between major genes (genotypes) of bird.
σ^2_E = Error variance component

The standard error of the repeatability estimates was estimated using the following model

$$S.E.(R) = \frac{\sqrt{(2(1-R)^2\,[1+(k-1)R]^2)}}{k(k-1)(N-1)}$$

Where;
t = intra class correlation
σ^2_w = variance (error).
k = number of record per bird.
Eigen value model for estimating egg quality:

$$Y_\mu = Wp^{1/2}\,x + \sigma\, V^N.$$

Where;
W= Variance of N representing the signature matrix (assumed to be orthogonal).
P=Diagonal (ei□Ni;1 ≤ i ≥ L) or diagonal with finite of power amount pis, each with multiplicity Ni.
X = Trait (egg length, egg thickness)

Results

Effects of genotype on egg internal and external traits:

Table 1 shows that there were no significant (p>0.05) differences any of the internal characteristics of the eggs of the birds with the genotypes. Mean values were statistically similar when compared, however values ranged from 16.70 ± 0.53 g to 16.98 ± 0.70 g for yolk weight, 1.13 ± 0.04 cm to 1.25 ± 0.12 for yolk height, 4.35 ± 0.05 cm to 4.61 ± 0.08 cm for yolk breadth, 16.58 ± 0.48 g to 17.00 ± 0.86 g for albumen weight and 0.41 ± 0.03 cm to 0.42 ± 0.01 cm for shell thickness. Likewise, from table 2, the external characteristics of the eggs were not significantly (p>0.05) affected by the genotypes of the birds. The external egg traits were similar (p>0.05) when eggs from the three genotype birds were compared. The birds produced eggs weighing 38.90 ± 0.85 g to 40.39 ± 0.72 g, with lengths

Table 1: Effect of genotypes on the internal egg quality parameters of Nigerian indigenous chicken

	Frizzle feather (n = 26)	Normal feather (n = 127)	Naked neck (n = 26)	P – value
Yolk weight (g)	16.98 ± 070	16.85 ± 036	16.70 ± 053	0.9535
Yolk height (cm)	1.13 ± 004	1.13 ± 003	1.25 ± 012	0.2504
Yolk breadth (cm)	4.61 ± 008	4.35 ± 005	4.37 ± 021	0.2805
Albumen weight (g)	17.00 ± 086	16.58 ± 048	16.69 ± 081	0.9228
Shell thickness (cm)	0.41 ± 002	0.42 ± 001	0.41 ± 003	0.9605

n – Number of samples

Table 2: Effect of genotypes on the external egg quality parameters of Nigerian indigenous chicken

	Frizzle feather (n = 26)	Normal feather (n = 127)	Naked neck (n = 26)	P – value
Egg weight (g)	40.39 ± 072	39.82 ± 060	38.90 ± 085	0.5341
Egg length (cm)	5.09 ± 005	4.97 ± 003	4.92 ± 004	0.0970
Egg thickness (cm)	3.80 ± 002	3.89 ± 008	3.76 ± 004	0.5315

n – Number of samples

ranging from 4.92 ± 0.04 cm to 5.09 ± 0.05 cm and thickness ranging from 3.76 ± 0.04 cm to 3.89 ± 0.08 cm.

Pearson correlation among orthogonal egg qualities traits in Nigerian indigenous chicken:

Table 3 shows the Pearson's correlation between the internal and external egg traits of the normal feather, frizzle feather and naked neck birds in Table 3 below. Associations recorded for the egg traits of the normal feather birds ranged from -0.25 to 0.68. Most of the associations were low i.e. below 50 % however, strong association was recorded for the association between egg weight and egg length ($r = 0.67$, $p<0.05$), egg weight and albumen weight ($r = 0.68$, $p<0.05$) and the association between yolk weight and yolk breadth ($r = 0.65$, $p<0.05$).

There were strong associations for the egg traits recorded for the naked neck birds between egg weight and egg thickness ($r = 0.66$, $p<0.05$), egg weight and albumen weight ($r = 0.71$, $p<0.05$), egg thickness and yolk breadth ($r = 0.63$, $p<0.05$) and between egg thickness and yolk breadth ($r = 0.71$, $p<0.05$). Other recorded associations were below 60 % for the naked neck birds.

The frizzle feather birds also recorded high correlations for some of the egg traits. Strong associations were also recorded for egg weight and albumen weight ($r = 0.63$, $p<0.05$), egg length and egg thickness ($r = 0.76$, $p<0.05$), egg length and yolk weight ($r = 0.85$, $p<0.05$) and between yolk height and albumen weight ($r = 0.68$, $p<0.05$).

Variation linked component matrix, communalities, eigen values and percentage of total variance of external egg quality traits of indigenous Nigerian chicken

The eigen values of the total variance, the component matrix and the communalities of the external egg traitsareshown in Table 4. The communalities represent estimates of the variance in each variable accounted for by the components. It ranged from 0.249 – 0.819, 0.428 – 0.997 and 0.946 – 0.997 in normal feathered, naked neck and frizzle feathered chickens respectively. The Eigen values showed the amount of variance out of the total variance explained by each of the factors.

Three principal components were extracted from normal feathered with Eigen values of 1.577 for the first principal component (PC1), 0.899 for the second principal component (PC2) and 0.522 for the third principal component (PC3). The three principal components accounted for 100% of the total variance present in the three original variables. PC1 had high loadings (correlations between the components and the variables) on shell thickness (0.661) and egg length (0.638). PC2 and PC3 were orthogonal to PC1 and loaded heavily on egg weight (0.913).

In Naked neck, three principal components were also extracted with Eigen values of 2.234, 0.725 and 0.040 for PC1, PC2 and PC3 respectively. The PC 1 and PC 2 accounted for 98.65% of the total variance present in the original variables. PC1 had high loadings on egg length (0.642), shell thickness (0.766) and egg weight (0.427). In PC2, a positive high loading score was observed on egg weight (0.903) and a negative loading score on egg length (-0.280) and shell thickness (-0.323). PC3 was most highly correlated with shell thickness (0.700).

In Frizzle feathered, similar situation was found as in the naked neck three principal components were also extracted after PC1 and PC2 accounted for 98.23% of the total variance in the original variables with Eigen values of 1.943, 1.003 and 0.053 for PC1, PC2 and PC3 respectively. PC1 had low positive on egg weight (0.006) and negative loadings on egg length (-0.706) and shell thickness (-0.707). PC2 had high positive loadings on egg weight (0.998) while PC3 was most highly correlated with egg length (0.705).

Table 5 shows stepwise regression of external egg quality parameters on egg weight of Nigerian indigenous chicken. Two models were adopted in the prediction of egg weight in normal feather birds. The R2 for the first model was 0.02 while for the second model (0.43). The R2 model for the first and the second model for naked neck were 0.183 and 0.186

Table 3: Pearson's correlation of the internal and external egg quality characteristics of the normal feather frizzle feather and naked neck

	Parameter	Egg weight	Egg length	Egg thickness	Yolk weight	Yolk height	Yolk breadth	Albumen weight	Shell thickness
Normal feather	Egg length	0.67**							
	Egg thickness	0.29**	0.24						
	Yolk weight	0.40**	0.47**	0.11					
	Yolk height	0.04	0.28**	-0.17	0.27**				
	Yolk breadth	0.38**	0.36**	0.10	0.65**	0.32**			
	Albumen weight	0.68**	0.44**	0.23	-0.25**	-0.15	-0.12		
	Shell thickness	0.28**	0.36**	0.17	-0.03	-0.11	-0.10	0.35**	
Naked neck	Egg length	0.38							
	Egg thickness	0.66**	0.22						
	Yolk weight	0.46**	0.16	0.63**					
	Yolk height	0.06	-0.08	0.08	-0.12				
	Yolk breadth	0.07	-0.05	0.71**	0.55**	-0.06			
	Albumen weight	0.71**	0.22	0.13	-0.17	0.02	-0.40**		
	Shell thickness	0.02	-0.09	-0.23	-0.31	-0.20	-0.31	0.26	
Frizzle feather	Egg length	0.34							
	Egg thickness	0.32	0.76**						
	Yolk weight	0.31	0.85**	0.50**					
	Yolk height	0.55*	0.45	0.31	0.54**				
	Yolk breadth	0.40	-0.01	-0.21	0.24	0.39			
	Albumen weight	0.63**	0.47	0.46	0.50**	0.68**	0.30		
	Shell thickness	-0.25	0.21	0.24	0.00	-0.64**	-0.27	-0.44	

**P<0.05 **P<0.01*

Table 4: Principal components extracted for external egg quality parameters in Nigerian indigenous chicken

Parameter	PC1	PC2	PC3	Communality
Normal feather				
Weight	0.392	0.913	-0.102	0.249
Length	0.638	-0.351	-0.684	0.577
Thickness	0.661	-0.203	0.721	0.819
Standard deviation	1.256	0.948	0.723	
Eigen value	1.577	0.899	0.522	
% of total variance	52.59	29.98	17.43	
Naked neck				
Weight	0.427	0.903	0.029	0.428
Length	0.642	-0.280	-0.713	0.997
Thickness	0.636	-0.323	0.700	0.961
Standard deviation	1.494	0.851	0.200	
Eigen value	2.234	0.725	0.040	
% of total variance	74.48	24.17	13.46	

Parameter	PC1	PC2	PC3	Communality
Frizzle feather				
Weight	0.006	0.998	-0.058	
Length	-0.706	0.046	0.705	0.946
Thickness	-0.707	-0.036	-0.706	0.997
Standard deviation	1.394	1.001	0.230	
Eigen value	1.943	1.003	0.053	
% of total variance	64.79	33.44	17.74	

Table 5: Stepwise regression of external egg quality parameters on egg weight of Nigerian indigenous chicken

Variable	Model	Standard Error	R^2
Normal feather			
Length	EW=3.8479+0.327L	0.563	0.020
Length and thickness	EW=3.5613-0.798L+2.432T	1.089	0.43
Naked neck			
Length	EW=2.9935+2.189L	1.963	0.183
Length and thickness	EW=2.9149+3.088L-0.973T	2.362	0.186
Frizzle feather			
Length	EW=3.9328+0.204L	2.890S	0.001
Length and thickness	EW=3.6065+4.055L-4.271T	3.209	0.054

EW - egg weight, L - egg length, T- egg thickness

Table 6: Repeatability estimates of the external egg quality traits of the Nigerian indigenous chicken

	Repeatability	Standard error of mean	P – value
Egg weight	0.064	0.037	< 0.0001
Egg length	0.024	0.018	0.00012
Egg thickness	0.010	0.013	0.0987

respectively. The R2 model for the first and second model for frizzle was 0.001 and 0.054 respectively.

Repeatability estimates of the external egg quality traits of the Nigerian indigenous chicken

Repeatability estimates for egg weight and length was significant ($p<0.05$) but estimates for egg thickness was not significant ($p>0.05$). The repeatability estimates were generally low with egg weight recording 0.064 ± 0.037, egg length recording 0.024 ± 0.018 and egg thickness recording 0.010 ± 0.013 (Table 6).

Discussion

Principal component analysis (PCA) revealed three discernible patterns of variation in the genetic groups (Figure 1). The first principal component (PC1) accounted for the largest variance in the three genotypes studied. This had been the usual trend in studies that involved PCA as stated by earlier researchers (Ajayi *et al*., 2008; Mendes, 2009; Yakubu *et al*., 2009; Udeh and Ogbu, 2011). The eight traits were collapsed into single measurements and the percentage of the variance explained in the model in the three genotypes for internal egg qualities. Communality values obtained for the

component analysis of egg quality parameters represented the percentage contribution of each variable to the total variance. This gives weight to the appropriateness of performing component analysis (Okepeku *et al*., 2011).

The means for normal, frizzle and naked neck genotypes of egg weight were high respectively for internal egg parameters. Mean for normal, frizzle and naked neck genotypes of egg weight were high respectively for external egg parameters. This result was in agreement with egg weight and other characteristics of egg parameters on Nigerian indigenous chicken published by Nwosu and Omeje (1985).

The highest positive correlation was recorded as 0.68 between egg weight and albumen weight and the lowest negative correlation was between albumen eight and yolk weight for internal egg quality. The highest positive correlation of 0.96 was between egg length and egg thickness and the lowest positive correlation 0.43 was between egg weight and egg length. Positive correlation of traits suggest that the traits are under the same gene action (pleiotropy) (Yakubu *et al*., 2009) and selection of traits may lead to correlated response in the other trait.

Coefficient of determination (R2) values computed for egg parameters were high for length and thickness. Based on stepwise elimination procedure, length and thickness were better in predicting egg weight in multiple linear regression models.

Conclusion

It was concluded that major genes (normal, frizzle and naked neck) had no significant effects on the internal and external quality traits of the eggs.

Further research should centre on the effect of these major genes on important external quality like egg weight and shape index and also on heat tolerance of the chickens in tropical environment as well as body weight.

Further genetic evaluation of the frizzle feathered bird should be carried out to determine other traits that can be of economic importance. This will serve as basis of inclusion of birds with major genes in the process of expanding the narrow genetic base on which chicken breeding presently operates.

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AFRICAN UNION - INTERAFRICAN B*UREA*U FOR ANIMAL RESOURCES (AU-IBAR)

Bulletin of Animal Health and Production in Africa
Guide for Preparation of Papers
Notes to Authors

The Editor in Chief
September 2019

Aims and scope

The Bulletin of Animal Health and Production in Africa (BAHPA) of the African Union Interafrican B*urea*u for Animal Resources (AU-IBAR) is a scientific journal which publishes articles on research relevant to animal health and production including wildlife and fisheries contributing to the human wellbeing, food security, poverty alleviation and sustainable development in Africa. The bulletin disseminates technical recommendations on animal health and production to stakeholders, including policy makers, researchers and scientists in member states. The Bulletin is the African voice on animal resources issues specific to Africa.

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- *Chapter in a Book:* Leach J, 1993. Impacts of the Zebra Mussel (Dreissena polymorpha) on water quality and fish spawning reefs of Western Lake Erie. In Zebra Mussels: Biology, Impacts and Control, Eds., Nalepa T, Schloesser D, Ann Arbor, MI: Lewis Publishers, pp: 381-397.
- *Reports:* Makarewicz JC, Lewis T, Bertram P, 1995. Epilimnetic phytoplankton and zooplankton biomass and species composition in Lake Michigan, 1983-1992. US EPA Great Lakes National Program, Chicago, IL. EPA 905-R-95-009.
- *Conference Proceedings:* Stock A, 2004. Signal Transduction in Bacteria. In the Proceedings of the 2004 Markey Scholars Conference, pp: 80-89.
- *Thesis:* Strunk JL, 1991. The extraction of mercury from sediment and the geochemical partitioning of mercury in sediments from Lake Superior, Unpublished PhD thesis, Michigan State University, East Lansing, MI.
- *Web links:* Cerón-Muñoz M F, Tonhati H, Costa C N, Rojas-Sarmiento D and Solarte Portilla C 2004 Variance heterogeneity for milk yield in Brazilian and Colombian Holstein herds. Livestock Research for Rural Development. Volume 16, Article #20 Visited June 1, 2005, from http://www.lrrd.org/lrrd16/4/cero16020.htm

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