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Morphometrics and carcass production of Nile crocodile (*Crocodylus niloticus*) under intensive production system

Bob Mali*, Lillian Owembabazi, Celsus Sente and Sam Okello

College of Veterinary Medicine, Animal Resources and Biosecurity, Makerere University Kampala, Uganda.

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The aim of this study was to determine the carcass production and obtain linear models for the estimation of live weight of Nile crocodile (*Crocodylus niloticus*), reared under intensive system. Three-year-old crocodiles destined for slaughter were restrained, stunned and thereafter, the spinal cord severed instantly. The live weight of each crocodile was measured and the corresponding morphometric measurements were taken. The measurements included: body length, height at withers, heart girth, loin/inguinal girth, head width, head length, length of hind quarter and hindquarter width. Upon slaughter of the crocodiles, the carcass weight was measured and the dressing percentage was calculated. Independent sample T tests were used to determine significant differences between male and female morphometric measurements and production. Linear and multiple linear regressions were used to obtain models, for estimation of live weight of Nile crocodile. IBM® SPSS® statistics 24 was used for the analysis. The study revealed males were larger than females. With linear regression analysis, the highest accuracy of live weight prediction at 76% was achieved using heart girth. With multiple linear regressions, 85% accuracy in estimation of Nile crocodile live weight, under intensive system of production was achieved using all eight predictors.

Key words: Body measurements, carcass, *Crocodylus niloticus*, linear models, live weight prediction.

INTRODUCTION

Crocodilian farming is a relatively novel form of animal production that lacks the over 5,000 year history of accumulated knowledge on animal husbandry, available for most conventional livestock (Manolis and Webb, 2006). International trade in crocodilian products was only possible when strict set of conservation criteria were met. The pioneering crocodilian farms were mainly focused on skin production in facilities distant from wild populations. In Australia, two crocodile species, *Crocodylus porosus* and *Crocodylus johnstoni,* are farmed. *Crocodylus niloticus* has been ranched in Zimbabwe since 1963. In Uganda, where wild harvesting

*Corresponding author. E-mail: bob.mali@mak.ac.ug.

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is practiced, eggs are collected from the wild and hatched on farm. The farms are licensed to do egg collection once a year and release a proportion of raised two-year-old juveniles back into the wild. As early as 1995, it was suggested that the farming of *C. niloticus* for skins would have a positive effect on the conservation of this species in the wild (Hoffman and Cawthorn, 2012).

In addition to skin, crocodile meat, considered a delicacy and relished by societies especially in Australia, South Africa, Thailand, Ethiopia, Cuba, and in regions of the United States of America, is generally consumed as a by-product of the skin trade (Hoffman et al., 2000). It is white and firm, with a flavor lying between chicken, veal, and fish (Hoffman and Cawthorn, 2012). Due to the need for supply of large quantity of skin, crocodiles are often slaughtered in relation to size and not age. Animals have a balanced relationship between body weight and body measurements that have been used extensively for selection practices (Lawrence and Fowler, 2002). Slaughter of crocodiles based on size for larger skin area inadvertently could create larger meat yield. The accuracy of functions used to predict live weight or growth characteristics of live animals (Sowande and Sobola, 2008), could be of immense financial contribution to the crocodile farming enterprise. This study, therefore, aimed to determine the carcass production and obtain linear model for the estimation of live weight of Nile crocodile, reared under intensive system.

MATERIALS AND METHODS

Study area

The study was conducted at Camp crocs crocodile farm Buwama, located in the Central part of Uganda, about 70 km from Kampala City. The farm has a total 1,500 crocodiles reared under intensive system. Nile crocodile eggs are collected from Murchison Falls National Park and hatched on farm. The crocodiles are divided into 3 age groups; yearlings below 1 year, juveniles and adults at 2 and 3 years, respectively. They are fed on minced beef, fish and chicken. Annually, 500 three year-old crocodiles are slaughtered for skin production.

Study design and sample size determination

The study involved morphometric and nutritional evaluation of *C. niloticus,* which was carried out as follows: at a confidence interval of 95%, a 0.05 level of significance, an effect size of 0.35 and 8 predictors (body measurements), a total of 66 crocodiles was determined as the sample size, using G*power 3.1 statistical package. Considering 500 crocodiles were slaughtered, every seventh crocodile from both the 231 males and 269 females stunned and slaughtered were included in the study, creating a total sample size of 66, which comprised 33 male and 33 female crocodiles. Tags were placed on the crocodile's tails to keep track of crocodiles during the stunning, skinning and carcass weighing process.

Morphometrics and live weight determination

The three year-old crocodiles were restrained by trained staff using ropes, passed around the crocodiles jaws (NRMMC, 2009). Upon restraint, the crocodile was stunned using a captive-non penetrating bolt pistol and thereafter, the spinal cord severed instantly with one blow of a heavy hammer on a sharp metal chisel positioned between the skull and the first cervical vertebra, behind the cranial platform (Manolis and Webb, 2006). The live weight of each crocodile was measured by hanging, on a weighing scale and readings were noted. The corresponding morphometric measurements were taken using a tape measure and recorded. The measurements included: body length (BL), the distance from snout tip to tail tip; height at withers (HAW), the length between the highest point over the scapula to the ventral surface of crocodile without inclusion of scute height; heart girth (HG), the circumference of the body behind the forelimbs; loin/inguinal girth (LG), circumference of the body before hind limbs; head width (HW), the distance between the lateral canthi of the eyes; head length (HL), the perpendicular distance between the snout tip and center of skull between the eyes; length of hind quarter (LHQ), the perpendicular distance between the 10th rib and the pelvic ventral tuberosity of the tuber iscshii; and hindquarter width (WHQ), the width of the pelvis (Figure 1).

Carcass weight and dressing percentage determination

The crocodiles were slaughtered and carcasses hang to facilitate blood exsanguination and cessation of the post-mortem movements. This was followed by skinning. Care was taken to avoid mechanical damage to the skin, since it is sold to tanneries. Crocodilian skin was separated from the underlying fascia and flesh by smooth strokes of a sharp small blade. The correct opening lines were made on the animal skin, so that the final shape of the skin complied with accepted market standards. The carcass weight was measured using a weighing scale and the dressing percentage was calculated by dividing the carcass weight by the live weight of the animal and expressing the result as a percentage.

Statistical analyses

Independent sample T tests were used to determine significant differences between male and female morphometric measurements and production. Linear and multiple linear regressions were used to obtain models, for estimation of live weight of Nile crocodile reared under intensive systems. IBM® SPSS® statistics 24 was used for analyses.

RESULTS AND DISCUSSION

Nile crocodile morphometrics under intensive farming systems

The morphometrics of Nile crocodile under intensive farming system are shown in Table 1. Independent sample t tests revealed that male crocodiles had a greater BL, HAW, HG, LG, HW, HL, HQL and HQW than females. Studies have depicted sexual dimorphism exhibited by crocodiles in the wild, with males being larger than females (Warner et al., 2016; Padilla et al.,

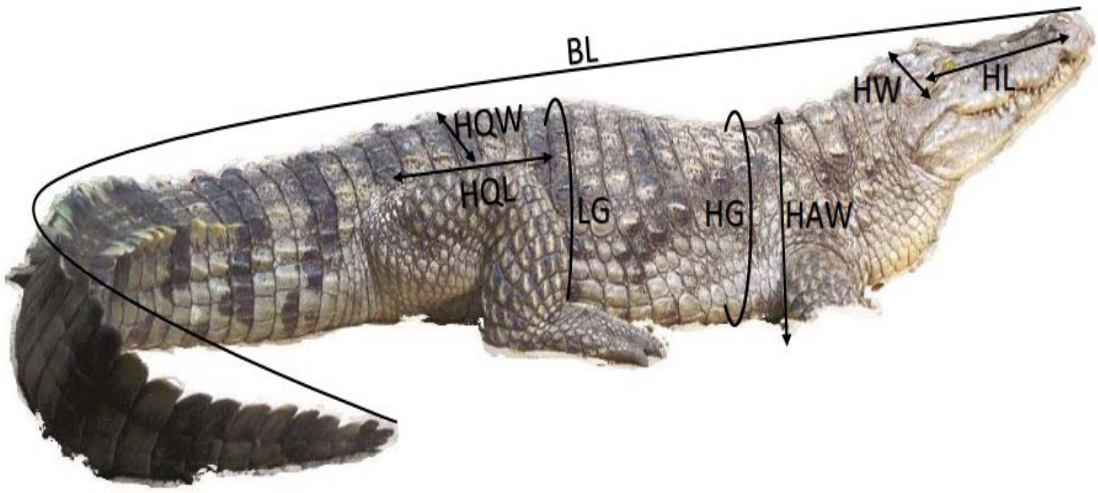

Figure 1. Morphometric measurements of *Crocodylus niloticus*. BL: Body length; HAW: height at withers; HG: heart girth; LG: loin girth; HW: head width; HL: head length; LHQ: hind quarter length; HQW: hind quarter width.

Table 1. Morphometrics of Nile crocodile under intensive farming system.

Trait	Female n=33 Measurement (cm)	Male n=33 Measurement (cm)	SEM	*p*
BL	138.06	154	1.50	<0.001
HAW	7.88	10.88	0.73	0.039
HG	32.42	38.76	0.58	<0.001
LG	34.97	40.09	0.62	<0.001
HW	10.30	11.49	0.19	<0.001
HL	19.79	22.27	0.25	<0.001
HQL	11.46	12.67	0.20	0.002
HQW	9.21	10.82	0.17	<0.001

BL: Body length; HAW: height at withers; HG: heart girth; LG: loin girth; HW: head width; HL: head length; LHQ: hind quarter length; HQW: hind quarter width.

2020). The same traits were observed in this study and could be attributed to the faster growth rate that male species have in comparison to females (Hutton, 1987; Wilkinson et al., 2016).

Live weight estimation of Nile crocodile under intensive farming system

With linear regression analysis, the highest accuracy of live weight prediction at 76% shown in Table 2 was achieved using HG as a predictor. However, through multiple linear regression, 85% accuracy in estimation of Nile crocodile live weight under intensive system of production was achieved using all eight predictors, as shown in Table 3. The equation generated for estimation of Nile crocodile live weight (LW) using all eight predictors was:

$$LW = -18.5+0.078BL+0.064HAW+0.265HG+0.003LG+0.236HW+0.053HL+0.102HQL+0.324HQW$$

In other studies, HG has been used as a single predictor of LW, for animal species (Asefa et al., 2017; Sherwin et al., 2021) and has proven to be more accurate than other body measurements (Matsebula et al., 2013). Crocodiles in this study are no exception to this finding as the

Table 2. Linear models for estimation of Nile crocodile live weight under intensive farming system using single predictors.

Predictor	Constant	Regression coefficient	*p*	R^2
BL	-21.70	0.23	<0.001	0.74
HAW	9.24	0.21	0.001	0.15
HG	-9.97	0.60	<0.001	0.76
LG	-3.48	0.39	<0.001	0.38
HW	0.93	0.95	<0.001	0.20
HL	-13.60	1.18	<0.001	0.57
HQL	-1.43	1.05	<0.001	0.27
HQW	-6.14	1.74	<0.001	0.58

BL: Body length; HAW: height at withers; HG: heart girth; LG: loin girth; HW: head width; HL: head length; LHQ: hind quarter length; HQW: hind quarter width.

Table 3. Multiple linear model for estimation of Nile crocodile live weight under intensive farming system using eight predictors

Variable	Regression Coefficient	*p*	R^2
Intercept	-18.50		
BL	0.08	<0.001	0.85
HAW	0.06		
HG	0.27		
LG	0.00		
HW	0.24	-	-
HL	0.05		
HQL	0.10		
HQW	0.32		

highest accuracy for LW estimation, through use of a single predictor, was attained by use of HG. However, the accuracy of LW estimation has been shown to improve when HG is used in combination with the other morphometric measurements derived from an animal (Katongole et al., 2013). This could be the reason why the use of 8 predictors produced a higher accuracy of Nile crocodile LW estimation in this study.

Nile crocodile production under intensive farming system

The production of Nile crocodile under intensive farming system is presented in Table 4. Independent sample t tests revealed greater live and carcass weights for male in comparison to female Nile crocodiles. However, male carcass dressing percentage was not greater than that of female Nile crocodiles.

The sexual dimorphism observed in studies (Warner et al., 2016; Padilla et al., 2020) with males growing faster than females andattaining larger morphometric measurements, could be accounted for the larger live and carcass weight observed in male crocodiles, in comparison to females. However, the smaller carcass dressing percentage of male crocodiles in comparison to that of females could be due to carcass dressing percentage being a ratio depicting proportion of carcass weight to live weight of the same animal. Carcass dressing percentage is not affected by sex, according to Stanisz et al. (2015) and, therefore, is similar in both females and males of the same species, despite their body sizes not being the same.

Conclusion

The study revealed that even though Nile crocodile males are larger, their carcass dressing percentage under intensive production system is not greater than that of the females. The use of 8 predictors for estimation of crocodile live weight, gave a higher accuracy of proximity

Table 4. Production indices of Nile crocodile under intensive farming system.

Production index	Female	Male	SEM	*p*
	n=33	n=33		
LW (kg)	8.80	13.60	0.40	<0.001
CW (kg)	4.87	7.58	0.22	<0.001
CP (%)	55.30	55.40	0.06	0.319

LW: Live weight; CW: carcass weight; CP: carcass dressing percentage.

than when a single predictor is used. Therefore, the estimation equation with 8 predictors should be used when estimating the live weight of the Nile crocodile.

CONFLICTS OF INTERESTS

The authors have not declared any conflicts of interests.

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