

## BARYMETRIC FORMULAS APPLICABLE TO CHICKENS OF THE LOCAL BREED (GALLUS GALLUS) ON THE EAST COAST OF MADAGASCAR.

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## Abstract

A better morphological knowledge of the local chicken will influence how to improve breeding techniques. Production is based on the carcass yield of the animal. This is mainly the direct result of the weight of the live chicken. This live weight is the only parameter used in estimating the commercial value of local chicken. The objective of this study is to develop and validate barymetric equations for estimating live weight in local chickens reared on the east coast of Madagascar. An equation for predicting the live weight of local chicken breeds based on measurement variables is designed using a linear regression method:  $PV = a + b_1LC + b_2TP + b_3LCou + b_4ENV + b_5LT + b_6DT + b_7HCr + b_8LCr + b_9HB$ . The variables are classified and then entered into the model equation according to their level of correlation with the variable to be explained. For the live weight prediction equation, the best barymetric formula is the one formed by 4 variables where  $PV = -1503.25*LC - 60.16*ENV + 76.76*TP + 107.29*Lcou$  ( $n=902$ ;  $R^2 = 0.785$ ;  $R^2_{aj} = 0.784$ ;  $ETR=366.18$ ;  $CV=16\%$ ;  $p<0.0001$ ). The reliability of the barymetric equation in this study is confirmed. The accuracy of the live weight of local chickens is essential to enable better valorisation of the sector, especially economically. The results demonstrate that barymetric formulas provide a reliable tool for estimating live weight in local chicken breeds and can be effectively used in field conditions where weighing scales are unavailable.

**Keywords :** *Modelling, barymetric, local poultry, eastern coast of Madagascar*

## Liste des abréviations

Amp: Ampasimbe

Amb: Ambodimanga II

CR: Rural commune

CVR: Residual coefficient of variation

DT: tarsus diameter

ENV: wingspan

ETR: Residual standard deviation

HB: height of wattle

HCr: height of comb

k: number of explanatory variables

LC: body length

Lcou: neck length

LCr: comb length

LT: tarsus length

Mah: Mahambo

MR: Mean response or average weight

N F: number of factors

n: size of the observed population

PV: live weight of chicken

PVc: Calculated live weight

PVm: Average live weight

$R^2$  : coefficient of determination

$R^2_{aj}$ : adjusted coefficient of determination

SCR: sum of squares of residuals

SCT: sum of squares total

TP: breast circumference

Var: variables

## Introduction

The breeding of the local "gasy" chicken breed contributes not only to improving the socio-cultural life but also, and above all, to the economy and nutrition of the population of the Big Island. This breeding contributes significantly to the food security of rural and urban households (Bonfoh et al., 1997). It is also a means of combating poverty in rural areas (Gueye, 1998a, b). According to Gueye (2009), poultry is raised in 60 to 80% of rural households in West Africa. Beyond its socio-economic importance, local poultry production faces major technical constraints, particularly the lack of simple and reliable tools for estimating live body weight under traditional farming conditions. In this context, barymetric approaches based on morphometric measurements represent a practical and scientifically relevant alternative to direct weighing, especially in rural areas where access to scales is limited. It is therefore important to use a scientific approach to determine the significant value of this animal. Unfortunately, family-scale poultry farming is given little consideration in the public policies of developing countries. The subject of the growth and development of local Malagasy chickens has not been adequately addressed in research. In particular, few studies have focused on the development of barymetric formulas linking body measurements to live weight in local chicken populations. Therefore, in order to promote this invaluable local product, it is necessary to address the question of the development and applicability of barymetric models for estimating live weight in local chickens (*Gallus gallus*) reared on the east coast of Madagascar. By definition, a model is a hypothesis or concept that attempts to reproduce reality in a very simple way, while ignoring certain characteristics of the real system according to the modeler's objective (Coquillard and Hill, 1997). In this case, a model always provides new knowledge and does not necessarily constitute a perfect reproduction of reality because it is constructed based on a set of objectives, which determine the modelling assumptions and the degree of simplification adopted. Indeed, a model is characterised by its level of simplification and its degree of reproduction of reality (Hantanirina, 2010). In poultry science, barymetric models rely on mathematical relationships between live weight and easily measurable morphometric traits such as body length and thoracic perimeter. The functions make it possible to model the evolution of poultry weight and growth rates. They reflect the growth dynamics of birds using sigmoid curves in two phases separated by an inflection point at which the growth rate is at its maximum (Laird et al., 1965; Parks, 1982). The objective of this study is to develop and validate barymetric equations for estimating live weight in local chickens reared on the east coast of Madagascar. The hypothesis tested in this study is that live body weight can be reliably predicted using a limited number of morphometric measurements, reflecting proportional

changes in body morphology with increasing weight. Such prediction equations could provide farmers and technicians with a simple decision-making tool for managing local poultry production systems. This manuscript is organized as follows: first, the materials and methods adopted in this study are described; second, the results obtained are presented; this is followed by a discussion of the main findings; finally, concluding remarks are provided.

## **1. Materials and Methods**

### **1.1. Animal material**

Chickens (males and females) over 6 months of age were weighed and measured. There were a total of 902 (313 roosters and 589 hens) distributed as follows in the three rural communes of the study area: 103 cocks and 260 hens in Mahambo, 96 cocks and 132 hens in Ambodimanga II, and 114 males and 197 females in Ampasimbe Manantsatrana (Sendramampionona et al., 2020). The use of adult chickens is consistent with previous barymetric studies, which recommend mature individuals to ensure stable morphometric–weight relationships (Bekele et al., 2021)

### **1.2. Weighing and measuring**

Weighing was carried out using an SCA-301 electronic scale with a capacity of 7,000 g and an accuracy of 1 g for weighing (PV). Measurements were taken using a 150 cm tape measure to measure linear body parameters (LC, ENV, TP, LCO, DT, LT), and by a 20 cm vernier caliper with an accuracy of 1 mm to obtain small measurements (LCr, HC, HB). This approach based on simple, low-cost measurement tools is widely recommended for rural poultry systems where access to weighing equipment is limited (Liswaniso et al., 2025). The 10 parameters collected using this equipment are (Sendramampionona et al., 2020):

- Live weight (PV): weight of the live animal.
- Body length (LC): length between the tip of the maxillary rostrum (beak) and the tip of the cauda (or tail, excluding feathers); the bird's body is stretched to its full length.
- Wingspan (ENV): length between the tips of the right and left wings after stretching them to their full length.
- Neck length (LCO): the distance between the base of the head and the starting point of the thorax above the crop.
- Chest circumference (TP): circumference of the pectoral region measured at the tip of the chest (pectus): distance from the joint with the drumstick to the cushion and metatarsal.
- Tarsus length (LT): length of the tarsus from the joint with the drumstick to the dewclaw on each leg.
- Tarsus diameter (DT): measurement of the circumference of the tarsus

- Comb height (HCr): height of the crest from its tip to its base
- Length of the comb (LCr): length along the crest.
- Barbillon height (HB): vertical measurement of the barbillon

### 1.3. Barymetric study

An equation for predicting the live weight of local breed chickens based on measurement variables is designed using a linear regression method. The target models are multiple linear equations according to the following general formula:

$$PV = a + b_1LC + b_2TP + b_3CLou + b_4ENV + b_5LT + b_6DT + b_7HCr + b_8LCr + b_9HB \quad (1)$$

According to (1), PV, the live weight of the chicken, is the variable to be explained. The variables body length (LC), chest circumference (TP), neck length (Lcou), wingspan (ENV), tarsus length and tarsus diameter of the poultry in millimetres, such as comb height (HCr), comb length (LCr) and wattle height (HB), are the explanatory variables. Multiple linear regression remains one of the most commonly used and robust statistical methods for estimating live body weight from biometric traits in poultry (Liswaniso et al., 2025). The constants (bi)<sub>i</sub> are the significance coefficients of the explanatory variables. They are associated with p-values, calculated using the regression table. "a" is an initial condition constant (Dagnelie, 1970 cited by Randriamandratondrakotonirina, 2019 and Hantanirinina, 2010).

In this study, the variables are classified and then introduced into the model equation according to their level of correlation with the variable to be explained. The process continues until all variables have been introduced. This type of model makes it possible to predict the weight of the chicken during an observation period of the farm (Randriamandratondrakotonirina et al., 2016). Similar stepwise and progressive regression strategies have been successfully applied in recent poultry barymetric studies (Bekele et al., 2021; Liswaniso et al., 2025)

The reliability of the model's prediction depends on the following statistical indicators:

- The critical probability "p" or p-value

The residual variance is evaluated in relation to this critical probability "p". A low residual variance, explained by regression, which is related to the estimation error, is , resulting in a "p" value of less than 0.05 (Dagnelie, 1975). Therefore, the smaller "p" is, the more reliable and acceptable the model is. if "p" is greater than 0.05, the model is not reliable because the residual variance (variance of errors) represents a significant portion of the total variance (Randriamandratondrakotonirina, 2019).

- The coefficient of determination  $R^2$

This is the ratio of the variation explained by the model to the total variation (Dagnelie, 1975; Confais and Le Guen, 2006). The model is significant in showing the correlation between the

explained variable and the explanatory variable(s) (Tomassone, 1989). The model is reliable if  $R^2$  is close to 1. In the R software, the coefficient of determination  $R^2$  is called Multiple R-squared. It is expressed by the formula (Guyader, 2012):

$$R^2 = 1 - \frac{SCR}{SCT} \quad (2)$$

- The adjusted coefficient of determination (adjusted  $R^2$ )

Unlike  $R^2$ , adjusted  $R^2$  takes into account the degree of saturation of the model in explanatory variables (Randriamandratondrakotonirina, 2019). Compared to the number of explanatory variables,  $R^2$  tends to increase, so adjusted  $R^2$  is a more effective indicator. A better equation has an adjusted  $R^2$  close to 1. Adjusted  $R^2$  allows us to identify the appropriate number of parameters up to which a model can be saturated. Adjusted  $R^2$  stabilises at a certain value, i.e. when the number of parameters is sufficient to constitute the model. In the R software, the adjusted  $R^2$  coefficient is called Adjusted R-Squared. It is expressed by the formula (Guyader, 2012):

$$R^2_{\text{adjusted}} = 1 - \frac{(n-1)}{n-k-1} (1 - R^2) \quad (3)$$

- The residual standard deviation or ETR.

This is the root of the means of the squares of the residual deviations. It is expressed using the same unit as the dependent variable. In our case, this is the live weight of the chickens, and it represents the average value of the estimation error of this variable by the model. The model is more reliable if its RSE is low.

- The residual coefficient of variation (RCV), expressed as a percentage of BW. This is a translation of the ETR in relation to the average live weight (Confais and Le Guen, 2006). It supplements the information provided by ETR. For animals with an average weight of 1400 g, an average estimation error of  $ETR=258$  g for a given barometric model is equivalent to a CVR of 18%, i.e. an 18% error relative to the average weight. The equation is more reliable when the RCV is small. The residual coefficient of variation is expressed by the formula (Randriamandratondrakotonirina, 2019; Guyader, 2012; Confais and Le Guen, 2006)

$$CVR = \frac{ETR}{MR} \times 100 \quad (4)$$

For practical purposes, it is easier to use the results table from the R software. Each explanatory variable in the model is associated with a significance hypothesis of a p-value. Thus, a p-value of less than 0.05 allows us to reject the hypothesis of non-significance of the coefficient, i.e. to accept the relevance of the associated explanatory variable. Variables in the weight prediction model equation with a p-value greater than 0.05 can be assumed to be ineffective. They can be pruned after correlation analysis. The remaining variables will be further evaluated by their p-

values until the model is relevant, i.e. with a better adjusted  $R^2$ . It should be noted that it is always useful to look at the evolution of the coefficient of determination ( $R^2$ ), the stability of the adjusted  $R^2$ , which allows the number of variables that is adequate and sufficient for the model to be found, and the evolution of the residual standard deviation (ETR) as a function of the number of variables introduced (Randriamandratondrakotonirina, 2019). In this study, the progressive regression method is used. It is effective when the number of explanatory variables is quite high (Dagnelie, 1970). Numerous methods are currently being developed to deal with this type of problem, such as PLS regression, with increasingly powerful software. These will be the subject of our future work.

This study adopts a quantitative empirical approach based on biometric measurements. The choice of barymetric modeling is justified by its relevance for estimating live weight in rural poultry systems where access to weighing equipment is limited.

#### **1.4. Data processing equipment**

The data are processed using R software version 3.5.0. The multiple regression model was obtained using the `lm` function in R (Heumann and Shalabh, 2016; Heiberger and Holland, 2015). However, Microsoft Excel 2013 Xlstat software version 2018 was used to produce a simplified result after processing. All statistical results are interpreted at a significance level of  $\alpha = 0.05$ .

## **2. Results**

According to Pearson's correlation matrix, the ranking of variables in relation to their interrelationships with weight (greater  $r$ ) is as follows: chest circumference (TP), body length (LC), wingspan (ENV), neck length (Lcou), barbell height (HB), comb height (HCr), tarsus diameter (DT), comb length (LCr) and tarsus length (LT), with respective correlation coefficients  $r$ : 0.864; 0.852; 0.846; 0.804; 0.772; 0.752; 0.735; 0.718; 0.326. The prioritisation of measurement variables in the construction of the prediction model depends on their correlation with live weight.

### **2.1. Prediction equation for the live weight of the total local chicken population based on measurement variables**

Among the 9 measurement variables for the total population, the chest circumference (CC) parameter is introduced first to determine the weight prediction model equation. It has the strongest correlation coefficient with weight ( $r=0.864$ ). The others are then added one by one in descending order of correlation coefficient. The value of the coefficient of determination  $R^2$  obtained by the first parameter (TP) is 0.746.

**Table N°1: Equations for predicting the live weight of the total local chicken population**

N F	Var	Model equations	R <sup>2</sup>	R <sup>2</sup> aj ETR	Pr>F	CV
1	TP	PV = 213.16 + 75.14*TP	0.746	0.746396.85	<0.0001	0.40
2	TP, LC	PV = -265.60 + 35.63*LC + 50.03*TP	0.754	0.753391.05	<0.0001	0.23
3	TP, LC, ENV	PV = -678.53 + 63.46*LC - 55.39*ENV + 89.47*TP	+0.763	0.763383.68	<0.0001	0.42
4	TP, LC, ENV, Lcou	PV = -1503.25*LC - 60.16*ENV + 76.76*TP + 107.29*Lcou	0.785	0.784366.18	<0.0001	0.16
5	TP, LC, ENV, Lcou, HB	PV = -1156.17 + 61.76*LC + 63.55*ENV + 76.53*TP + 72.54*Lcou + 29.96*HB	-0.789	0.788362.56	<0.0001	0.82
6	TP, LC, ENV, Lcou, HB, HCr	PV = -1073.96 + 61.01*LC + 63.19*ENV + 76.71*TP + 64.68*Lcou + 6.35*HCr + 26.93*HB	-0.789	0.788362.57	<0.0001	0.78
7	TP, LC, ENV, Lcou, HB, HCr, DT	PV = -1245.84 + 60.95*LC + 64.27*ENV + 75.35*TP + 65.90*Lcou + 3.42*HCr + 22.87*HB + 56.49*DT	-0.791	0.789361.47	0.0001	0.22
8	TP, LC, ENV, Lcou, HCr, HB, DT, LCr	PV = -1258.78 + 60.72*LC + 64.11*ENV + 75.22*TP + 67.71*Lcou + 4.08*HCr - 0.67*LCr + 22.81*HB + 57.35*DT	-0.791	0.789361.66	0.0001	0.61
9	TP, LC, ENV, Lcou, HB, HCr, DT, LCr, LT	PV = -1229.37 + 61.13*LC + 64.09*ENV + 74.20*TP + 69.80*Lcou - 5.98E02*LCr + 4.02*HCr - 5.98E02*LCr + 22.57*HB + 59.82*DT	-0.791	0.789361.82	<0.0001	0.14

Source: Author, based on statistical analysis

R<sup>2</sup> improves by 0.008 points and the residual standard deviation decreases by 5.45g, or 0.28% of the average weight, by adding the body length (LC) variable. The introduction of the third variable, wingspan (ENV), contributes to an improvement in R<sup>2</sup> of 0.009 and the residual

standard deviation is reduced from 391.05 to 383.68, or 7.19g. This improvement in the coefficient of determination continues by 0.022 and 0.004 when adding the fourth and fifth variables (neck length (Lcou) and barbell height (HB)), respectively, and the residual standard deviation also continues to decrease. The equation is no longer interesting from the fifth parameter onwards, as  $R^2$  remains stable and does not change until the ninth variable. Thus, the best equation for predicting the weight of the total population of local breed chickens on the east coast of Madagascar is the one formed by four variables: chest circumference (TP), body length (LC), wingspan (ENV) and neck length (Lcou), hence the equation:

$$PV = -1503.25*LC - 60.16*ENV + 76.76*TP + 107.29*Lcou \quad (n=902; R^2 = 0.785; R^2_{aj} = 0.784; ETR = 366.18; CV = 16\%; p < 0.0001).$$

## 2.2. Determination of weight prediction equation according to sex of local chicken based on measurement variables

### 2.2.1. Prediction equation for female chickens

As with the total population, the chest circumference (TP) variable, with  $r = 0.904$ , is the first to be introduced into the equation to predict weight. The value of the coefficient of determination  $R^2$  obtained by this first parameter is 0.818 with a residual standard deviation of 245.49.

**Table N°2: Prediction equations for the live weight of female chickens**

N F	Var	Model equations	$R^2$	$R^2_{aj}$	ETR	Pr>F	CV
1	TP	$PV = 245.85 + 76.37*TP$	0.818	0.817	245.49	<0.0001	0.38
2	TP, ENV	$PV = 267.38 + 17.42*ENV + 57.49*TP$	0.819	0.818	244.82	<0.0001	0.41
3	TP, ENV, LC	$PV = -43.97 + 22.45*LC - 4.81*ENV + 64.75*TP$	+0.821	0.820	243.31	<0.0001	0.20
4	TP, ENV, LC, DT	$PV = -912.50 + 14.36*LC - 9.69*ENV + 54.68*TP + 342.56*DT$	+0.850	0.849	223.20	<0.0001	0.13
5	TP, ENV, LC, DT, Lcou	$PV = -896.02 + 14.38*LC - 9.59*ENV + 54.64*TP - 2.26*Lcou + 344.20*DT$	+0.850	0.849	223.40	<0.0001	0.06
6	TP, ENV, LC, DT, Lcou, HB	$PV = -1293.41 + 8.87*LC + 1.37*ENV + 51.73*TP + 31.95*Lcou - 50.91*HB + 380.51*DT$	+0.861	0.859	215.24	<0.0001	0.77

- 
- 7 TP, ENV, PV = -1266.37 + 18.41\*LC - 2.10\*ENV + 0.864 0.863 212.83 <0.0001 0.52  
LC, DT, 50.91\*TP +  
Lcou, 18.44\*Lcou - 26.59\*HCr - 45.58\*HB +  
HB, HCr 384.61\*DT
- 
- 8 TP, ENV, PV = -296.18 + 11.21\*LC - 5.09\*ENV + 0.881 0.880 199.19 <0.0001 0.17  
LC, DT, 71.21\*TP - 109.50\*Lcou - 20.65\*HCr +  
Lcou, 65.29\*LCr - 25.29\*HB +  
HB, HCr, 287.57\*DT  
LCr
- 
- 9 TP, ENV, PV = -322.69 + 9.18\*LC - 4.82\*ENV + 0.883 0.881 198.32 <0.0001 0.12  
LC, DT, 77.65\*TP - 125.39\*Lcou + 30.84\*LT -  
Lcou, 21.57\*HCr + 53.25\*LCr -  
HB, HCr, 27.14\*HB + 273.68\*DT  
LCr, LT
- 

Source: Author, based on statistical analysis

The coefficient of determination  $R^2$  increases by 0.001; 0.002 and 0.029; by adding respectively wingspan (ENV) for 2 variables, body length (LC) for 3 variables and tarsus diameter for 4 variables, where the increase is maximal. The decrease in residual standard deviation is also significant for the 4-variable equation with 20.11g. It is no longer worthwhile to continue predicting chicken weight using a model with more than 4 variables. Hence, the best equation for predicting the live weight of female chickens is

$$PV = -912.50 + 14.36*LC - 9.69*ENV + 54.68*TP + 342.56*DT \quad (n=589; R^2=0.850; R^2_{adj}=0.849; ETR=223.20; CV= 13\%; p<0.0001)$$

### 2.2.2. Prediction equation for male chickens

Unlike female chickens, the comb length parameter (LCr) has the strongest correlation with live weight, with  $r= 0.877$ . The value of  $R^2$  is 0.770 for the one-parameter model and the residual standard deviation is 398.08. The value of  $R^2$  increases by 0.086 for two variables when adding comb height; by 0.015 with three parameters such as comb length, comb height and neck length; and by 0.039 when introducing the fourth parameter, body length.

**Table N°3: Prediction equations for the live weight of male chickens**

NF	Var	Model equations	R2	R <sup>2</sup> aj	ETR	Pr>F	CV
1	LCr	$PV = -350.27 + 102.85*LCr$	0.770	0.769	398.08	<0.0001	0.26
2	LCr, HCr	$PV = -318.38 + 106.03*HCr + 60.76*LCr$	0.856	0.855	314.68	<0.0001	0.34
3	LCr, HCr, LCo	$PV = -1264.73 + 97.60*LCou + 85.10*HCr + 52.41*LCr$	0.871	0.870	298.33	<0.0001	0.12
4	LCr, HCr, LCo, LC	$PV = -2434.99 + 61.14*LC + 54.43*Lcou + 79.41*HCr + 40.54*LCr$	0.910	0.909	249.87	<0.0001	0.11
5	LCr, HCr, LCo, LC, TP	$PV = -2140.85 + 37.31*LC + 24.53*TP + 43.17*Lcou + 79.35*HCr + 38.53*LCr$	0.917	0.916	239.89	<0.0001	0.17
6	LCr, HCr, LCo, LC, TP, ENV	$PV = -2140.07 + 31.57*LC + 13.81*ENV + 16.23*TP + 43.70*Lcou + 79.81*HCr + 38.29*LCr$	0.918	0.917	239.09	<0.0001	0.15
7	LCr, HCr, LCo, LC, TP, ENV, HB	$PV = -2170.02 + 33.12*LC + 16.65*ENV + 15.16*TP + 35.57*Lcou + 59.20*HCr + 36.02*LCr + 38.05*HB$	0.926	0.925	227.24	<0.0001	0.38
8	LCr, HCr, LCo, LC, TP, ENV, HB, LT	$PV = -1931.57 + 33.96*LC + 16.93*ENV + 13.78*TP + 37.47*Lcou - 26.91*LT + 63.17*HCr + 36.64*LCr + 37.35*HB$	0.927	0.925	226.22	<0.0001	0.10
9	LCr, HCr, LCo, LC, TP, ENV, HB, LT, DT	$PV = -1773.03 + 33.13*LC + 17.65*ENV + 15.49*TP + 27.56*Lcou - 18.58*LT + 65.98*HCr + 38.11*LCr + 40.39*HB - 48.43*DT$	0.929	0.927	223.23	<0.0001	0.19

Source: Author, based on statistical analysis

As soon as the second variable is introduced, the reduction in residual standard deviation is exceptional, falling from 398.08 to 314.68, giving 83.4g. In fact, for cocks, the best equation for predicting live weight is:

$PV = -318.38 + 106.03*HCr + 60.76*LCr$  (n= 313; R<sup>2</sup> =0.856; R<sup>2</sup> aj=0.855 ; ETR= 314.68; CV= 34.28% ; p<0.0001).

### 2.3. Determination of weight prediction equation according to rural municipalities

#### 2.3.1. Prediction equation for the live weight of local chickens in the municipality of Ambodimanga II

For chickens in the rural municipality of Ambodimanga II, comb height (HCr) has a strong correlation with the live weight of the animal ( $r=0.850$ ). The coefficient of determination and residual standard deviation of the weight prediction model by HCr are 0.722 and 399.94, respectively. By introducing the second variable, chest circumference (TP),  $R^2$  improves by 0.051 points and the residual standard deviation decreases by 37.63 g.

**Table N°4: Weight prediction equations in the rural commune of Ambodimanga II**

NF	Var	Model equations	$R^2$	$R^2$ aj	ETR	Pr>F	CV
1	HCr	$PV = 1027.49 + 144.05 \cdot HCr$	0.722	0.721	399.94	<0.0001	0.72
2	HCr, TP	$PV = 580.95 + 38.24 \cdot TP + 78.37 \cdot HCr$	0.773	0.771	362.31	<0.0001	0.40
3	HCr, TP, Lcou	$PV = -181.25 + 29.22 \cdot TP + 89.85 \cdot Lcou + 56.49 \cdot HCr$	+0.782	0.779	355.84	<0.0001	0.17
4	HCr, TP, Lcou, LC	$PV = -706.41 + 36.09 \cdot LC + 2.24 \cdot TP + 95.04 \cdot Lcou + 57.42 \cdot HCr$	+0.788	0.785	351.29	<0.0001	0.22
5	HCr, TP, Lcou, LC, ENV	$PV = -1233.59 + 69.31 \cdot LC - 69.72 \cdot ENV + 52.37 \cdot TP + 96.99 \cdot Lcou + 61.77 \cdot HCr$	0.802	0.798	340.49	<0.0001	0.42
6	HCr, TP, Lcou, LC, ENV, LCr	$PV = -1184.16 + 73.41 \cdot LC - 73.95 \cdot ENV + 52.24 \cdot TP + 84.58 \cdot Lcou + 57.52 \cdot HCr + 6.37 \cdot LCr$	0.803	0.797	340.63	<0.0001	0.58
7	HCr, TP, Lcou, LC, ENV, LCr, HB	$PV = -1167.13 + 73.38 \cdot LC - 74.10 \cdot ENV + 52.36 \cdot TP + 83.12 \cdot Lcou + 55.95 \cdot HCr + 6.03 \cdot LCr + 3.95 \cdot HB$	0.803	0.797	341.36	<0.0001	0.81
8	HCr, TP, Lcou, LC, ENV, LCr, HB, LT	$PV = -2198.51 + 75.96 \cdot LC - 71.58 \cdot ENV + 46.55 \cdot TP + 79.76 \cdot Lcou + 107.94 \cdot LT + 47.13 \cdot HCr + 2.88 \cdot LCr + 4.95 \cdot HB$	0.810	0.803	335.85	<0.0001	0.089
9	HCr, TP, Lcou, LC, ENV, LCr, HB, LT	$PV = -2326.71 + 76.97 \cdot LC - 72.51 \cdot ENV + 44.41 \cdot TP + 88.04 \cdot Lcou + 101.44 \cdot LT +$	0.811	0.803	336.07	<0.0001	0.21

$$\text{Lcou, LC, } 46.12 \cdot \text{HCr} + 1.84 \cdot \text{LCr} + 3.07 \cdot \text{HB} + \text{ENV, LCr, } 38.39 \cdot \text{DT}$$

$$\text{HB, LT,}$$

Source: Author, based on statistical analysis

Beyond these two variables, no equation is of interest because there is no significant increase in R<sup>2</sup>. Therefore, for the municipality of Ambodimanga II, the most reliable equation for predicting the live weight of chickens of the local breed is

$$\text{PV} = 580.95 + 38.24 \cdot \text{TP} + 78.37 \cdot \text{HCr} \quad (n=228; R^2=0.773; R^2_{aj}=0.771; \text{ETR}=362.31; \text{CV}=40\%; p<0.0001).$$

### 2.3.2. Prediction equation for the live weight of local chickens in the municipality of Mahambo

For chickens in the rural commune of Mahambo, the parameter with the strongest correlation coefficient with weight is chest circumference (TP) with  $r=0.766$ . The coefficient of determination and residual standard deviation of the weight prediction model by TP are 0.784 and 392.19, respectively.

**Table N°5: Weight prediction equations in the rural commune of Mahambo**

NF	Var	Model equations	R <sup>2</sup>	R <sup>2</sup> <sub>aj</sub>	ETR	Pr>F	CV
1	TP	$\text{PV} = 100.81 + 79.33 \cdot \text{TP}$	0.781	0.780	392.19	<0.0001	0.46
2	TP, LC	$\text{PV} = -486.72 + 45.93 \cdot \text{LC} + 46.22 \cdot \text{TP}$	0.791	0.790	382.99	<0.0001	0.24
3	TP, LC, ENV	$\text{PV} = -795.24 + 67.19 \cdot \text{LC} - 42.14 \cdot \text{ENV} + 75.77 \cdot \text{TP}$	0.796	0.794	379.32	<0.0001	0.45
4	TP, ENV, Lcou	$\text{PV} = -1365.35 + 60.85 \cdot \text{LC} - 46.02 \cdot \text{ENV} + 71.05 \cdot \text{TP} + 79.04 \cdot \text{Lcou}$	0.806	0.803	370.78	<0.0001	0.16
5	TP, ENV, Lcou, HB	$\text{PV} = -1072.67 + 60.21 \cdot \text{LC} - 47.45 \cdot \text{ENV} + 71.34 \cdot \text{TP} + 50.75 \cdot \text{Lcou} + 21.42 \cdot \text{HB}$	0.808	0.805	369.44	<0.0001	0.87
6	TP, ENV, Lcou, HB, DT	$\text{PV} = -1129.47 + 58.6 \cdot \text{LC} - 46.31 \cdot \text{ENV} + 69.92 \cdot \text{TP} + 49.43 \cdot \text{Lcou} + 17.93 \cdot \text{HB} + 31.83 \cdot \text{DT}$	0.808	0.805	369.57	<0.0001	0.23

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7	$TP, LC, PV = -1214.80 + 59.58*LC - 47.35*ENV + 0.808$ $ENV, 69.98*TP + 56.65*Lcou - 5.32*HCr +$ $Lcou, HB, 20.32*HB +$ $DT, HCr 34.18*DT$	0.804 0.804 369.95 <0.0001 0.87
<hr/>		
8	$TP, LC, PV = -1097.43 + 60.68*LC - 47.80*ENV + 0.809$ $ENV, 70.93*TP + 41.71*Lcou - 10.83*HCr +$ $Lcou, HB, 5.20*LCr +$ $DT, HCr, 21.17*HB + 26.65*DT$ $LCr$	0.804 0.804 370.04 <0.0001 0.64
<hr/>		
9	$TP, LC, PV = -1115.87 + 60.60*LC - 47.92*ENV + 0.809$ $ENV, 71.52*TP + 40.54*Lcou + 3.46*LT -$ $Lcou, HB, 10.72*HCr +$ $DT, HCr, 4.82*LCr + 21.34*HB + 24.87*DT$ $LCr, LT$	0.804 0.804 370.55 <0.0001 0.14

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Source: Author, based on statistical analysis

By introducing the second variable, body length (LC),  $R^2$  improves by 0.01 points and the residual standard deviation decreases by 9.2 g. None of the following equations have a better  $R^2$  and residual standard deviation than the one composed of two variables. Therefore, for chickens in the rural commune of Mahambo, the equation for predicting their weight is:

$PV = - 486.72 + 45.93*LC + 46.22*TP$  (n=363;  $R^2 = 0.791$ ;  $R^2_{aj} = 0.790$ ; ETR=382.99; CV=24%;  $p < 0.0001$ ).

### 2.3.3. Equation for predicting the live weight of local chickens in the municipality of Ampasimbe Manantsatrana

Chest circumference is the first variable introduced to compose the equation for predicting the weight of chickens in the rural commune of Ampasimbe Manantsatrana with  $r = 0.848$ . The coefficient of determination  $R^2$  of the equation is 0.719 and the standard deviation is 395.37.

**Table N°6: Equation for predicting weight in the commune of Ampasimbe Manantsatrana**

NF	Var	Model equations	R2	R <sup>2</sup> aj	ETR	Pr>F	CV
1	TP	$PV = 298.31 + 71.63*TP$	0.719	0.718	395.37	<0.0001	0.38
2	TP, LC	$PV = -95.04 + 27.47*LC + 53.03*TP$	0.725	0.723	391.86	<0.0001	0.21
3	TP, LC, ENV	$PV = -612.03 + 63.03*LC - 69.36*ENV + 101.58*TP$	+0.744	0.742	378.53	<0.0001	0.38
4	TP, ENV, Lcou	$PV = -1387.04 + 59.12*LC - 0.770 - 70.23*ENV + 86.02*TP + 104.82*Lcou$		0.767	359.72	<0.0001	0.16
5	TP, ENV, Lcou, HB	$PV = -1041.54 + 61.21*LC - 74.73*ENV + 84.6*TP + 69.95*Lcou + 34.45*HB$	0.778	0.774	354.28	<0.0001	0.77
6	TP, ENV, Lcou, HB, HCr	$PV = -990.19 + 60.94*LC - 74.81*ENV + 84.87*TP + 64.79*Lcou + 3.83*HCr + 33.03*HB$	0.778	0.773	354.79	<0.0001	0.73
7	TP, ENV, Lcou, HB, HCr, DT	$PV = -1273.25 + 63.04*LC - 80.48*ENV + 86.05*TP + 59.28*Lcou - 1.43*HCr + 26.58*HB + 102.49*DT$	+0.783	0.778	350.68	<0.0001	0.21
8	TP, ENV, Lcou, HB, HCr, DT, LCr	$PV = -1211.62 + 64.62*LC - 81.40*ENV + 86.53*TP + 49.27*Lcou - 4.90*HCr + 3.37*LCr + 27.02*HB + 99.84*DT$	0.784	0.778	351.07	<0.0001	0.60
9	TP, ENV, Lcou, HB, DT, HCr, LCr, LT	$PV = -1124.88 + 67.43*LC - 80.77*ENV + 79.87*TP + 62.55*Lcou - 25.12*LT - 6.41*LCr + 27.18*HB + 106.99*DT$	0.785	0.778	350.79	<0.0001	0.16

Source: Author, based on statistical analysis

Furthermore, it is the equation composed of four variables: chest circumference (TP), body length (LC), wingspan (ENV) and neck length (Lcou) that shows the greatest improvement in

$R^2$  with 0.026 points and a significant decrease in the residual standard deviation of weight of 18.81 g. Thus, the reliable equation for predicting the live weight of native chickens from Ampasimbe Manantsatrana is

$PV = - 1387.04 + 59.12*LC - 70.23*ENV + 86.02*TP + 104.82*Lcou$  (n= 311;  $R^2 = 0.770$ ;  $R^2_{aj} = 0.767$ ; ETR= 359.72; CV= 16%;  $p < 0.0001$ ).

### 3. Discussions and recommendations

#### 3.1. Barymetric formula for the total chicken population on the east coast of Madagascar

The nine measurement parameters are used in the equation to predict the live weight of local breed chickens on the east coast of Madagascar. Chest circumference (TP) was used primarily because it is the variable most closely correlated with weight. This method of introducing an animal's chest circumference first for barometry is frequently used in various studies, particularly in rabbits in central Madagascar (Randriamandrakotonirina et al., 2016b), a study of barymetrics in local cattle breeds in Côte d'Ivoire (Poivey *et al.*, 1980), and in Senegal in sheep and cattle (Fall *et al.*, 1982). Furthermore, this is confirmed by the definition stating that barymetry is an estimate of an animal's live weight based on a prediction equation including measurements, particularly chest circumference (Jussiau and Papet, 2015). The model for predicting the weight of the total chicken population using only chest circumference (TP) had a coefficient of determination ( $R^2_{adjusted} = 0.746$ ) that was still far from the reference value of 1 (Randriamandrakotonirina et al., 2016b). Therefore, the introduction of the second variable enriched the information obtained by the equation. The model provided by two variables is always more reliable than one (Landais, 1983). The most important live weight prediction model is the one composed of four variables: chest circumference (TP), body length (LC), wingspan (ENV), and neck length (Lcou). The adjusted  $R^2$  value of this 4 parameter equation is very high at 0.784. Comparable levels of predictive accuracy have been reported for local chicken populations in Ethiopia and Zambia using similar morphometric combinations (Bekele et al., 2021; Liswaniso et al., 2025). The adjusted  $R^2$  value is the main criterion for the reliability of the predictive equation. For the total chicken population, the average values of the live weight and chest circumference variables are  $1906.97 \pm 787.43$  g and  $22.54 \pm 9.05$  cm, respectively. Let us solve the equation for predicting live weight using the average value for chest circumference and compare the result. The equation is  $PV = 213.16 + 75.14*TP = 213.16 + 75.17*(31.59) = 2586.83$  g. The result of this equation more or less coincides with the average live weight value mentioned above ( $1906.97 + 787.43 = 2694.4$ g). Thus, farmers, particularly

those in the Fénérive-Est District, who never weigh their chickens, can estimate the live weight of their poultry by simply measuring their chest circumference.

### 3.2. Barymetric formula according to the sex of indigenous chickens

The equation for predicting the highest live weight in female chickens is composed of four variables: chest circumference (TP), body length (LC), wingspan (ENV) and tarsus diameter (DT), while that for roosters consists of only two variables: comb height (HCr) and comb length (LCr). Sexual dimorphism affecting morphometric predictors of live weight has also been documented in recent poultry studies, where males show stronger associations with secondary sexual traits (Bekele et al., 2021). In fact, the prediction model for roosters suggests that it is possible to identify the animal based on the quantitative characteristics of their combs. These are more developed in male chickens of the local breed than in females. In chickens, certain genes do not have the same effect depending on sex, particularly in the case of the comb. The *Gallus gallus* rooster has a simple, straight, serrated comb on the upper front part of its head, while the female has a small, straight comb (Coquerelle, 2000). Despite this, the adjusted  $R^2$  value of the male chicken model is higher than that of the female model: 0.855 versus 0.849. The regression equation for male chickens is therefore more reliable and better than that for female chickens for predicting live weight. This further confirms the sexual dimorphism in favour of males of the local chicken breed on the east coast of Madagascar. This result confirms those of Akouango and his colleagues, who reported that the regression coefficient is higher in adult male than female Ndama cattle in Congo Brazzaville, but differs from that of rabbits in the Amoron'i Mania region, where there is dimorphism in favour of females (Akouango *et al.*, 2010; Randriamandrakotonirina *et al.*, 2016b).

### 3.3. Barymetric formula according to the study area

For the study area, there are several differences in the barymetric formula, both in terms of the adjusted coefficient of determination ( $R^2$  adjusted) and the number and characteristics of the parameters that constitute it. The rural commune of Mahambo has the best adjusted  $R^2$  value, which is significantly higher (adjusted  $R^2= 0.791$ ) than those of the other two communes, Ambodimanga II (adjusted  $R^2= 0.771$ ) and Ampasimbe Manantsatrana (adjusted  $R^2= 0.767$ ). The equation for predicting the live weight of Mahambo chickens is composed of two linear measurement variables, chest circumference (TP) and body length (LC), while that of Ambodimanga II is composed of chest circumference (TP) and comb height (HCr), and that for Ampasimbe Manantsatrana is formed by four variables: chest circumference (TP), body length (LC), wingspan (ENV) and neck length (LCou). Such spatial variability in barymetric models has also been observed in recent studies on local poultry populations raised under

heterogeneous agro-ecological conditions (Bekele et al., 2021). Solving these equations using the maximum average value for each variable gives the following results:

**Table N°7 : Comparison of the average live weight value by solving the prediction equation in each rural municipality**

CR	Prediction equation	Value of variables					PVm (maximum average value)	PVc
		TP	LC	ENV	Lcou	HCr		
<b>Mah</b>	PV = -486.72 + 45.93*LC + 46.22*TP	18.04±7.52 (25.56)	25.72±5.73 (31.45)				1578.47±665.44 (2,243.91)	2139.16
<b>Amb</b>	PV=580.95 38.24*TP + 78.37*HCr	+15.88±4.34 (20.22)				3.05±1.30 (4.35)	1526.29±374.25 (1900.54)	1695.07
<b>Amp</b>	PV = - 1387.04 + 59.12*LC 70.23*ENV + 86.02*TP + 104.82*Lcou	18.9±6.90 (25.8)	27.17±5.45 (32.62)	19.45±7.63 (27.08)	10.99±0.72 (11.71)		1703.95±543.63 (2,247.58)	2086.38

Source: Author

Thus, according to Table N°7, the resolution with the smallest difference between the average live weight and the calculated live weight is minimal for the equation for the Mahambo commune (104.75) compared to those for Ambodimanga II (205.47) and Ampasimbe Manantsatrana (161.2). This confirms that the best model for predicting the weight of local breed chickens in the Fénériver-Est District is that of the Mahambo commune:  $PV = - 486.72 + 45.93*LC + 46.22*TP$ . In addition, a barymetric equation estimated by chest circumference is highly recommended (Jussiau and Papet, 2015). Polynomial regression of weight on chest circumference is highly recommended to obtain the most accurate predictive equation (Dodo *et al.*, 2001). Furthermore, this equation is the easiest for farmers in rural areas to use, as it is more practical to take linear measurements of chickens (body length and chest circumference). The equation of a series of regression lines is preferable for adult animals (Johansson *et al.*, 1954 cited by Randriamandratondrakotonirina *et al.*, 2016b).

## Conclusion

In conclusion, this study was based on an application of linear regression in characterising the growth and predicting the weight of local chicken breeds on the east coast of Madagascar. Growth is a physiological phenomenon of great zootechnical interest. Indeed, the size-weight relationship (between live weight (PV) and body length (LC)) of indigenous chickens on the east coast of Madagascar, obtained by logarithmic resolution of the equation  $PV = aLC^b$ , revealed that these birds have minor allometric growth with a value of  $b$  generally less than 3. Chickens of the local breed in the District of Fénérive-Est grow mainly in length rather than live weight. Although the nature of growth as a whole is similar, it is always variable depending on age, individual, sex, ecological conditions, feeding behaviour, breeding practices and animal health. Furthermore, sexual dimorphism in favour of males has always been observed. The second part of this study dealt with barymetrics, which consists of finding an equation to predict weight based on measurement variables and the approximate age of the chicken. Thus, the chest circumference (TP) variable was primarily used in this weight prediction. However, a single variable did not provide a significantly reliable model, hence the coefficients of determination ( $R^2$  and  $R^2$  adjusted) become increasingly important as the parameters are gradually introduced into the weight prediction equation. For practical reasons, the author chose the model for predicting the live weight of chickens of the local breed in the municipality of Mahambo:  $PV = -486.72 + 45.93*LC + 46.22*TP$ , based on chest circumference (TP) in cm and body length (LC) in cm, as the explanatory variables are easy for farmers to measure and the accuracy obtained is acceptable. By simply solving this equation, the live weight value obtained is approximately the same as that of the average weight. In addition, more than 79% of the variation was explained by this model. However, the equation for predicting the live weight of local chickens by age also made it possible to obtain a model that explained between 50 and 60% of the variation. This model, obtained from the approximate age, is not very robust. It is therefore essential to develop an adequate method for determining the precise age of the animal. These results verify the two hypotheses of this study, which claim that the growth of local breed chickens follows a biological, physiological and ecological logic and that at least two measurement variables can be used to obtain a significant and reliable model for predicting chicken live weight. The knowledge gained from this research can help traditional poultry farmers, especially smallholders, to manage their poultry farms effectively in physiological (feed rations, animal health care, breeding equipment, etc.) and technical terms. Better chicken growth always contributes to greater nutritional, financial and social value for the farmer.



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