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Title: Archaeological and biometric perspectives on the development of chicken landraces in the Horn of Africa

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Abstract

Domestic chickens (*Gallus gallus domesticus* L., 1758) were integrated into agricultural systems in the Horn of Africa as early as the pre-Aksumite period (c. 2,500 years ago), after they were introduced from Asia through land and maritime trade and exchange. In this paper, we explore the development of chicken landraces in this region by examining continuity and change in chicken body size. Specifically, we compare the measurements of chicken bones dating from 800 BCE to 400 BCE from the pre-Aksumite site of Mezber in northern Ethiopia, with those of modern chickens (of known age and sex) from northern Ethiopia and a population of known age and sex cross-bred red junglefowl (*Gallus gallus* L., 1758), curated at the Natural History Museum at Tring (UK). Considered together, these datasets provide insight into African poultry development and offer the first metrical baselines of chickens with known history in the region. Thus, this study has the potential to underpin future studies of domestic fowl morphology in Africa.

Introduction

Since their domestication in Southeast Asia c. 3,500 years ago (Peters, in prep.), chickens (*Gallus gallus domesticus* L., 1758) have become the most widespread livestock on the planet (Lawler, 2016). Transported initially as exotic animals for sport, ritual, and human sustenance (Lawler, 2016; Perry-Gal et al., 2015; Peters et al., 2015; Redding, 2015; Sykes, 2012), chickens were finally integrated into farming systems in the Horn of Africa in the pre-Aksumite period (c. 2,500 years ago), following their introduction to Africa from Asia through land and maritime trade and exchange (Gifford-Gonzalez and Hanotte, 2011; MacDonald and Edwards, 1993; Woldekiros and D'Andrea, 2016). The earliest chicken remains in Africa were recovered from the site of Mezber in the Tigrai region of northern Ethiopia. The site has occupation dating to the Initial (c. cal 1600–900 BCE), Early (c. cal 850–750 BCE), Middle (c. cal 600–400 BCE), and Later (cal 400 BCE–1BCE/CE) Pre-Aksumite periods, with chicken remains present in all but the earliest phases (D'Andrea and Welton, in prep.).

In Africa, as elsewhere, chickens played a significant role in the ancient economy and culture (Mwacharo et al., 2011, 2013; Woldekiros and D'Andrea, 2016). Today, they continue to make a considerable impact on the national GDP of most African countries and provide an important source of protein (in the form of meat and eggs) to small-scale farmers and households (Sonaiya et al., 1999). Although we have a good understanding of the broad origins of African chickens, less is known about the development of landraces in Africa or the way in which they were combined to create new and sustainable agricultural systems. These lacunae are mainly due to preservation biases (e.g. small samples of fragmented bones in the archaeological record) and the close morphological similarity of chickens and local galliforms (e.g. *Francolinus* sp. and *Numidinae*). Apart from MacDonald's (1992) study of the osteomorphological separation of galliforms (*Francolinus* sp., *Numida*, *Guttera*, *Agelastes* sp., and *Gallus gallus domesticus*) in the West African savanna, no modern baseline of known age/sex specimens exists with which to compare chicken bones from African archaeological sites.

This paper lays the foundation for a greater understanding of ancient chicken diversity in Ethiopia. It presents the results of a biometrical analysis of modern chickens, which were analyzed to generate baseline data from chickens of known sex, age, and environmental and cultural context. Importantly, the chickens analyzed here are derived from the same region as the ancient site of Mezber, enabling a direct comparison of past and present populations in Tigrai (Fig. 1). The data form a research platform upon which future studies of African morphotypes can be built. The detailed data collected from the modern chicken bones from Mesert village in Ethiopia are the first of their kind for Africa.

Materials and methods

To examine the selection history and biodiversity of early African chickens, we undertook an osteometric investigation of ancient and modern chickens from northern Ethiopia.

Modern material

Modern local Ethiopian chickens were collected from Mesert village in Enderta district (Tigrai region, northern Ethiopia) (Fig. 1). Enderta district covers 3,175 square kilometers and has a population density of 36 persons per square kilometer (CSA, 2007, 2011). The village is located at an altitude of 2,296 meters above sea level and has an annual temperature of 22 degrees Celsius and an annual rainfall of 510 to 1,530 millimeters (CSA, 2007, 2011). Mesert villagers are small-scale farmers. Culturally, they are considered Tigraian, linked with the ancient

Aksumites of the north Ethiopian highlands. They are predominantly Orthodox Christian and speak Tigrai: a Semitic language spoken by the Tigraians of Ethiopia and southern Eritrea.

The site selection strategy aimed at selecting one location/village that had not been exposed to a recent introduction of “non-native” chickens (i.e. imported Western stock), but had a high concentration of chicken landraces that were local to the region. Further site selection criteria necessitated the selection of a region near ancient trade routes through which faunal exchanges had occurred (Fig. 1) and where archaeological sites had produced ancient chicken specimens. The selected village is located near a major ancient Aksumite long-distance trade route running north–south, passing through major Aksumite and pre-Aksumite sites and connecting the north Ethiopian highlands to Adulis (Harrower and D’Andrea, 2014)—a major pre-Aksumite and Aksumite port on the Red Sea.

The skeletons of 25 local Ethiopian chickens were used for this study. Adult (i.e. skeletally mature) chickens were used, to avoid age biases. The chickens—12 male and 13 female—were acquired from the meals of 20 local farm households that had been consumed between December 27 and December 30, 2016. Ethnographic interviews of the farmers—conducted by one of the authors (HW)—revealed that the chickens had not only been fed, but they had also scavenged food from their surroundings. The study also provided the approximate age of the chickens, in months and weeks, revealing that the chickens had hatched between 2013 and 2014 (Table S1). The skeletons were prepared on site, following zooarchaeological protocols (e.g. Davis and Payne, 1992). The cleaned skeletons are currently in storage at the ARCCH osteology laboratory in Addis Ababa, Ethiopia. Prior to slaughter, the following data were collected: height, wing span, eye color, plumage color, shank color, and live weight. Carcass weight was also taken after slaughter, permitting an exploration of the relationship between bone measurements and body mass.

Six skeletally mature cross-bred modern red junglefowl (*Gallus gallus* L., 1758) (*n*=6), curated at the Natural History Museum at Tring (for details of this collection, see Foster, 2018; Roberts, 2014; Thomas et al., 2016), provided a comparative dataset (Table S2), facilitating a comparison of modern and ancient Ethiopian chickens to wild morphotypes.

Archaeological material

The archaeological data were derived from the pre-Aksumite site of Mezber, in the Tigrai region of the north Ethiopian highlands (Woldekiros and D'Andrea, 2016). The pre-Aksumites were an agrarian society, representing one of the earliest farming communities within the Horn of Africa (D'Andrea, 2008; Harrower et al., 2010; Phillipson, 2012). Archaeological sites associated with pre-Aksumite culture are found in both the north Ethiopian and Eritrean highlands (Fattovich, 1990; Phillipson, 2012). Fowl bones made up 3% of the fauna recovered from Mezber, and included specimens from 42 domesticated chickens (*Gallus gallus domesticus*), 5 cf. *G. gallus*, 14 *Francolinus* sp., 8 cf. *Francolinus*, and 132 Aves indeterminate (Woldekiros and D'Andrea, 2016). The chicken samples were collected from a pre-Aksumite stratigraphic context dating cal. 921–801 BCE. Of the domestic chicken bones, 16 were measurable and are discussed in this article. As indicated in Table 2, the humerus-Bd, radius-Bd, coracoid-GL, carpometacarpus-GL and -BP, tibiotarsus-GL, -Dip, -Dd, and –BD, and tarsometatarsus-GL, -Bp, and -Bd (after von den Driesch, 1976) provided useful comparisons with modern chicken bones from Mesert village.

Chicken bones were separated from closely related galliforms using modern reference samples from the region and the History of Veterinary Medicine and Institute of Palaeoanatomy in Munich, alongside published criteria (Bocheński and Tomek, 2009; MacDonald, 1992). Detailed information on the archaeological context of the site of Mezber, the fowl bones recovered, the elements identified, and the criteria used to identify them is published in Woldekiros and D'Andrea (2016).

Metrical analyses

Both the ancient and the modern material were measured to the nearest hundredth of a millimeter using digital calipers, following the standards developed by von den Driesch (1976). Measured anatomical parts included: scapulae-GL and –Bp; coracoids-GL; humeri-GL, -Bp, and –Bd; radii-GL and –Bd; ulnae-GL and –Dip; carpometacarpi-GL; femora-GL, -Bp, and –Bd; tibiotarsi-GL, -Dip, -Bd, and –Dd; and tarsometatarsi-GL, -Bp, and -Bd.

Log scaling was employed to maximize the potential of the metrical data and to permit direct comparison of measurements taken in the same anatomical planes. This technique involved converting all measurements to base-10 logarithms by relativizing each against a standard (Albarella, 2002; Meadow, 1999; Simpson et al., 1960, 2003). For this study, the cross-bred junglefowl were used as the standard: we calculated the average measurement for female and male specimens, separately; we then added the measurements together and divided the resulting figure by two. A positive value indicates that the archaeological/modern specimens are larger than the wild standards; a negative value indicates that they are smaller; and a value of zero indicates that the standard and archaeological/modern specimens are comparably sized. For clarity of presentation, the figures (on the x-axes) present the log-scaled values multiplied by 100.

The statistical significance of differences in metrical datasets was tested using the non-parametric Mann-Whitney U-test using PAST (Palaeontological Statistics) (Hammer et al., 2001), in recognition of the fact that the sample sizes were unequal and the data for most phases were not normally distributed.

Results

Summary statistics for the 25 Tigrai chicken skeletons are provided in Table 1; the underpinning raw data are presented in Table 1S. Table 2 compares the range of measurements (males and females combined) with published data from McDonald (1992).

The coefficients of variation for the 25 chickens exhibited a moderate degree of variability. A value greater than six was considered indicative of the presence of two or more morphotypes with different shapes (Simpson et al., 1960, 2003). Within this sample, 9 out of 21 measurements for males and 8 out of 21 measurements for females exceeded this value (Table 1). The elemental distribution also differed by sex: 8 out of 9 (89%) male CVs exceeding 6 were hind limb bone measurements, compared with only 5 out of 8 (63%) in females. This suggests the presence of more than one morphotype within the modern population.

Variation based on sex. Unsurprisingly, male chickens were consistently larger than female chickens (Table 1). The percentage difference in size between male and female chickens was largest (over 17%) for the following element measurements: tarsometatarsus-GL, -Bp, and -Bd; femur-Bd; tibiotarsus-GL, -Dip, -Bd, and -Dd; and ulna-Dip. Thus, the measurements showed that the size difference between male and female chickens was greatest in hind limb bones, presumably reflecting the greater body mass of cockerels.

Figure 2 illustrates the clustering of male and female chickens based on tarsometatarsus measurements, revealing that there was no overlap in length between male and female chickens, and that males were consistently larger than females. This was also true for the cross-bred red junglefowl (Fig. 2).

Variation based on carcass weight. Figure 3 presents the correlation between carcass weight and chicken size, based on the distal breadth of the femur. The data show that, in general, heavier chickens had broader bones. Femur breadth also indicated sexual dimorphism: the heavier male chickens had a broader femur breadth than the female chickens (Fig. 3). Statistical analysis of the modern Ethiopian chickens, using linear regression model (Gravetter and Wallnau, 2013), shows a significant positive correlation between carcass weight and femur breadth for both sexes (Fig. 3).

Archaeological material. Measurements of the distal and proximal ends of domestic chicken bones recovered from the site of Mezber revealed that chickens in the pre-Aksumite phase were small, relative to modern African chickens (Table 2) (Woldekiros and D'Andrea, 2016).

Combining the archaeological and ethnoarchaeological data

Size variation and log-scaled comparison. In nearly all cases, the Mezber chickens were smaller than the modern examples. Indeed, the Mezber chickens tended to center around zero, suggesting that they were comparable in size to the cross-bred junglefowl (Figs. 4A–4C). Unfortunately, the small sample size and the consequent lack of variation within the distribution makes it difficult to comment upon sexual dimorphism within the archaeological sample with confidence. The modern chickens were consistently larger than the junglefowl and the ancient chickens in all three anatomical planes (lengths: U=25; p=0.005; breadths: U=62; p=0.005; depths: U=0; p=0.001), and the sexual dimorphism of this population is evidenced by a bimodal distribution (Figs. 4A–4C).

As shown in the log-transformed data by skeletal element (Fig. 5), some parts of the skeleton changed more dramatically than others. For instance, in the modern Tigrai birds, wing bones were closer in size to the junglefowl standard than were leg bones (femurs were much larger in the modern birds). The depth measurements of ancient chickens (albeit only represented by the tibiotarsus and scapula) were much smaller than those of the modern chickens, indicating the impact of selection for increased body mass on the depth of the long bones.

Discussion and conclusion

Ethnoarchaeological research in Mesert has revealed the significance of cultural decisions and farming practices in the selection of local chickens in the Tigrai region of Ethiopia. People choose domestic chickens based on their ability to survive with minimal management, their ability to withstand local diseases and parasites, and their presentation of culturally desirable traits such as bright, multi-colored feathers, a specific comb type, and a desirable shank color. Unlike industrial chickens, for domestic chickens, productivity and potential output are less significant considerations.

Though the African chickens in the pre-Aksumite site of Mezber were relatively small (similar in size to the cross-bred red junglefowl), our ability to assess measurement variability in the specimens between sites and over time was hampered by the limited availability of sample material and the difficulty of establishing sex ratios. It is likely that there was complex inter-site variation in the size of chickens, based on the routes and times of their initial introduction. Analysis of modern chicken specimens from the rural households of Mesert village in Tigrai region, northern Ethiopia, provided a baseline for our understanding of the variability and breed history of domestic chickens in the ancient Horn of Africa. The modern specimens showed clear clustering according to sex and carcass weight. Male chickens were consistently larger than female chickens and heavier chickens tended to have broader joints. This finding reflects the biological relationship between bone width and body mass in birds and mammals (e.g. Applegate and Lilburn, 2002; Campione and Evans, 2012).

The measurements of modern Mesert chickens were similar or slightly smaller than MacDonald's (1992) measurements of modern chickens (Table 2). The modern chicken bone measurements published by MacDonald were probably taken from a sample collected in Sahelian West Africa; however, the exact location, age, and phenotypic characteristics of these chickens were not reported. Notably, modern local Ethiopian chickens were larger than their ancient counterparts in all three anatomical planes, especially with respect to length and depth (less so breadth) (Fig. 4). Comparison revealed some dramatic contrasts between elements. For example, the wing bones of the modern Tigrai birds were closer in size to those of the junglefowl, but their leg bones (e.g. femurs) were not. This suggests that either the chickens in Tigrai resulted from selective breeding or that new morphotypes were introduced to the region after the pre-Aksumite period. The coefficients of variation for the modern chickens also showed moderate variability, indicating the presence of more than one morphotype within the modern population. This variability was most pronounced in the hind limb. For example, the hind limb coefficients of variation for 8 out of 9 (89%) male chickens exceeded 6, while the same was true for only 5 out of 8 (63%) coefficients of variation for female chickens. Unfortunately, the absence of chicken bones from later archaeological sites in Ethiopia prevents us from determining when this “improvement” occurred, but we suggest that this question should be the focus of future research. Currently, comparative data on changes in chicken size is lacking in the Horn of Africa, as well as elsewhere in Africa. When bird bones are recovered from archaeological sites, they are often badly fragmented. However, the biometrical data presented in this paper from northern Ethiopia, as well as data from a few pre-existing studies, enable us to start to draw a general pattern of domestic fowl size and shape in ancient and modern populations.

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Supporting information

The supporting table (S1) shows osteometric data from a collection of six known age and sex cross-bred red junglefowl stored at the Natural History Museum at Tring (UK). These data (derived from Foster, 2018; Roberts, 2014; Thomas et al., 2016) were used to assess the proximity of modern and ancient Ethiopian chickens to wild morphotypes. Table S2 represents the osteometric data and general description of the 25 modern chickens collected from Mesert village.

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Table 1. Mean values, co-efficients of variation, and standard deviation of 25 (12 male and 13 female) local northern Ethiopian domestic chicken limb bone measurements. Percentage differences between mean size for males and females is also included.

		Scapula		Coracoid	Humerus			Ulna		Radius	
		GL	**Dic**	**GL**	**GL**	**Bp**	**Bd**	**GL**	**Dip**	**GL**	**Bd**
M (n=12)	**Mean**	78.56	13.65	61.11	79.80	20.84	16.26	79.06	14.39	71.76	7.35
	SD	3.84	0.97	3.62	4.29	1.23	0.86	3.84	0.85	3.64	0.33
	CV	4.89	7.13	5.93	5.38	5.90	5.26	4.86	5.91	5.08	4.51
F (n=13)	**Mean**	69.94	11.74	53.05	69.22	17.95	14.18	67.95	12.26	61.52	6.34
	SD	3.34	0.80	1.94	2.61	1.13	0.74	2.89	0.70	2.43	0.48
	CV	4.78	6.86	3.66	3.77	6.29	5.21	4.26	5.74	3.94	7.64
% difference		12.32	16.28	15.18	15.28	16.13	14.62	16.35	17.37	16.64	15.96

Table 1. (Continued)

		Carpo-metacarpus	Femur			Tibiotarsus				Tarsometatarsus		
		GL	**GL**	**Bp**	**Bd**	**GL**	**Dip**	**Dd**	**Bd**	**GL**	**Bp**	**Bd**
M (n=12)	**Mean**	42.17	90.98	17.79	18.12	132.40	24.28	13.99	13.17	92.33	15.57	14.93
	SD	2.34	5.60	1.33	1.30	6.43	1.94	0.87	0.99	5.59	1.01	0.71
	CV	5.54	6.15	7.47	7.17	4.85	7.98	6.22	7.49	6.05	6.48	4.73
F (n=13)	**Mean**	36.89	78.15	15.39	14.90	112.08	20.08	11.85	11.57	75.15	13.13	12.72
	SD	1.61	3.89	1.28	1.19	4.35	1.58	0.71	0.66	3.41	0.89	0.84
	CV	4.36	4.98	8.29	7.96	3.88	7.86	5.97	5.74	4.54	6.81	6.57
% difference		14.30	16.42	15.59	21.59	18.13	20.95	18.03	13.81	22.86	18.55	17.38

Table 2. Size range of modern and archaeological domestic chicken specimens, including data from MacDonald (1992)

Measurements		Modern Mezber (12 male, 13 female)	Modern West Africa (4 male, 6 female)	Archaeological Mezber
Scapula	GL	64.80–87.40	N/A	N/A
	Dic	10.60–15.50	9.30–15.50	N/A
Coracoid	GL	50.50–68.00	40.10–72.00	40.90–46.00
Humerus	GL	65.00–88.50	48.20–91.20	N/A
	Bp	15.90–23.20	13.70–24.60	N/A
	Bd	13.00–17.90	11.00–19.20	15.70
Ulna	GL	63.80–86.90	N/A	N/A
	Dip	10.80–16.00	9.80–16.50	N/A
Radius	GL	57.70–79.00	N/A	N/A
	Bd	5.60–7.80	5.40–9.70	6.43
Carpometacarpus	GL	34.30–47.10	23.90–48.80	28.51–56.00
Femur	GL	72.10–102.00	48.70–114.60	N/A
	Bp	13.30–20.70	12.60–22.30	N/A
	Bd	12.90–21.00	11.10–21.20	N/A
Tibiotarsus	GL	105.10–146.60	65.60–156.40	114.20
	Dip	17.10–28.80	13.80–26.00	N/A
	Dd	10.70–16.00	N/A	7.22–10.34
	Bd	10.60–15.60	8.90–14.80	8.66–12.88
Tarsometatarsus	GL	70.10–106.50	40.80–114.40	60.82–82.21
	Bp	12.10–18.10	10.50–17.70	10.50–13.32
	Bd	11.40–16.10	9.30–19.30	10.00–14.43

Figure 1. Map showing the Mezber site and the modern Mesert village (northern Ethiopia).

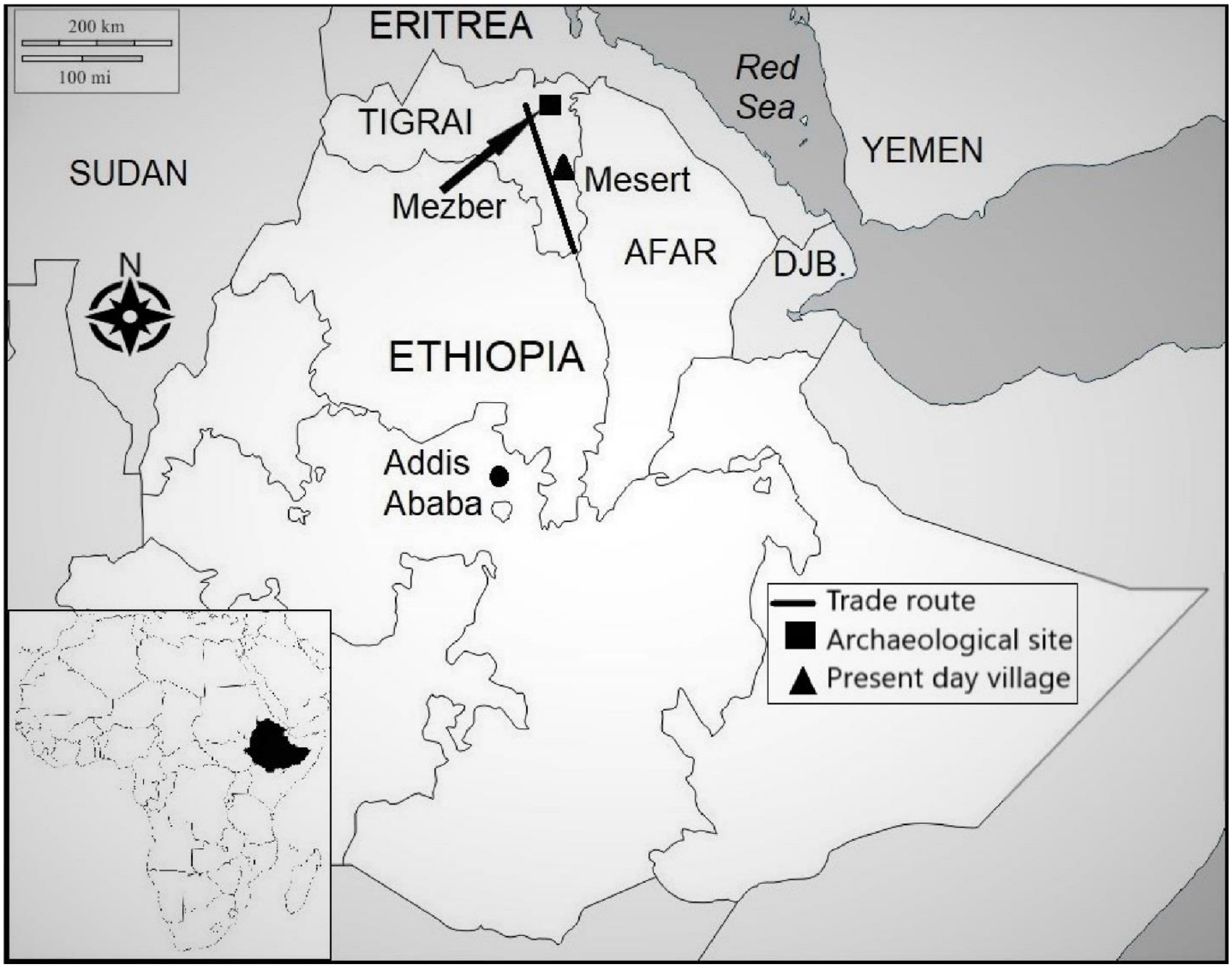

Figure 2. Clustering of male and female modern chickens from Mesert village and cross-bred red junglefowl, based on tarsometatarsus-GL and -Bp measurements (Thomas et al., 2016).

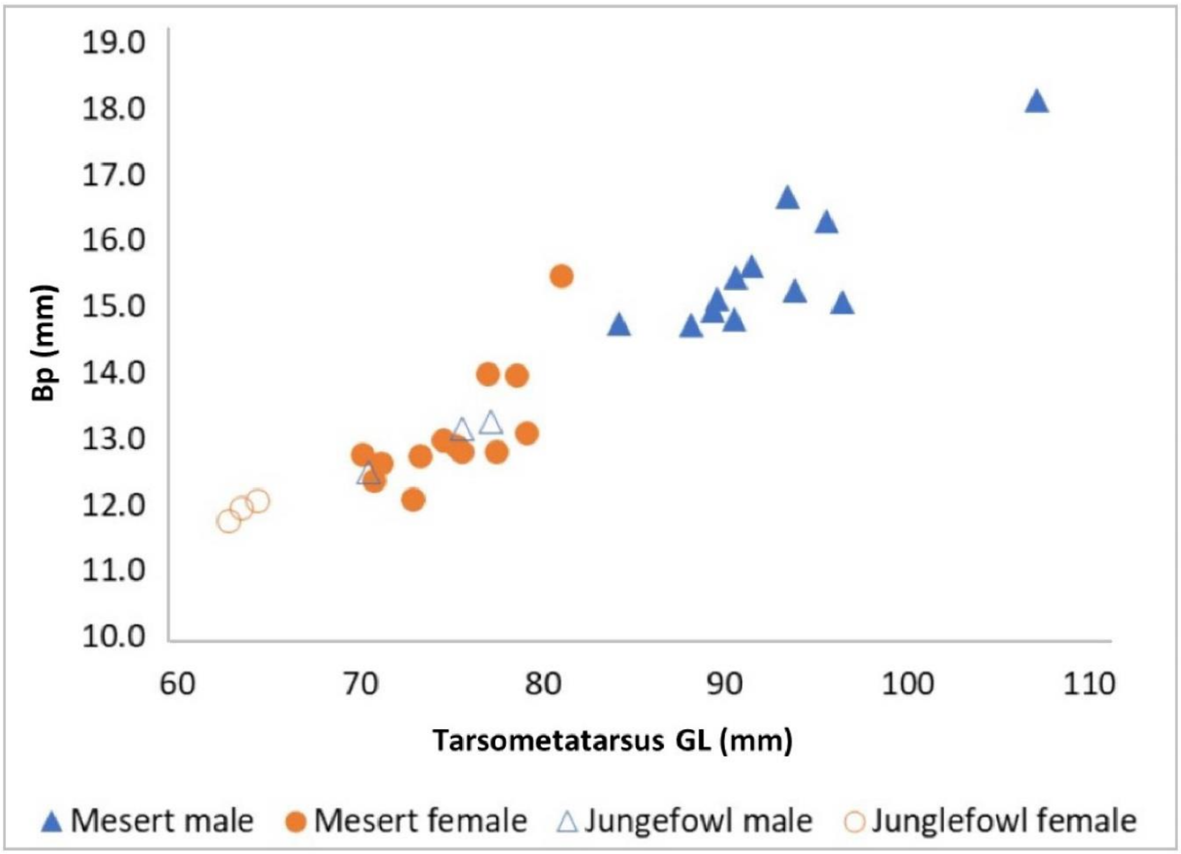

Figure 3. Linear regression model showing the relationship between carcass weight and femur distal breadth for male and female modern chickens from Mesert, Ethiopia (r=0.91; p=0.00).

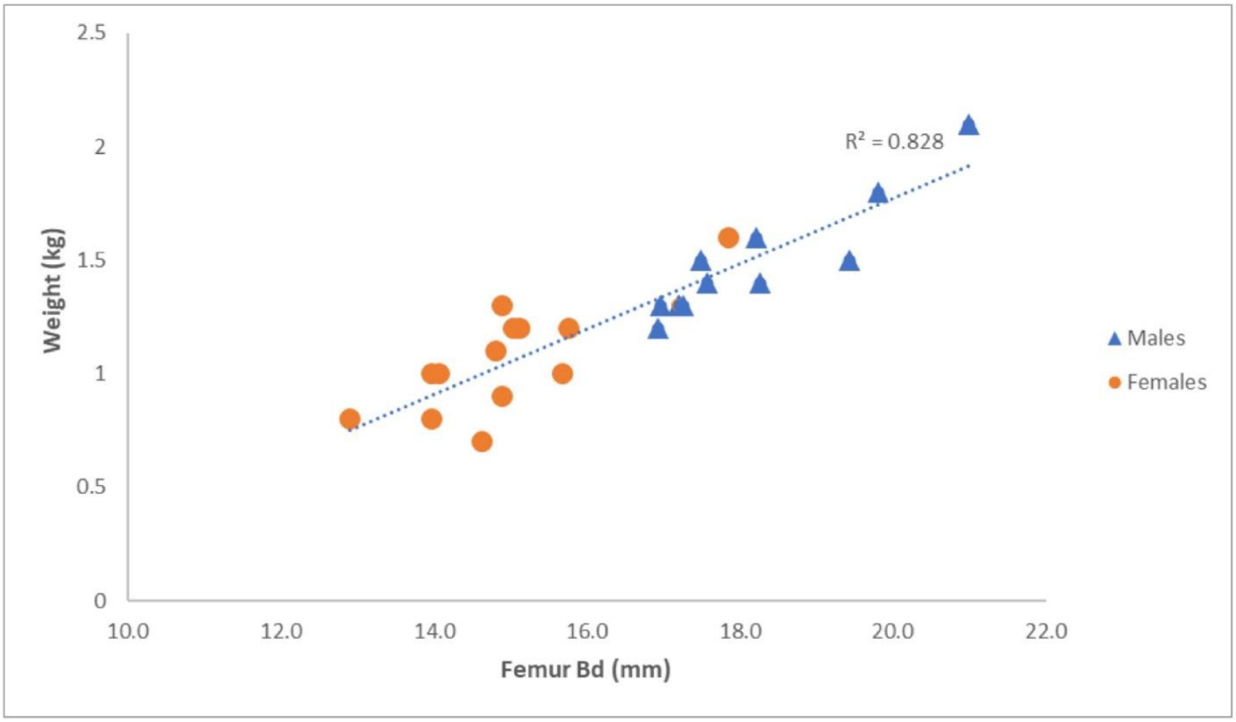

Figure 4. Log-scaled comparison of pre-Aksumite and modern chickens from Mesert across the three anatomical planes: lengths - coracoid GL, carpometacarpus GL, tibiotarsus GL, tarsometatarsus GL; breadths – humerus Bd, radius Bd, tibiotarsus Bd, tarsometatarsus Bd, tarsometatarsus Bp, tarsometatarsus Bd; depths – tibiotarsus Bd.

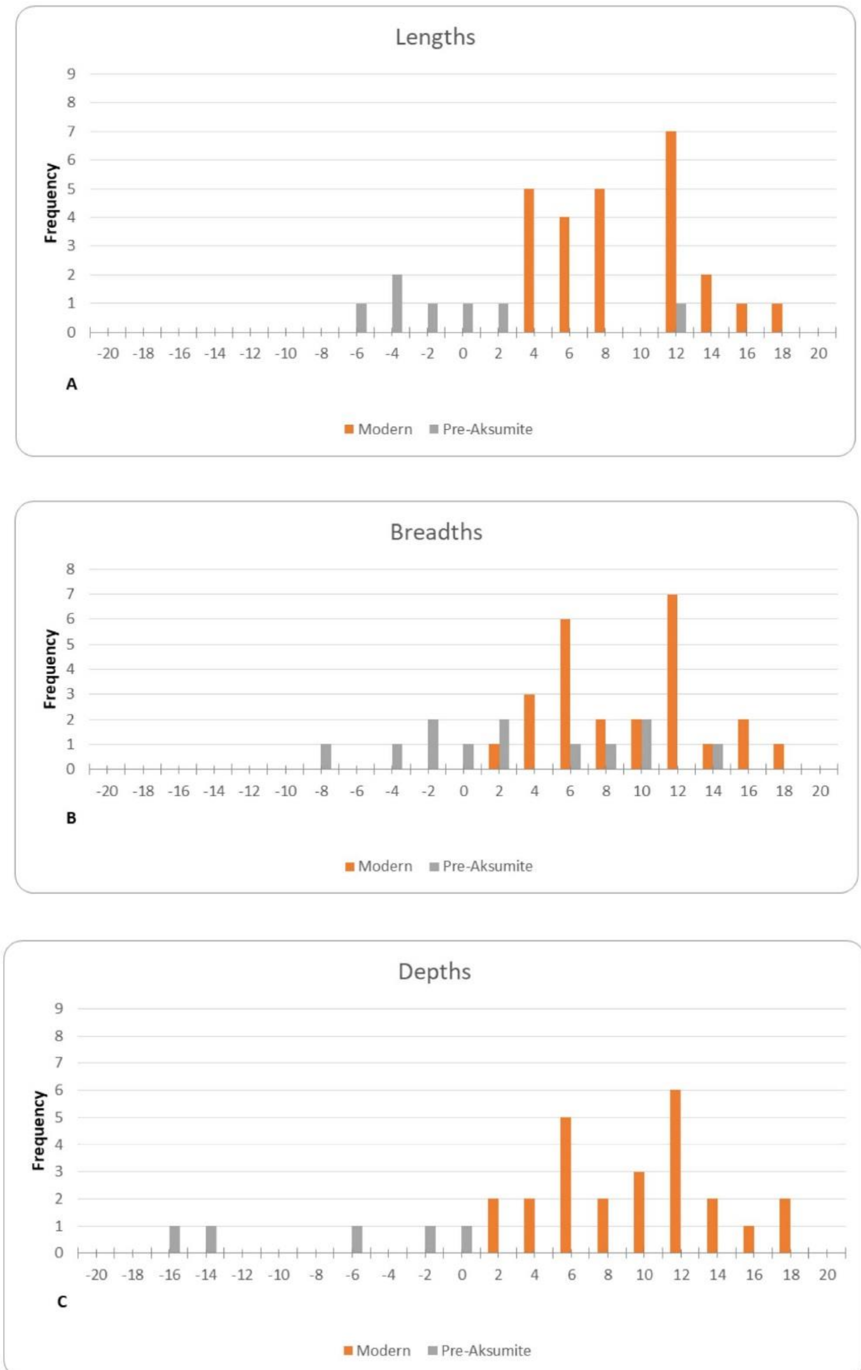

Figure 5. Log-scaled comparison of pre-Aksumite and modern chickens from Mesert by element. The standard is provided by cross-bred junglefowl from Tring.