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MORPHOLOGICAL AND MORPHOMETRIC FEATURES OF INDIGENOUS CHICKEN IN SOUTHWEST ETHIOPIA

Zerihun BALCHA [1], Mekuanent BAYE[1] ✉, Worku MASHO [1] and Zelalem ADMASU [1]

Department of Animal Science, Mizan-Tepi University, P.O Box: 260, Mizan-Aman, Ethiopia

✉Email: mekuanentbaye@mtu.edu.et

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ABSTRACT: Morphological and morphometric characterization of indigenous chicken ecotypes were carried out in West-Omo zone of Southwest Ethiopia. Nine qualitative and fifteen quantitative traits were observed and measured from 660 matured chickens of both sexes. The data was analysed using SPSS version 21 and SAS version 9.1. Majority of the qualitative and quantitative traits were significantly influenced by sex and agro-ecological zones. The predominant plumage color, feather distribution, shank color, skin color, ear-lobe color, eye color, head shape, comb type, and feather morphology were red (38.4%), normal (96.2%), yellow (45%), white (48.8%), red (42.1%), red (28.6%), flat plain (94.4%), single (64.7%) and normal (100%). The body weight of matured male chickens in highland, mid-altitude and lowland agro-ecologies was 2.1±0.02 kg, 2.2±0.05 kg, and 2.0±0.03 kg, respectively, while females weighed 1.4±0.01 kg, 1.5±0.00 kg, and 1.4±0.01 kg in highland, mid-altitude, and lowland agro-ecologies, respectively. Males were also superior to females in terms of body length (BL) values of 42.0±0.19 cm and 37.7±0.06 cm, respectively. The prediction of body weight could be based on regression equation y = -1.02+0.10 CC (chest circumference) for male and y= -1.26+0.07BL of hen in highland altitude, y = -1.06+0.11 CC of male and y= -0.78+0.05 BL of hen in mid-altitude and similarly y = -0.90+0.10 CC in lowland male and y= -1.33+0.07 BL of lowland hen. Therefore, chest circumference for males and body length for females were the best variables to predict the body weight of chickens than other variables. The current finding shows there was heterogeneity in a population of indigenous chickens in the studied agro-ecology. This gives an opportunity for genetic improvement of indigenous chickens within a population.

Keywords: Genetic improvement; Indigenous chicken; Morphological; Morphometric; West-Omo zone.

INTRODUCTION

Ethiopia is a home for at least seven indigenous chicken ecotypes namely Farta, Horro, Jarso, Konso, Mandura, Tepi, and Tillili (EBI, 2016), with an estimated 60.04 million poultry heads. Despite the low productivity, the indigenous chicken population represents 88.5% of the poultry flock in Ethiopia (CSA, 2018). Indigenous chickens are resistant to common poultry diseases and feed quality and quantity fluctuation, requiring minimal input (Desta and Wakeyo, 2012; Desta, 2021). More than 90% of the country's egg and meat production is produced by indigenous chicken managed in the traditional way (Melesse and Negesse, 2011). However, only a few recognized chicken breeds have a fair description of their physical appearance, as well as indications of their level of performance, reproduction, and genetic characteristics. Thus, a basic understanding of a livestock species' or breed's defining characteristics that distinguish out from other breeds or species is required for genetic improvement and designing an appropriate breeding plan (Oguntunji and Ayorinde, 2015; Bibi et al., 2021).

Characterization of farm animal genetic resources is a strategy for identifying several breeds or populations in a particular production zone by defining their morphological and productive characteristics (FAO, 2012). It has also been revealed that, distinct breeds will be expected to boost the number of livestock breeds in the country (Georges et al., 2019). Morphometric measurements have been applied to identify the types of different livestock breeds and could generate preliminary evidence for the choice of a particular breed (Mwacharo et al., 2006). On-farm characterization help to ensure the long-term improvement and conservation of indigenous animal genetic resources, and it's becoming more popular in determining variation between and among the breeds (Alderson, 2018; Dobrzański et al., 2019).

There have been morphological and genetic characterization works on indigenous chicken ecotype found in Sheka zone of Southern nation and nationality people regional state of Ethiopia (Assefa and Melesse, 2018a). However, there is a scarcity of such information documented by morphological and morphometric evaluation across the various agro-ecologies of the study sites. Thus, it is believed that in such remote areas, genetic originality may still be found. The phenotypic features of distinct breeds are thus critical as a foundation for establishing long-term genetic improvement approaches. Therefore, this study aimed to systematically identify the morphological and Morphometrical characteristics of indigenous chickens reared under the different agro-ecologies of West-Omo zone of southwest Ethiopia.

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MATERIALS AND METHODS

Animal care and ethical issues

Mizan-Tepi University, College of Agriculture and Natural resource ethics Committee approved the experiment (1956ET-18/2021) after a careful assessment of ethical and animal care issues. Directive 2010/63/EU of the European Union guidelines (2010) concerning the treatment and use of animals for research and development purposes were employed.

Description of the study areas

The research was carried out in Ethiopia's Maji and Bero district, West-Omo zone (WOZ) of the South Nation's Nationalities and Peoples Regional State (SNNPRS). The districts were chosen based on their chicken population potential as well as their production environment. The detailed description is fully explained as follows (Table 1).

Table 1 - Description of study areas

Description	Bero District	Maji District
Geographical Location	06˚ 15.213ˈN and 35˚13.449′ E	6°12′N and 35°35′E
Temperature (°C)	20.1- 27.5 C˚	15.1- 27.5 C˚
Annual rainfall (mm)	1,401 to 1,800	400-1800
Altitude (m.a.s.l)	501 to 1,750	500–2500
Chicken population (head)	174,075	226,772

Source: WOZADMD, 2019.

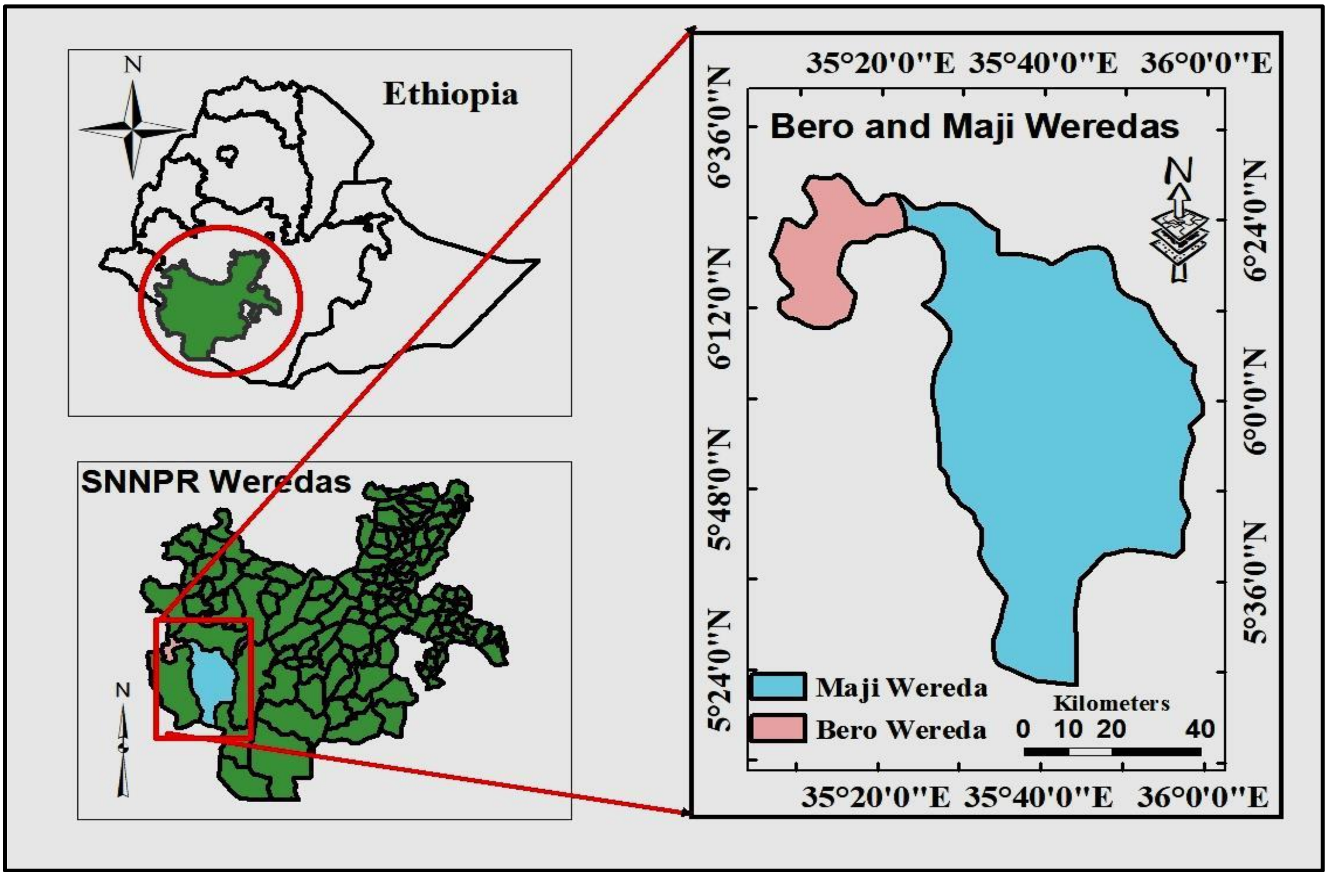

Figure 1 - Map of the study area

Site selection and sampling techniques

Prior to sampling, key informants and zonal livestock and fisheries resource experts were consulted to understand more about the genetic diversity of indigenous chicken in the study area. A quick field survey was conducted to determine the distribution of indigenous chicken breeds in the study area and to design a sampling framework from which sampling units were taken. A multistage purposive sampling technique was used to identify samples in the study zone. West-Omo zone is structured into seven districts and one urban town which was stratified and purposely selected based on its chicken population. Of these Bero and Maji districts were purposively selected and stratified into three agro-ecological

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zones of highland, mid-altitude, and lowland, to assess the effect of agro-ecologies on the morphology of chicken ecotype. Then a total of six kebeles were selected purposively from both districts (two kebeles from each agro-ecologies) based on suitability for chicken production, accessibility to market and road, security, and willingness of the farmers to participate in the study. Thus, a total of 660 chickens were considered for both qualitative and quantitative trait studies. Animals samples were identified in accordance with FAO (2012) guidelines and the morphometric investigation comprised chickens belonging to 240 households.

Data collection

Quantitative and qualitative traits

Data on qualitative (morphological features) and quantitative (morphometric measures) variables were gathered and documented using a format based on the FAO's standard description list (FAO, 2012). As per the visual observation, a total of 9 qualitative characteristics were measured and recorded (Figures 2-5), including Plumage Color (PC), Shank Color (SC), Feather Morphology (FM), Feather Distribution (FD), Skin Color (SkC), Earlobe Color (ELC), Eye Color (EC), Head Shape (HS) and Comb Type (CT). Likewise, 15 quantitative traits/parameters were measured and recorded using measuring tape and a measuring stick, which included Body weight (BW), Body Length (BL), Chest Circumference (CC), Wing Span (WS), Neck Length (NL), Shank Length (SL), Shank Circumference (SC), Thigh Circumference (TC), Wattle Length (WL), Wattle Width (WW), Comb Length (CL), Comb Height (CH), Beak Length (BkL), Beak Width (BkW) and Height at Back (HB) were taken measurements at early in the morning to avoid the effect of feeding and watering on the chickens weight. Less than or equal to 4 chickens per household/farmer were chosen to avoid genetic resemblance. Two researchers carried out the measurements, one taking the measurements and the other collecting data. All measures were obtained by the same researcher throughout the investigation to reduce subjective error.

Data analysis

The frequency technique PROC FREQ in the Statistical Package for the Social Sciences (SPSS, ver. 21) was used to examine different measurements of qualitative morphological features. The Chi-square ($x2$) test was performed to determine if there was a significant relationship between the categorical variables. Quantitative data (body weight and linear body measurement) were subjected to GLM (Generalized Linear Model) procedures of Statistical Analysis System (SAS, 2008 ver. 9.1) by fitting agro-ecology and sex as independent variables. For each physical attribute across agro-ecology and sex, the least square means and standard errors were determined.

Body weight and linear body measurements of female and male individual chickens were determined using the following model:

$Yijk = \mu + Ai + Sj + (AxS)ij + eijk$

Where:

$Yijk$ = the observed k (body weight or linear body measurements) in the ith agro-ecology and jth sex

μ = overall mean

Ai = fixed effect of ith agro-ecology (Highland, Mid-altitude, Lowland)

Sj = fixed effect of jth sex (male, female)

$(AxS)ij$= the interaction effects of ith agro-ecology and jth sex

$eijk$ = random error

The following models were used for the estimation of body weight from linear body measurements.

For males:

$Yj = \beta 0 + \beta 1\ X1 + \beta 2\ X2 + \beta 3\ X3 + \beta 4\ X4 + ej$ for males

Where: Y = the dependent variable (body weight); $\beta 0$= the intercept;

X1, X2, X3 and X4 are the explanatory variables (chest circumference, thigh circumference, body length and shank length)

$\beta 0$= the intercept

$\beta 1$ ..., $\beta 4$ are regression coefficients of the variables X1..., X4

ej = random error

For females:

$Yj = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \beta 5X5 + \beta 6X6 + eij$ for females

Where: Yj = the dependent variable (body weight);

$\beta 0$= the intercept

X1, X2, X3, X4, X5, and X6 are independent variables (Body length, neck length, shank circumference, height at back, wattle length, and thigh circumference);

$\beta 1$... $\beta 6$ are regression coefficients of the variables X1..., X6

ej = random error

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RESULT AND DISCUSSION

Qualitative traits in the study zone

The physical qualities of livestock breeds must be described in detail to form a breed and design a breeding plan for a certain production system (Machete et al., 2021; Tadele et al., 2019). Morphological features of the indigenous chicken population in the study agro-ecologies are summarized in Table 2. The most predominant plumage color, feather distribution, shank color, skin color, ear-lobe color, eye color, head shape, comb type, and feather morphology were red (38.4%), normal (96.2%), yellow (45%), white (48.8%), red (42.1%), red (28.6%), flat plain (94.4%), single (64.7%) and normal (100%). According to the Chi-square test, the frequency distributions among the three agro-ecologies were significantly different (P<0.05) with respect to all qualitative traits except for skin color.

Plumage color variation

Male and female indigenous chickens with diverse plumage colorations are shown in Figure 2. Brown plumage color was predominant among female chickens in the mid-altitude zone (39%), whereas red plumage color was observed in both highland and lowland agro-ecologies with 42% and 39%, respectively. For male chickens, the predominant plumage color was red mixed with black (45%) in mid-altitude, red (95%) in highland, and red (35%) in lowland agro-ecologies. The variation in plumage color might be due to a farmer's traditional selection method, the environment, or genetic variation. Similar to the current finding, Assefa and Melesse (2018b) find that male chickens in Yeki district have red plumage color (37.5%). Tadele et al. (2019) also found that red was the major plumage color of male chickens throughout the study districts of Kaffa zone, accounting for 59.3%, while reddish-brown plumage color was prominent for females in all districts. However, our findings are contradicted with the value of Alebachew et al. (2019) in the Benshangul Gumuz area of western Ethiopia, who found that white (39%) was the most common plumage color for Bambassi ecotypes, followed by black (12.7%) and gray (12.7%). The current finding also contradicts with Getachew and Negassi (2016) who found that roughly 58.3% of male chicken populations in the north-bench district had black plumage, followed by white, Gebsima (15.0%), and red plumage (11.9%).

Eye color variation

Orange eye color (Figure 2) was predominant for male and female chickens in all agro-ecologies with an overall proportion of 41.7% followed by red (28.6%) yellow (26.8%), brown (1.1%), and whitish pale (1.8%). Similarly, Aklilu et al. (2013) found that orange eye color (wild-type color) was observed in higher frequency in Horro chicken (87.84%), followed by the red eye color. The pigmentation (carotenoid pigment) and blood flow to a variety of structures within the eye play significant roles in eye color variation (Crawford, 1990).

Skin color variation

Four skin colors (Figure 3) namely white, yellow, black, and grey were observed (Table 2) of which 57.3 % of chickens in highland areas had skin with white color followed by 47.2% and 41.8% in mid-altitude and lowland agro-ecologies, respectively. Likewise, Aklilu et al. (2013) indicated that most of the local chickens observed in Horro district had white (77.03%) skin color followed by yellow (22.07%) and bluish-black (0.9%). Rajkumar et al. (2017) also found that skin color variations of white, pink, and yellow were observed in indigenous chicken populations, and that white skin color was the most prominent among them. The finding disagrees with Churchil et al. (2019) who reported that the skin color was 100% yellow for Aseel male chicken in India. According to Eriksson et al. (2008), the presence or absence of carotenoid pigments results in yellow or white skin. Domestic hens with yellow skin are homozygous for a recessive gene that inhibits the synthesis of an enzyme called BCDO2 (beta-carotene dioxygenase 2) in comparison to white chickens with the dominant allele. This recessive gene may have been introduced from Grey Jungle fowl (*Gallus sonnerati*).

Head and feather morphology

There is a significant (P<0.01) relationship between chicken feather morphology and agro-ecologies (Figure 4). The feather morphology of local hens, regardless of sex, was found to be 100 % normal among the agro-ecologies. The proportion of flat head chicken was dominant in all agro-ecologies with an overall percentage of 94.4% while, the remaining proportion (5.6%) accounted for Gutye (crested) head shape. The findings were similar to that of Nigussie et al. (2015), who found that the predominant head shape of local chickens across agro-ecology was flat heads, with 98.2%, 92.7% and 92.3%, respectively from highland, mid-altitude, and low land, and the rest was Gutye (crested) head-shaped. In Makurdi, Egahi et al. (2010) obtained 82.05 percent for the plain head shape type of native chickens. Kibret (2008) on the other hand, founds 48.82% and 51.18% for plain and crested head shape types, respectively

Comb type variation

Four comb types, single, double, pea, and rose were identified in the order 64.7%, 10.3%, 5.6%, and 19.4%, respectively (Table 2; Figure 4). The current study revealed that the single comb type was predominant accounting for 36.3 %, 76.8%, and 80.9% in highland, mid-altitude, and lowland agro-ecologies, respectively followed by the rose comb type, accounting for 35.4 %, 12.3%, and 10.5 % in the agro-ecologies mentioned. Consistent with the current finding, Assefa and Melesse (2018) reported that single comb types for mid-latitude and lowland were found in Sheka indigenous chicken. Moreover, Emebet et al. (2014) indicated that single and rose comb types were present in 59.2% and 31.8% of chickens in the Southwest and South regions of Ethiopia, respectively. In contrast to our finding, Churchil et al. (2019) pea comb type is dominant for Aseel chicken in India. Comb size is linked to gonadal development and light intensity, although comb type is a result of gene interaction (Bell and WeaverJr., 2002).

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Shank color variation

According to the current study, four shank colors were identified namely yellow, grey, white, and black shank color (Figure 5). Yellow color occurred highest (45 %) followed by grey color (38.6%), white color (12.9%), and black color (3.5%). Similarly, Mogesse (2007a) reported yellow shank color as the highest in Ethiopian native chickens. Mancha (2004), on the other hand, found that the most prevalent shank colors in Plateau State were pink, dark-ash, ash, and pale yellow.

Ear lobe color variation

Earlobe color had a significant (P<0.01) relationship across all the study agro-ecologies (Figures 2-4). Five types of earlobe colors (red, white, yellow, grey, and dark brown were identified among the indigenous chickens with 42.1%, 32.7%, 21.7%, 2.3%, and 1.2%, respectively) were identified among the indigenous chicken in the study area. Male ear lobe color was yellow (50%) in the lowland, whereas red was more common in the highland and mid-latitude regions, with values of 50% and 50%, respectively. Female ear lobe color was red (as 67%) in the highland, but white (as 48% and 41%) in the mid-altitude and lowland, respectively. The finding of the current study was comparable with reports on Assel chicken (Rajkumar et al., 2017) and indigenous Shaka chicken (Assefa and Melesse, 2018).

Black plumage with black shank colour

White plumage with orange eye colour

Brown plumage colour

The dominant plumages colour

Figure 2 - Pictures showing plumage color of indigenous chickens in West-omo Zone

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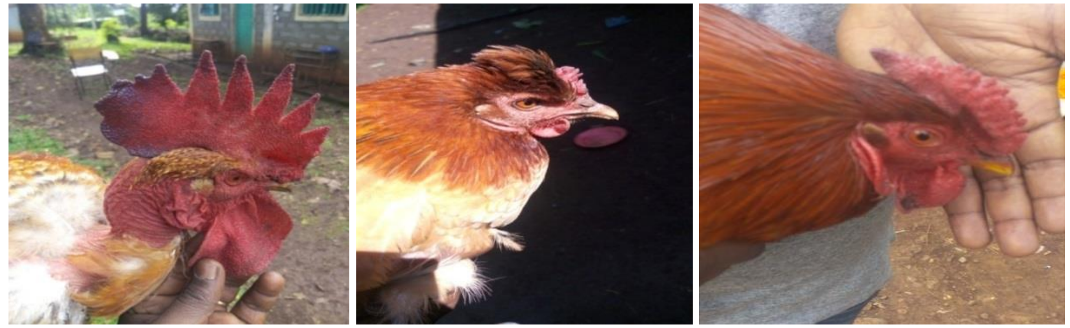
Yellow skin necked neck Black skin naked neck Red skin naked neck

Figure 3 - Pictures showing skin colors of indigenous chickens in West-omo Zone.



Single comb type Crest/Gutye headed type Rose comb type

Figure 4 - Pictures showing comb structure and head type of indigenous chickens in West-Omo zone

Black shank colour Yellow shank colour Grey shank colour White shank colour

Figure 5 - Picture showing shank color of indigenous chickens in West-omo Zone.

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Table 2 - Qualitative characteristics of chickens in the study agro-ecology

Traits	Attribute	Agro-ecology																			
		Highland						Mid-altitude						Lowland						Overall	
		F		M		T		F		M		T		F		M		T			
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Plumage color	Red (*Key*)	84	42	19	95	103	46.8	62	31	4	20	66	30	78	39	7	35	85	38.6	254	38.4
	Golden	12	6	-	-	12	5.45	23	11.5	3	15	26	11.8	20	10	1	5	21	9.5	59	8.9
	Gebsima	8	4	1	5	9	4	3	1.5	4	20	7	3.18	3	1.5	3	15	6	2.7	22	3.3
	Brown	64	32	-	-	64	29	78	39	-	-	78	35.45	61	30.5	1	5	62	28.1	204	34
	Black (*Tikur*)	22	11	-	-	22	10	6	3	-	-	6	2.7	10	5	1	5	11	5	39	5.9
	Grey	6	3	-	-	6	2.7	2	1	-	-	2	0.9	7	3.5	1	5	8	3.6	16	2.4
	Tikur teterma	-	-	-	-	-	-	3	1.5	-	-	3	1.36	2	1	-	-	2	0.9	5	0.75
	White	-	-	-	-	-	-	4	2	-	-	4	1.8	-	-	-	-	-	-	4	0.6
	Kokima	4	2	-	-	4	1.8	13	6.5	-	-	13	5.9	4	2	-	-	4	1.8	21	3.2
	Red with black	-	-	-	-	-	-	2	1	9	45	11	5	9	4.5	6	30	15	6.8	26	3.9
	Multicolor	-	-	-	-	-	-	4	2	-	-	4	1.8	6	3	-	-	6	2.7	10	1.5
Test	X^2 and P-value																			67.9	***
Eye color	Red	68	34	4	20	72	32.7	74	37	4	20	78	35.4	36	18	3	15	39	17.7	189	28.6
	Yellow	48	24	4	20	52	23.6	34	17	6	30	40	12.18	78	39	7	35	85	38.6	177	26.8
	Orange	76	38	12	60	88	40	88	44	9	45	97	44	80	40	10	50	90	40.9	275	41.7
	Brown	4	2	-		4	1.8	-	-	1	5	1	0.45	2	1	-	-	2	0.9	7	1.1
	Whitish pale	4	2	-		4	1.8	4	2	-	-	4	1.8	4	2	-	-	4	1.8	12	1.8
Test	X^2 and P-value																			34.8	***
Skin-color	White	109	54.5	17	85	126	57.2	100	50	4	20	104	47.2	82	41	10	50	92	41.8	322	48.8
	Yellow	24	12	-	-	24	10.9	41	20.5	6	30	47	21.3	57	28.5	6	30	63	28.6	134	20.3
	Grey	60	30	-	-	60	27.2	38	19	8	40	46	20.9	40	20	4	20	44	20	150	22.7
	Black	7	3.5	3	15	10	4.5	21	10.5	2	10	23	10.4	21	10.5	-	-	21	9.5	54	8.2
Tests	X^2 and P-value																			31.2	***

M= male; F= female; T=Total; N= Number of chicken exhibiting a particular qualitative character; X^2 = Chi square test; ***; significant at *P*<0.01

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Table 2 - Continued																					
Traits	Attribute	Agro-ecology																			
		Highland						Mid-altitude						Lowland						Overall	
		F		M		T		F		M		T		F		M		T			
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Shank color	Yellow	88	44	12	60	100	45.5	80	40	15	75	105	47.7	86	43	16	80	102	46.4	297	45
	Grey	74	37	6	30	80	36.3	81	40.5	5	25	86	39	85	42.5	4	20	89	40.4	255	38.6
	Black	4	2	2	10	6	2.7	14	7	-	-	14	6.3	3	1.5	-	-	3	1.3	23	3.5
	White	34	17	-	-	34	15.4	25	12.5	-	-	25	11.3	26	13	-	-	26	11.8	85	12.9
Tests	$X^2$and P-value																			10.9	0.09
Feather distribution	Normal	198	99	20	100	218	99.1	198	99	18	90	216	98.18	183	91.5	18	90	201	91.36	635	96.2
	Nacked neck	2	1	-		2	0.9	2	1	2	10	4	1.8	17	8.5	2	10	19	8.6	25	3.8
Tests	$X^2$and P- value																			21.5	0.0001
Feather morphology	Normal	200	100	20	100	220	100	200	100	20	100	220	100	200	100	20	100	220	100	660	100
	Silky	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Test	$X^2$and P-value																				
Head shape	Flat plain	196	98	20	100	216	98.18	184	92	20	100	204	92.7	183	91.5	20	100	203	92.3	623	94.4
	Gutye	4	2	-	-	4	1.8	16	8	-	-	16	7.2	17	8.5	-	-	17	7.7	37	5.6
Tests	$X^2$and p-value																			8.9	0.01
Comb type	Single	78	39	2	10	80	36.3	156	78	13	65	169	76.8	159	79.5	19	95	178	80.9	427	64.7
	Double	42	21	4	20	46	20.9	8	4	2	10	10	4.54	12	6	-	-	12	5.45	68	10.3
	Pea	16	8	-	-	16	7.2	14	7	-	-	14	6.36	6	3	-	-	7	3.18	36	5.6
	Rose	64	32	14	70	78	35.45	22	11	5	25	27	12.27	23	11.5	1	5	23	10.45	129	19.4
Tests	X^2 and P-Value																			125.04	0.000
Ear-lobe color	Red	134	67	10	50	144	65.4	57	28.5	10	50	67	30.45	62	31	5	25	67	30.4	278	42.1
	White	28	14	-	-	28	12.7	96	48	5	25	101	45.9	82	41	5	25	87	39.54	216	32.7
	Yellow	34	17	10	50	44	20	38	19	5	25	43	19.5	46	23	10	50	56	25.4	143	21.7
	Grey	4	2	-	-	4	1.8	7	3.5	-	-	7	3.1	4	2	-	-	4	1.8	15	2.3
	Dark brown	-	-	-	-	-	-	2	1	-	-	2	0.9	6	3	-	-	6	2.7	8	1.2
Test	X^2 andP-value																			94.7	0.0001

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Quantitative trait measurements

Data on live body weight and linear body measurements of existing chicken ecotypes are widely used in the selection program (Mohammed et al., 2017). According to Tareke et al. (2018), live body weight and linear body measurement play an important role in genetic improvement and breed selection. Live body weight (kg) and other linear body measurements (cm) of indigenous chickens across the studied agro-ecologies are shown in Table 3.

Table 3 - Least squares mean (LSM) and (SE) of live body weight (kg) and other linear body measurements (cm) of indigenous chicken affected by agro-ecology, sex, and sex × agro-ecology interaction

	N	BW	BL	CC	NL	TC	SL	HB
Levels		LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Overall	660	1.8±0.01	39.6±0.1	26.5±0.05	11.2±0.07	10.8±0.06	7.7±0.02	27.7±0.06
CV		9.5	4.07	2.9	9.6	10.5	5.22	3.66
R^2		0.66	0.40	0.73	0.56	0.60	0.39	0.61
Agro-ecology		**	**	**	**	**	**	**
Highland	220	1.7±0.01^{a}	39.6±0.13^{a}	26.6±0.09^{a}	10.9±0.09^{a}	10.7±0.09^{a}	7.8±0.03^{c}	27.8±0.12^{a}
Mid-altitude	220	1.8±0.01^{b}	40.5±0.11^{b}	27.2±0.09^{b}	11.6±0.07^{b}	11.8±0.07^{b}	7.7±0.02^{b}	27.8±0.10^{a}
Lowland	220	1.7±0.01^{a}	39.4±0.13^{a}	26.8±0.08^{a}	10.8±0.10^{a}	10.0±0.10^{a}	7.5±0.02^{a}	27.3±0.09^{b}
Sex		**	**	**	**	**	**	**
Male	60	2.1±0.02	42.0±0.19	29.0±0.18	12.9±0.09	13.2±0.16	8.2±0.08	29.7±0.2
Female	600	1.4±0.00	37.7±0.06	24.8±0.03	9.4±0.05	9.2±0.04	7.2±0.01	25.5±0.01
Sex × agro-ecology		**	**	**	**	**	*	*
Male, highland	20	2.1±0.02^{a}	42.3±0.15^{a}	28.8±0.22^{a}	13.1±0.13^{a}	13.2±0.24^{a}	8.7±0.09^{a}	30.2±0.17^{a}
Female, highland	200	1.4±0.03^{a}	37.3±0.10^{a}	24.5±0.04^{a}	9.8±0.08a	8.7±0.06^{a}	7.3±0.02^{a}	25.7±0.08^{a}
Male, mid-altitude	20	2.2±0.05^{b}	42.2±0.39^{a}	29.4±0.26^{b}	13.0±0.08^{a}	13.6±0.18^{b}	8.0±0.13^{b}	30.1±0.39^{b}
Female, mid-altitude	200	1.5±0.05^{b}	38.4±0.09^{b}	25.1±0.05^{b}	10.0±0.05^{a}	9.9±0.05^{b}	7.2±0.02^{a}	25.7±0.05^{a}
Male, lowland	20	2.0±0.03^{c}	41.5±0.24^{b}	28.9±0.27^{a}	12.5±0.22^{b}	12.8±0.20^{c}	7.9±0.14^{b}	28.9±0.27^{c}
Female, lowland	200	1.4±0.01^{a}	37.3±0.12^{a}	24.7±0.05^{a}	9.1±0.08^{b}	9.0±0.09^{c}	7.0±0.02^{a}	25.3±0.06^{a}

Table 3 - Continued

	N	SC	CL	CH	WW	WL	BkL	BkW	WS
		LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE	LSM±SE
Overall	660	4.1±0.02	3.9±0.04	3.1±0.05	3.3±0.03	3.6±0.04	2.5±0.02	1.6±0.01	40.2±0.09
CV		10.72	22.82	37.78	18.43	24.65	12.48	16.17	3.48
R^2		0.45	0.66	0.58	0.73	0.66	0.10	0.11	0.42
Agro-ecology		**	**	NS	**	**	NS	NS	**
Highland	220	4.0±0.03^{a}	4.0±0.07^{a}	3.1±0.08^{a}	3.4±0.04a	3.7±0.06a	2.2±0.03a	1.6±0.01^{a}	40.2±0.12^{a}
Mid-altitude	200	4.2±0.03^{b}	4.0±0.07^{a}	3.2±0.07^{a}	3.7±0.06b	3.8±0.07a	2.3±0.02a	1.6±0.02^{a}	40.8±0.10^{a}
Lowland	220	3.9±0.03^{a}	3.7±0.06^{b}	2.9±0.07^{a}	3.4±0.05a	3.3±0.07b	2.3±0.02a	1.6±0.01^{a}	39.8±0.11^{b}
Sex		**	**	**	**	**	**	**	**
Male	60	4.7±0.09	5.4±0.17	4.5±0.18	4.7±0.14	5.1±0.15	2.3±0.05	1.7±0.02	42.2±0.17
Female	600	3.5±0.01	2.4±0.02	1.6±0.02	2.2±0.02	2.1±0.02	2.2±0.01	1.5±0.01	38.4±0.06
Sex × agro-ecology		*	*	**	**	**	NS	*	**
Male, highland	20	4.5±0.12^{a}	5.6±0.38^{a}	4.8±0.28^{a}	4.6±0.13^{a}	4.7±0.09^{a}	2.4±0.07^{a}	1.8±0.03^{a}	42.6±0.20a
Female, highland	200	3.4±0.02^{a}	2.5±0.03^{a}	1.6±0.04^{a}	2.1±0.03^{a}	2.3±0.04^{a}	2.2±0.02^{b}	1.5±0.01a	38.2±0.09a
Male, mid-altitude	20	4.9±0.17^{b}	5.4±0.32^{a}	4.4±0.39^{b}	5.1±0.22^{b}	5.6±0.29^{b}	2.2±0.07^{a}	1.6±0.03^{b}	42.5±0.09a
Female, mid-altitude	200	3.6±0.02^{a}	2.5±0.03^{a}	1.7±0.04^{b}	2.5±0.02^{b}	2.3±0.03^{a}	2.2±0.02^{b}	1.6±0.02^{a}	39.0±0.08b
Male, lowland	20	4.4±0.13^{a}	5.2±0.18^{a}	4.4±0.29^{b}	4.6±0.21a	4.9±0.29^{a}	2.3±0.07a	1.5±0.04^{b}	41.5±0.23b
Female, lowland	200	3.4±0.02^{a}	2.2±0.03^{b}	1.5±0.03^{c}	2.0±0.02a	1.8±0.03^{b}	2.3±0.02^{b}	1.5±0.01^{a}	38.0±0.10a

LSM=Least squares means; SE= Standard error; R^2=R-square; CV=Coefficient of Variation; Means with different superscripts within the same column and class are statistically different (at least *P*<0.05); Ns = Non –significant; * Significant at (P< 0.05); **significant at (P<0.01); BW=Body Weight; BL=Body Length; CC= Chest circumference; NL=Neck length; TC=Thigh circumference; SL=Shank length; HB= height at back; SC=Shank circumference; CL=Comb length; BkL= Beak length; BkW= Beak Width; WL= Wattle length; CH=Comb height; WW=Wattle width.

Effect of agro-ecology, sex and their interaction

Agro-ecology

Body weight (BW), body length (BL), chest circumference (CC), neck length (NL), thigh circumference (TC), shank length (SL), height at back (HB), shank circumference (SC), comb length (CL), wattle width (WW), wattle length (WL), and Wing Span (WS) showed a significant difference (P<0.05) among the studied agro-ecologies. However, beak length (BkL), beak width (BkW), and comb height (CH) were not significantly (P>0.05) different. Similarly, Melesse and Negesse (2011) indicated that significant differences were observed in CC, SL, NL, BL, WL, WS, WW, CL, and HB of local chicken ecotypes across all agro-ecologies of Tigray's central zone. The body weight of chickens (1.8±0.02 kg) in the mid-altitude was significantly higher (P<0.05) than chickens in the highland (1.7±0.01 kg) and lowland agro-ecologies (1.7±0.01 kg). The variation in body weight might be due to the existence of many strains, management practices, and production systems among the studied agro-ecologies. The mean body weight of chicken (1.8±0.02 kg in mid-altitude) was higher than Tareke et al. (2018), who reported that chickens reared in the Bale zone Oromia regional state weighed 1.1 kg and Assefa and Melesse (2018) who found that the overall mean body weight of indigenous chicken in Sheka zone was 1.68±0.2 kg. The

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mean body weight of chickens in the current study indicated that local chickens were heavier in the studied agro-ecologies. This implies they are more productive for carcass production. This agrees with there is strong correlation with meat yield and body weight as a proxy indicator of production (FAO, 2012). On the other hand, the CC values for highland, midland, and lowland were 26.6±0.09, 27.2±0.09, and 26.80±0.08 cm, respectively.

The result on CC was higher than the values (25.4±0.1 cm) of Tareke et al. (2018) for indigenous chicken in Bale zone. The wingspan values were 40.2±0.12, 40.8±0.10, and 39.8±0.11 cm in highland, mid-altitude, and lowland agro-ecologies, respectively, and the wattle width values were 3.4±0.04, 3.7±0.06, and 3.4±0.05 cm, in similar agro-ecologies respectively. The result on the wingspan was lower than the values (50.7±3.1 cm for males and 44.5±2.1 cm for females) of Assefa and Melesse (2018) for indigenous chickens in the Sheka zone.

Sex

Table 3 shows the average live body weight (kg) and other linear body measurements (cm) as affected by sex. The current results showed that sex had a significant ($P<0.05$) effect on body weight (BW), body length (BL), chest circumference (CC), neck length (NL), thigh circumference (TC), shank length (SL), height at back (HB), shank circumference (SC), comb length (CL), comb height (CH), wattle width (WW), wattle length (WL), wingspan (WS), beak length (BkL), beak width (BkW). The effect of sex on body weight and other body linear parameters found in this study agree with those of Melesse and Negesse (2011) for indigenous chicken in different Ethiopian zones, Assefa and Melesse (2018a,b) for Sheka indigenous chicken, and Tareke et al. (2018) for Bale indigenous chicken.

In all statistically analyzed linear body measurements, the male chicken was significantly higher ($P<0.05$) than its female counterpart; such variations might be attributed to the differential effects of testosterone in optimizing growth on muscle development and growth in general, as well as a more strong selection pressure on males than females (Islam et al., 2021). The lower body measurement values observed in this study for female chickens than for male chickens were also consistent with the findings of Fitsum (2015) who found that sexual dimorphism in chickens was manifested in a wide range of body attributes and across most breeds. This could be due to sex hormones, which may encourage males to build more muscles than girls.

Sex and agro-ecology interaction

The interaction of sex and agro-ecology had a significant effect ($P<0.05$) on SL, HB, SC, CL, BkW, BW, BL, CC, NL, TC, CH, WW, WL, and WS. However, they were not significant ($P>0.05$) for BkL. On contrary, Fitsum (2015) found that the interaction of sex and agro-ecology had no statistically significant ($P>0.05$) effect on BW and other linear body measurements of local chickens in the central Tigray zone. The significant variation in interaction between sexes and agro-ecology indicates the presence of distinct subgroups within the local chicken population. This diversity allows for genetic improvement both between and within sub-populations. The average body weights (BW) of male chickens in highland, mid-altitude, and lowland areas were 2.1±0.02, 2.2±0.05, and 2.0±0.03 kg, respectively. Males and female chickens were heavier at mid-altitude (2.1±0.02 and 1.5±0.04 kg) than the weight of chickens in highland (2.2±0.05 kg and 1.4±0.03 kg) and lowland (2.0±0.03 and 1.4±0.01 kg) agro-ecologies (Table 3) which corresponds to the finding of Hailu et al. (2018 a,b) who reported that the average body weight of male and female chicken in Guji zone was 2.1±0.05 and 1.5±0.02 kg, respectively. However, the result was higher than the values of Fitsum (2017) who indicated that the average live body weight of chicken in chicken midland and highland agro-ecologies were 1.36±0.02 and 1.36±0.03 kg, respectively.

Males' body length in highland, mid-altitude, and lowland agro-ecologies was 42.3±0.15, 42.2 ±0.39 and 41.5±0.24 cm, respectively, whereas for females about 37.3±0.10, 38.4±0.09, and 37.3±0.12 cm, were recorded in highland, mid-altitude, and lowland agro-ecologies, respectively. Chest circumference in male chickens was 28.8±0.22, 29.4±0.26, and 28.9±0.27 cm, and similarly, for females, 24.5±0.04, 25.1±0.05, and 24.7±0.05 cm were reported in highland, mid-altitude, and lowland agro-ecologies, respectively. The results on the measurements of the chickens' chest circumference and body length were consistent with those of Tadele et al. (2019) who found average body lengths of 41±0.11 and 37.4±0.08 cm for males and female chickens, respectively. Furthermore, Hailu et al. (2018) revealed that male and female indigenous chickens in the Guji zone had chest circumferences of 27.6±0.01% and 25.3±0.06%, respectively, and that the body length of indigenous chickens was 41.1 cm.

Neck length showed 13.1±0.13, 13.0±0.08, and 12.5±0.22 cm for males and 9.8±0.08, 10.0±0.05, and 9.1±0.08 cm for females in highland, mid-altitude, and lowland agro-ecologies, respectively. The shank length in highland, mid-altitude, and lowland agro-ecologies for male chickens was 8.7±0.09, 8.0±0.13, 7.9±0.14 cm, respectively, while for females it was 7.3±0.02, 7.2±0.02, and 7.0±0.02 cm, respectively. The current finding is similar to the report of Alebachew et al. (2019) who showed that shank length was 8.1±0.89 and 6.8±0.94 cm for males and females, respectively, while neck length was 12.6±3.2 and 10.8±2.13 cm for males and females in Benshangul Gumuz district. The findings were also in line with Tadele et al. (2019), who found that the average shank length of indigenous chickens in North Gondar was 8.1 cm and 7.49 cm in the Keffa zone (Tadele et al., 2019). The male wingspan was 42.6±0.20, 42.5±0.09 and 41.5±0.23 cm, while for the female it was 38.2±0.09, 39.0±0.08 and 38.0±0.10 cm, in Highland, midland and lowland agro-ecologies, respectively. The current finding was lower than Getachew and Negassi (2016) who stated that the wingspan of indigenous chickens in the study region was 70.34 cm for males and 60.87 cm for females, respectively in Bench-Maji zone. However, Guni and Katule (2013) found similar results for hens at 47.6 cm raised in Tanzania's Southern Highlands. The results of this study's wingspan were equivalent to those reported by Tadele et al. (2019) in the Keffa and North Shewa zones. In the current study, indigenous chickens had wingspans of 38.8 cm and 38.45 cm.

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Body weight of young chickens reached for market

The average body weight of mature indigenous chickens at marketable weight is shown in Table 4. There was a significant (P<0.05) difference in body weight between the sexes and across the study agro-ecologies. The average body weight of local adult chicken was 1.45±0.02 kg, which was higher than Aklilu et al. (2013) who reported values for Ethiopia's Horro and Jarso districts (1.29 kg and 1.12 kg, respectively), Yami and Dessie (1997) who reported values for Ethiopia's central highlands (1.04 kg) and Mogesse (2007b) who reported values for northwest Ethiopia (847.77 g). Similar to the current findings, Hailu et al. (2018 a,b) found higher average body weight results for indigenous chicken populations in Guji zone than the current finding. The body weight of chickens reaching market age in the midland was significantly higher (P<0.05) than in the lowland and highland agro-ecologies (P<0.01), implying that chickens in the mid-altitude weigh better at market age and/or reach market age at an earlier age than those in the lowland and highland agro-ecologies. The sex of chicken had a significant influence on body weight at market age (P<0.05) in this study. These might be due to management or environmental factors, within this age group; the average body weight for both sexes was 1.71±0.01 kg for men and 1.45±0.02 kg for females, respectively. The current finding for both sexes is in accordance with Agarwal et al. (2020) for native chickens of the Chotanagpur plateau of Jharkhand. However, Sanka and Mbaga (2014) found lower results for Tanzanian local chicken reared under intensive and semi-intensive production systems than the current research output. The result pertaining to body weight was higher than Padhi (2016), for indigenous chicken ecotypes. Sexual dimorphism is between the traits where the male chicken has a higher body weight when compared to the female chicken (Sanka and Mbaga, 2014). Body weight of both sexes at market age was significantly affected by agro-ecology and sex interaction (P<0.01). Males in the mid-altitude zone (1.8±0.05 kg) weighed more than those in the lowland zone (1.7±0.02 kg) and the highland zone (1.6±0.03 kg). Females in the mid-altitude, lowland, and highland agro-ecologies, respectively, weighed 1.5±0.01, 1.5±0.04, and 1.4±0.02 kg at market age.

Body weight prediction

The use of regression equations to predict animal weight from other easily obtained linear body parameters is critical in animal selection and marketing (Taye et al., 2016). The precision of functions used to forecast live weight or growth parameters from live animal data helps livestock producers to save a lot of money and time (Rojo-Gimeno et al., 2019). Bodyweight is a crucial measurement in poultry production since it is used to determine not only growth and feed efficiency but also economic and management choices (Dahloum et al., 2016).

However, a scale may not be provided in other situations. Scientists have developed prediction models to estimate live weight using linear body measurements due to practical problems in measuring live weight at the field level (Dahloum et al., 2016). Multiple regression models are excellent for forecasting animal body weight. However, because of the large number of predicted variables in the model, their biological interpretation might be misleading (Mendeș, 2009).

Multiple regression models were constructed for the estimation of body weight (BW) from other body linear measurements. Body length (BL), Chest circumference (CC), Neck length (NL), thigh circumference (TC), Back height (HB), Shank length (SL), Shank circumference (SC), Wingspan (WS), Comb length (CL), Comb height (CH), Wattle width (WW), Beak length (BL), and Beak width (BW) were all the measurements. Stepwise regression was used to choose independent variables for both sexes in each agro-ecology by entering all of the following features except BkL one at a time for males and females. Due to its bigger contribution to the model than other variables, chest circumference was consistently selected and put into the model in step one of stepwise regression among sex and agro-ecologies. This conclusion was in line with Liyanage et al. (2015) who found significant connections between body weight and every linear characteristic using regression analysis, with chest circumference and shank length being the strongest predictors of live weight in Sri Lankan village chickens. In the second phase of stepwise regression, two independent variables were chosen to be included in the model, three independent variables in the third step, and so on. The process of adding significant (P<0.05) and best among the rest of the variables to the model proceeded in phases until no other variable matched the P<0.05 significance threshold for inclusion. A selection of variables was used in each step after analyzing all variables to see whether any should be eliminated at that phase. For both sexes, the number of variables included in each stage, parameter estimates, and their contribution in terms of coefficient of determination (R2), root mean square error (MSE), Mallows C parameters C (p), Alkaike's Information Criteria (AIC), and Schwarz Bayesian Criteria (SBC) as shown in (Table 5). The coefficient of determination (R2) shows the percentage of total variability that the model accounts for.

In males, chest circumference was the first variable to explain more variation than other factors (87–90%), whereas BL was the first variable to explain more variation in females (59–80%).In line with the current study, Yakubu et al. (2009) and Ajayi et al. (2012) reported that body length (BL) was the most important contributor to variation in body weight in normal feathered Nigerian indigenous chickens. CC explained more variance for males (85% to 91%) than other variables under mid-land agro-ecology, but BL explained more variance for females (54% to 73%) than other body linear measurements. Similarly, in lowland agro-ecology, for males, CC explains (80 to 84 %) more variance for males than the remaining factors in lowland-agro-ecology, but BL for females had the first variable (69 to 80 %) to explain variance. In general, the R2 value of CC for males was lower in lowland agro-ecology than in the highland and mid-altitude agro-ecologies, but the R2 value of BL for females was lower in mid-altitude agro-ecology than in both highland and lowland agro-ecologies.

In highland altitude, y =-1.02 + 0.10 CC for male and y =-1.15 + 0.07BL + 0.09 NL for female, y =-1.06+ 0.11 CC for male and y =-0.76+ 0.04 BL + 0.06 TC for female in midland, and similarly, y =-0.90 + 0.10 CC for lowland male and y =-1.33 + 0.07 BL. As a result, CC for males and BL for females was the best predictor for predicting chicken body weight above other factors.

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Table 4 - Least squares means (LSM) ± standard error (SE) of live body weight (kg) of indigenous chickens reached for market the main effect of agro-ecology, sex, and sex by agro-ecology interaction

Levels	Number	Body Weight
Overall	180	1.6±0.01
R^2	180	0.36
CV	180	11.59
Agro-ecology		**
Highland	60	1.52±0.02[a]
Midland	60	1.66±0.04[b]
Lowland	60	1.56±0.1a
Sex		**
Male	120	1.71±0.01
Female	60	1.45±0.02
Sex × agro-ecology		**
Male; Highland	40	1.6±0.03[a]
Male; Mid-altitude	40	1.8 ±0.05[b]
Male; Lowland	40	1.7±0.02[c]

R^2=R-square; CV=Coefficient of Variation; Means with different superscripts within the same column and class are statistically different (at least P<0.05); **significant at (P<0.01).

Table 5 - Multiple regressions between body weight and other linear measurement for both sexes in study agro-ecology

Agro-ecology	Sex	Model	Intercept	β_1	β_2	β_3	β_4	β_5	R^2	C(P)	AIC	Root MSE	SBC
Highland	Male	CC	-1.02	0.10					0.87	9.18	-125.6	0.04	-123.6
		CC+TC	-0.68	0.07	0.03				0.90	1.57	-129.6	0.03	-126.6
	Female	BL	-1.26	0.07					0.59	230.3	-918.1	0.10	-911.5
		BL+NL	-1.15	0.04	0.09				0.73	81.3	-1003.5	0.08	-993.6
		BL+NL+SC	-1.24	0.04	0.08	0.07			0.76	50.5	-1026.9	0.07	-1013.7
		BL+NL+SC+HB	-1.55	0.03	0.07	0.06	0.02		0.79	30.2	-1044.0	0.07	-1027.7
		BL+NL+SC+HB+WL	-1.47	0.03	0.06	0.07	0.02	-0.02	0.80	21.7	-1052	0.07	-1032.2
Mid-altitude	Male	CC	-1.06	0.11					0.85	2.3	-99.20	0.07	-97.2
		CC+BL	-0.59	0.06	0.07				0.90	-1.4	-104.8	0.06	-101.9
		CC+BL+SL	-4.19	0.05	0.09	0.08			0.91	-0.5	-104.6	0.06	-101.4
	Female	BL	-0.78	0.05					0.54	141.6	-1058.5	0.07	-1051.9
		BL+TC	-0.76	0.04	0.06				0.67	49.6	-1121.7	0.06	-1111.8
		BL+TC+NL	-0.65	0.03	0.05	0.04			0.73	9.33	-1157.8	0.05	-1144.6
Lowland	Male	CC	-0.90	0.10					0.80	7.77	-109.6	0.06	-107.7
		CC+TC	-0.87	0.08	0.03				0.84	4.82	-112.3	0.05	-109.3
	Female	BL	-1.33	0.07					0.69	110.1	-980.5	0.08	-973.9
		BL+NL	-0.95	0.05	0.04				0.78	18.4	-1051.7	0.07	-1041.8
		BL+NL+HB	-1.45	0.04	0.04	0.03			0.80	5.23	-1064.5	0.06	-1051.3

R^2=R-square; MSE=Mean square of error; C(p)=Mallows C parameters; AIC =Alkaike's Information Criteria; SBC =Schwarz Bayesian Criteria

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CONCLUSION

The qualitative and quantitative features of indigenous chicken ecotypes showed significant phenotypic variation among sex and across agro-ecologies. The existence of significant genetic variability in indigenous chickens is supported by the large diversity of indigenous chicken phenotypes. The current study was one of the steps taken to document the chicken ecotype in the study area. Thus, the information could provide a better direction for developing a breeding plan for the improvement and conservation of indigenous chicken ecotypes. To improve the standardization of phenotypic descriptors, conservation, and genetic utilization, an in-depth molecular study is required to verify the level of genetic heterogeneity and relationship among indigenous local chicken ecotypes.

DECLARATIONS

We declare that this research work is original and has not been published elsewhere.

Corresponding Authors
Mekuanent Baye Wobetu; Email: mekuanent12@gmail.com

Authors' Contribution
All authors contributed equally in conducting and writing the research

Conflict of interest
There are no conflicts of interest declared by the authors.

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