



Research article

Production performance and egg quality evaluation of indigenous chickens across different agro-ecologies of Southern Ethiopia

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Abstract

Indigenous chickens were evaluated for their egg production, growth performances, and external and internal egg quality parameters across three agro-ecologies. For experiment, 540 (180 male and 432 female) chickens were distributed to the three agro-ecologies (lowland, midland, and highland) at their 20 weeks age. Body weight was recorded from each chicken during distribution, 4th week, and 8th week after distribution into pre-selected households. Egg production potential was identified from the indigenous chickens across different agro-ecologies. Moreover, egg quality traits were evaluated from randomly selected 270 (90 from each agroecology) eggs. Egg production of indigenous chickens in the highland was 47.7 which was highly significantly ($P = 0.0001$) lower number than of midland (54.2) and lowland (51.4). Except for Shell weight, all the external egg quality parameters evaluated were exhibited significant differences across different agro-ecologies. Among the internal egg quality parameters only albumen weight had a significantly ($P = 0.007$) higher in midland than highland. Most of the variation in egg weight was due to the positive correlation with egg length (69%), and egg width (67%). There was a variation for performance and egg quality traits of indigenous chickens in different agro-ecologies, especially better in midland, which might be resulted from the variation in environment, feed resources availability, and better management followed by households.

Keywords: Agroecology, Correlation, Egg production, Egg quality, Indigenous chicken

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INTRODUCTION

In Ethiopia, Indigenous chickens are the most widespread, and almost every rural family own, which provides a valuable source of family protein and income [Tadelle et al. \(2003\)](#). Traditional free scavenging is the common production system (no adequate supply of feeding, housing, and health care). This production system results in poor productive performance of indigenous chickens (low egg production performance, small-sized egg, long sexual maturity of hens and cockerels, high chicken mortality, and chickens were exposed to predators). Non- genetic factors such as feeding, housing, and health care, and other management practices have a much greater impact on production than genetics under a scavenging system of production.

The indigenous chickens have desirable characteristics such as thermotolerance, resistance to some diseases, good egg and meat flavour, hard eggshells, high fertility, and hatchability as well as high dressing percentage [\(Aberra et al., 2005, 2010\)](#). Indigenous chickens are poor in production and reproductive performance which characterized by small-sized eggs, slow growth rate, late maturity (longer reproductive cycle), slow age at first mating, small clutch size, natural learning to broodiness (broodiness for an extended period), and high mortality of chicks [\(Zemene et al., 2012\)](#).

The egg is one of the most essential cheap sources of protein in the human diet across the globe; egg quality is composed of those characteristics of an egg that affects its acceptability to consumers such as cleanliness, freshness, egg weight, shell quality, yolk index, albumen index, Haugh unit and chemical composition [\(Song et al., 2000\)](#). The quality of an egg ascertains the success of a poultry business because it is associated with the acceptability among the consumers [\(Rajkumar et al., 2009\)](#).

Egg quality is a factor that contributes to the better economic price of fertile and table eggs. In general, the characteristics of egg quality have a genetic basis [\(Silversides and Scott, 2001\)](#). Economic success for a production flock is measured with total egg production [\(Monira et al., 2003\)](#). Egg production is believed to be a complex qualitative trait that is influenced by several factors such as breed, nutrition, age, the weight of birds, level of production, management practices, and environmental factors [\(Oluyemi and Roberts, 2000\)](#). Certain traits of economic importance in egg production include egg production, egg quality traits, and other egg indices [\(Oluyemi and Robert, 2000\)](#). The study was started to check whether there are a difference of agro-ecologies for performance of the chickens and egg quality traits with the objectives, to identify productive performances of indigenous chickens at different agro-ecologies and to evaluate egg quality traits of indigenous chickens across different agro-ecologies.

MATERIALS AND METHODS

Study site

The study was conducted at the three agro-ecological zones (lowland, midland, and highland) of the Hadiya zone. The zone is located at the western margin of the great Ethiopian Rift Valley and the fringe of the Gurage mountains in the northern part of Southern Ethiopia. The zone is situated between 7°07'-7° 52'N and 37°29'-38°13'E.

Table 1 Description of agroecological zones

Agroecology	Features (Berhanu et al., 2020)
Lowland	Hot semi-arid, 800-1100 m.a.s.l, low vegetation, rain fall (400-500 mm), agro-pastoral, poor infrastructure
Midland	Hot sub humid, 1501-2500 m.a.s.l, high vegetable, rain fall (1001-1200 mm/year), temperature (16-20°C), mixed farming system, moderate infrastructure
Highland	Humid and sub humid, 1600-3348 m.a.s.l, high vegetable, rainfall (>1300 mm/year), temperature (7-12°C), mixed crop farming, poor to moderate infrastructure

m.a.s.l = meter above sea level, °C = degree Celsius

Sampling

Based on the information indicated in Table 1, three agro-ecologies were purposively identified. For this study, 540 normal feathered indigenous chickens (180 at each agroecology) were kept. The experimental chickens were collected from selected areas of the three agro-ecologies at their 20th weeks of age. At each agroecology, 180 (36 cockerels and 144 pullets) were kept to households that in the three agro-ecologies under 12 purposively pre-selected chicken rearing farmers at each agroecology to be managed under traditional rearing system/scavenging. The management of chickens was almost same under all households across the three agro-ecologies to reduce the effect towards feeding favor.

Data collection

Body weight was recorded both for male and female chickens from the date of distribution at 20 weeks of their age up to the 28th week of their age, and egg production of normal feathered indigenous chickens across different agro-ecologies was counted. Data on egg number was recorded for one calendar year to evaluate average egg production of each chicken per year.

Body weight was measured using a hanging spring balance. The mortality of the chickens due to different factors among the chickens too was monitored.

Moreover, egg quality analysis was done from the chickens distributed across lowland, midland, and highland ecological zones.

External and internal egg quality parameters

Eggs from healthy adult hens were collected to evaluate egg quality traits. The eggs were collected, labeled, and were transported to Hawassa University poultry farm. For egg quality traits, 270 eggs, (90 eggs from each agroecology) were randomly taken and evaluated.

The internal and external egg qualities including egg weight, egg length, egg width, yolk height, yolk diameter, shell thickness, albumen weight, albumen height, yolk weight, and yolk color were determined. Egg weight was measured by using a digital weighing balance (SF-400). Egg length and width were measured by using stainless hardened digital caliper. and egg shape index was calculated using the formula mentioned below. Following the eggs were broken on to a glass covered table and the albumen and yolk heights were measured using PAT.460176 Tripod Micrometer which was made in Japan. Yolk was carefully separated from the albumen and weighed. The cleaned eggshells were dried in the open air for 24 hours and weighed together with the

shell membrane. Then, the eggshell thickness was measured from the two ends and middle position of the egg using a digital caliper and the average of the three was used as a trait.

Based on the collected data, egg shape index, shell ratio, egg surface area, Haugh unit, yolk: albumen ratio, and yolk index were calculated.

Egg shape index

The egg shape index was determined by calculating the width and length of each egg using the formula derived by Reddy et al. (1979).

$$\text{Egg shape index (ESI)} = \text{egg width} / \text{egg length} \times 100.$$

Yolk index

The yolk index was calculated as the ratio of yolk height to yolk diameter without removing the yolk from albumen.

$$\text{Yolk index} = (\text{Average height of yolk/diameter of yolk}) \times 100$$

Haugh Unit (HU)

The unit was calculated for each egg by using the formula suggested by (Haugh, 1937).

$$\text{HU} = 100 \log (\text{H}+7.57-1.7\text{W}^{0.37}).$$

Where H = albumen height and W = egg weight

Yolk color

Yolk color was determined by comparing it with the Roche Yolk Colour (RYC) Fan (F. Hoffman and La Roche Ltd., Switzerland).

Egg surface area

The egg surface area (ESA) was determined by using the formula suggested by (Narushin, 2005).

$$\text{Egg surface area (ESA)} = 3.9782 \cdot \text{EW}^{0.7506}$$

Where EW is the egg weight (g)

$$\text{Yolk ratio} = (\text{yolk weight/egg weight}) * 100$$

$$\text{Albumen ratio} = (\text{albumen weight/egg weight}) * 100$$

$$\text{Yolk Albumen ratio} = (\text{yolk weight/albumen weight}) * 100$$

Data management and statistical analysis

Data were analyzed using SAS and SPSS. When F-test declared significance, Tukey test was used to separate the fixed effect means. Data on growth performances were analyzed by using the following statistical model:

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

Where: Y_{ij} = the overall value of observed variables; μ = overall mean of variables; A_i = the fixed effect of i th agro-ecologies (i = lowland, midland, and highland) and S_j = the fixed effect of sex on the variables (j = male and female), and e_{ij} = random error.

Data on egg production and egg quality trait were analyzed using the following model.

$$Y_i = \mu + A_i + e_i$$

Y_i = overall observations of dependent variables; μ = overall mean of variables; A_i = effect due of i th agroecology (i = lowland, midland, and highland) of j th chicken; e_i = random error term

RESULTS

Live body weight of indigenous chickens

On average 20 weeks aged chickens were collected from the three agro-ecologies and assigned randomly to pre-selected farmers. The body weight of chickens which was taken from their distribution up to the 8th (28th weeks age) week including the status of their week base body weight and their mortality is presented in Table 2.

In 20th week, live body weight was heavier for the chickens in midland than the remaining agro-ecologies; however, there is no significant ($P = 0.267$) difference between body weight of the chickens in lowland and highland agro-ecologies.

Table 2 Mean body weight (kg) of indigenous chickens in different agro-ecologies of Ethiopia

Week	Agro-ecologies (Mean±SD)			P-value		
	Lowland	Midland	Highland	LL vs ML	LL vs HL	ML vs HL
Week 20						
Male	0.83±0.15 ^a	0.95±0.15 ^b	0.79±0.16 ^a	0.0010	0.2670	0.0001
Female	0.53±0.14 ^a	0.59±0.18 ^b	0.50±0.11 ^a	0.0010	0.0730	0.0001
Week 24						
Male	1.14±0.12 ^{ab}	1.15±0.14 ^b	1.08±0.16 ^a	0.9610	0.0590	0.0460
Female	0.71±0.12 ^a	0.78±0.16 ^b	0.69±0.13 ^a	0.0001	0.162	0.0001
Week 28						
Male	1.32±0.11 ^b	1.35±0.12 ^b	1.25±0.12 ^a	0.4430	0.0340	0.0010
Female	0.92±0.11 ^a	0.99±0.14 ^b	0.89±0.10 ^a	0.0001	0.2290	0.0001

^{a,b} Means with different superscript letter in a row are significantly different, LL=Lowland, ML=Midland, HL=Highland

More proportion of male chicken loss (19.4%) was exhibited in lowland agroecology at the first four weeks of their distribution to pre-selected farmers followed by highland agroecology where about 14% of the male chickens were lost during the same week interval. Whereas the higher number of female chickens were lost from highland than the other agro-ecologies within the first four weeks of their distribution.

The next age interval when data were taken from the experiment chickens was 24th to 28th weeks age; where 10.4% of the female indigenous chickens were lost in the lowland and 6.25% of them were lost from each midland and highland.

Table 3 Mortality of chickens [N (percentage)] across different agro-ecologies of the study sites.

Agroecology	Number (total=540)	Time (week)		Total mortality
		20-24	24-28	
Lowland				
Male	36	7 (19.40)	-	7 (19.40)
Female	144	16 (11.10)	15 (10.40)	31 (21.50)
Midland				
Male	36	3 (8.33)	3 (8.33)	6 (16.70)
Female	144	16 (11.10)	9 (6.25)	25 (17.40)
Highland				
Male	36	5 (13.90)	1 (2.78)	6 (16.70)
Female	144	38 (26.40)	9 (6.25)	47 (32.60)

N = number of chickens

External egg traits

The egg production potential and external egg quality traits of indigenous chickens in different agro-ecologies have been shown in Table 4. Chickens in lowland and midland agro-ecologies have produced not significantly ($P = 0.110$) different number of eggs, however, the highland, indigenous chickens produced highly significantly ($P = 0.0001$) lower eggs number while compared to the other agro-ecologies.

The indigenous chickens in midland agroecology had significantly heavier mean egg weight (48.6 g) than the others. Lower mean egg weight was reported to be 46.6 g in lowland and 45.4 g in highland.

Egg surface area (73.3%) was significantly higher in midland agroecology. However, shell thickness (0.31 mm), and shell ratio (9.15%) were significantly higher in highland.

Table 4 Mean egg production and external egg quality parameters of indigenous chickens across different agro-ecologies

Parameters	Agroecology (Mean±SD)			P-value		
	Lowland	Midland	Highland	LLvsML	LLvsHL	MLvsHL
Egg production/hen/year	51.40±10.80 ^b	54.20±11.10 ^b	47.70±8.43 ^a	0.1100	0.0260	0.0001
Egg weight (g)	46.60±5.75 ^a	48.60±5.18 ^b	45.40±5.36 ^a	0.0350	0.3020	0.0001
Egg surface area (mm ²)	71.00±6.57 ^a	73.30±5.83 ^b	69.60±6.16 ^a	0.0330	0.3010	0.0001
Egg shape index (%)	72.70±3.07 ^a	75.10±4.00 ^b	73.60±4.15 ^a	0.0001	0.2750	0.0001
Shell weight (g)	4.04±0.75	4.02±0.64	4.10±0.68	0.9750	0.7930	0.6620
Shell thickness (mm)	0.25±0.06 ^a	0.26±0.09 ^a	0.31±0.05 ^b	0.7510	0.0001	0.0001
Shell ratio (%)	8.77±1.74 ^{ab}	8.30±1.20 ^a	9.15±1.68 ^b	0.1070	0.2390	0.0010

^{a,b} Means with different superscript letter in a row are significantly different, LL=Lowland, ML=Midland, HL=Highland, SD=standard deviation, vs=versus

Internal egg quality evaluation

Internal egg quality parameters are shown in Table 5. All internal egg quality traits have no significant difference across the three agro-ecologies except albumen weight which was significantly higher in midland (P = 0.007) over highland.

Table 5 Internal egg quality evaluation across different agro-ecologies

Parameters	Agroecology (Mean±SD)			P-value		
	Lowland	Midland	Highland	LLvsML	LLvsHL	MLvsHL
AW	24.30±4.49 ^{ab}	24.80±4.09 ^b	22.90±3.70 ^a	0.704	0.065	0.007
AH	5.35±1.13	5.48±1.08	5.36±1.42	0.761	0.998	0.797
AR	52.20±7.56	50.92±5.74	50.60±6.69	0.388	0.249	0.957
HU	76.33±9.01	76.41±9.23	76.55±10.51	0.998	0.987	0.995
YW	16.90±2.60	16.80±2.00	16.40±2.17	0.963	0.272	0.407
YI	40.90±4.28	41.20±3.76	40.50±4.74	0.892	0.784	0.502
YC	9.32±1.54	9.36±1.80	9.22±1.74	0.990	0.917	0.858
YR	36.70±5.84	34.90±4.46	36.40±4.81	0.053	0.950	0.108
YAR	71.20±12.80	69.30±11.50	73.20±13.80	0.599	0.527	0.103

AW= albumen weight, AH=albumen height, YW=yolk weight, YH=yolk height, YD=yolk diameter, YC= yolk color, AR=albumen ratio, YR=yolk ratio, YAR=yolk albumen ratio, HU=Haugh unit

Phenotypic correlations among external egg characteristics

Table 6 shows the correlations between external egg characteristics of indigenous chickens. Egg weight has a highly significant and strong positive (P = 0.0001) phenotypic correlation with egg length (0.69), and egg width (0.67). Likewise, egg weight has a highly significant (P = 0.0001) and negative correlation with shell thickness (-0.23).

While checking for egg width, it was non significantly (P = 0.1194) and negatively correlated with shell thickness (-0.10). The correlation of shell weight was positive with all evaluated external egg quality parameters.

Table 6 Pearson correlation of external egg parameters of indigenous chickens of Ethiopia

Parameters	Egg weight	Egg length	Egg width	Shell weight	Shell thickness
Egg weight	1.0000				
Egg length	0.6900 P<0.0001				
Egg width	0.6700 P<0.0001	0.5400 P<0.0001	1.0000		
Shell weight	0.2700 P<0.0001	0.2300 P<0.0001	0.2500 P<0.0001	1.0000	
Shell thickness	-0.2300 P=0.0009	-0.2100 P=0.0005	-0.1000 P=0.1194	0.0300 P=0.5877	1.0000

Phenotypic correlations among internal egg characteristics

Phenotypic correlations between internal egg characteristics are presented in Table 7. Albumen weight has a negative correlation with albumen height (-0.12), and Haugh unit (-0.28). Albumen weight was highly significantly ($P = 0.0001$) correlated with yolk weight, yolk diameter, and Haugh unit; unlike wise, albumen height did not significantly ($P = 0.0508$) contribute to the variation of the albumen weight.

Albumen height was another parameter that was strongly, positive, and highly significantly ($P = 0.0001$) correlated with Haugh unit (0.96). Highly correlation of Haugh unit with albumen height indicates that 96% of the variation in Haugh unit is due to the albumen height quality.

Table 7 Pearson correlation of internal egg parameters of indigenous chickens

Traits	Albumen weight	Albumen height	Yolk weight	Yolk height	Yolk diameter	Haugh unit
Albumen weight	1.0000					
Albumen height	-0.1200 P=0.0508	1.0000				
Yolk weight	0.3600 P<0.0001	-0.1600 P=0.0080	1.0000			
Yolk height	0.1300 P=0.0296	0.5000 P<0.0001	0.1000 P=0.0950	1.0000		
Yolk diameter	0.3200 P<0.0001	-0.2100 P=0.0006	0.6300 P<0.0001	-0.0800 P=0.2146	1.0000	
Haugh unit	-0.2800 P<0.0001	0.9600 P<0.0001	-0.2200 P=0.0002	0.4700 P<0.0001	-0.2800 P<0.0001	1.0000

DISCUSSION

Egg production and growth performance

Indigenous chickens produce the lowest number of eggs. Egg production per clutch (13.98) in the current study (Table 4) is in line with the reports of (Yadessa et al., 2017) who stated that indigenous chickens produce 14.3 eggs per clutch in Mezhenger, Sheka, and Benchi -Maji zones of Southwestern Ethiopia, and (Solomon et al., 2013) reported 13.56 eggs under existing farmer management condition in Metekel zone of Northwest Ethiopia. Addisu et al. (2013) reported higher number of egg production (16.88) in Quara and lower

number of eggs (11.9) in Tach Annachiho district. The variation in egg production exhibited for different studies might be due to variation in temperature, feed ingredients obtained through scavenging, age of chickens, gene of chicken population, and level of supplementation.

The egg production potential of local chicken is 30-60 eggs per year/hen under village management conditions in Ethiopia. With this potential of indigenous chicken, the demand for egg and chicken meat of Ethiopian populations cannot be satisfied (Geleta et al., 2013). This would imply the need to improve the egg production of indigenous chicken populations across the three agro-ecologies.

The productive performance of indigenous scavenging chickens is low because of their low egg production potential, high chicken mortality, and longer reproductive cycle (slow growth rate, late sexual maturity, and broodiness for an extended period). Pullets and cockerels reached sexual maturity at an average age of 6.4 months and 5.7 months, respectively. Even though the productivity of local chicken is very poor, they are very important to withstand certain harsh environmental conditions and can perform better under poor management than cross and exotic breeds, they are also well known to possess desirable characters, hatch their eggs, excellent foragers, resistance to common poultry disease and special meat and egg quality, and hard eggshells (Abdelqader et al., 2007). The low productivity of the indigenous stock could also partially be attributed to the low management standard of the traditional household poultry production system. It has been seen that the provision of vaccination, improved feeding, clean water, and night-time enclosure improve the performance of the indigenous chickens (Solomon, 2007).

Egg quality parameters

The Average egg weight obtained from the current study is in good agreement with the findings of Yonas et al. (2019) who reported 45.2 g for scavenging indigenous chickens reared around Hawassa. The egg weight of Indian backyard chicken reported by (Mandal et al., 2006) ranged from 35 to 40 g which finds lower than the present work. The mean egg weight of scavenging indigenous chickens in Tanzania reported by (Nonga et al., 2010) is also lower than the current result. Different studies reported varied egg traits due to the difference in study time, breed variation, environmental variation, variation in number of eggs evaluated, management difference and materials used for the study.

Aberra et al. (2013) found the lower measurements across different agro-ecologies of Ethiopia for egg weight (39.4 g in lowland, 40.2 g in midland, 39.3 g in highland), was reported lower; higher for average shell thickness (0.3 mm) than the current study (Table 4). While comparing agro-ecologies, the reports of Aberra et al. 2013 and this study were corresponding to egg weight, the midland agroecology has shown significantly heavier than the other agro-ecologies. The egg weight parameter might be affected by the strains, time of eggs laid, nutrition, environment, variations in managing, and the pre-hatched eggs.

The shell thickness in the present study was comparable with that of Fisseha et al. (2010) who reported that 0.26 mm in Northwestern Ethiopia whereas (Aberra et al., 2010) observed a relatively higher value (0.37 mm) in

Ethiopian naked neck chickens reared under improved production system. And (Desalew et al., 2015), reported on average 0.31 mm shell thicknesses in East Shewa of Ethiopia, which is higher than the current one. The variations in shell thickness among the indigenous chicken ecotypes reared in various parts of the country might be due to the availability of mineral calcium in the feed material they have had, type of management, type of chicken population, and environmental influence (Welelaw et al., 2018). According to King'ori (2012), shell thickness is influenced by calcium availability in layer nutrition and the ability of the hen to absorb calcium by the shell gland. The higher value of shell thickness in highland agroecology (0.31 mm) in the present study might be for the reason that, the better calcium content of the available feed resources they have been scavenged from and it leads to different strength towards egg breakage.

Albumen weight was influenced by the agro-ecological variations. The study conducted by Welelaw et al., 2018 in indigenous chickens of Eastern Ethiopia under traditional management system indicated that the lower records than this study (Table 5) for albumen weight (23.1). The albumen quality may be deteriorated by the ambient temperature.

Haugh unit is considered a typical measure of albumen quality. The Haugh unit of the indigenous chickens in highland (74.17) and midland (76.67) obtained by Getachew et al. (2016) in Western Shoa was comparably less than the report in the current study.

Correlation of egg quality traits

The significant positive correlations between egg weight and egg width observed in indigenous chickens are consistent with previous reports (Yakubu et al., 2008; Yousif and Eltayeb, 2011; Kgwatalala et al., 2016; Markos et al., 2017). Significant and positive correlation coefficients between egg weight and other external egg quality traits, such as egg width, egg length, and shell weight indicate that selection for higher egg weight in indigenous chickens could result in simultaneous positive improvements of the other traits but might negatively influence the shell ratio of local chicken ecotypes that is negatively correlated with egg weight.

As indicated in Table 6, egg length and egg width possess strong correlation to each other. Yakubu et al. (2008) reported a strong, positive, and significant correlation between egg length and egg width ($r = 0.71$) in the free-range naked neck and normal-feathered Nigerian indigenous chickens. Egg length was highly significantly ($P = 0.0001$) and positively correlated with egg width in the different strains of Tswana chickens (Kgwatalala et al., 2016). Significant correlation coefficients between egg length and egg width are because, egg length and egg width determine the holding capacity of an egg. Selection for egg length and egg width will thus result in simultaneous improvement in egg weight.

The correlation coefficients between egg width and shell weight observed in indigenous chicken population is consistent with Yousif and Eltayeb (2011) who reported correlation coefficients in different strains of Sudanese dwarf and naked neck chickens ($r = 0.39$ and $r = 0.37$, respectively). The positive correlation of albumen weight with yolk weight in indigenous chickens in the current study is in close agreement with previous reports that

showed a positive correlation between albumen weight and yolk weight in the Sudanese and Tswana local chickens (Yakubu et al., 2008; Kgwatalala et al., 2016). This implies that selection for improvement in albumen weight might lead to improvement in yolk weight and improvement in albumen weight that could help improvement in the total edible portion of the egg.

CONCLUSIONS

Under the farmers' management system, indigenous chickens perform relatively better in midland agroecology for egg production, growth performance, and most of the egg quality traits than the remaining two agro-ecologies that indicate the variation among indigenous chickens across different agro-ecologies that must be exploited through environmental influence, feed resources, the habit of supplementing and breeding strategies.

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AUTHOR CONTRIBUTIONS

Berhanu Bekele: conceptualization; designing methodology; data collection; formal analysis; writing original draft.

Aberra Melesse: conceptualization; supervision; modifying the manuscript. Wondmeneh Esatu: conceptualization; investigation; supervision; modifying the manuscript.

Tadelle Dessie: conceptualization; investigation; supervision; modifying the manuscript and funding. All authors have read and approved the final manuscript.

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