COMMERCIAL LAYING HEN PRODUCTION AND EGG VALUE CHAIN MAPPING IN NORTHERN ETHIOPIA †

[PRODUCCIÓN COMERCIAL DE GALLINAS PONEDORAS Y MAPEO DE LA CADENA DE VALOR DEL HUEVO EN EL NORTE DE ETIOPÍA]

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SUMMARY

Background: In Ethiopia, commercial farms have increased in farm size, and the majority of the large-scale poultry farms are concentrated around Addis Ababa the capital city of Ethiopia. **Objective:** To assess poultry production, map value chains and identify major production challenges in Northern Ethiopia. **Methodology:** A multistage sampling technique along with a proportionate sample size determination method was used to fix the sample size. Accordingly, 147, 109 and 64 poultry producers were selected from semi-intensive, small-scale, and medium-scale farms, respectively. Nine focus group discussions comprising relevant stakeholders were conducted. **Result:** The earlier age at first egg-laying in weeks was reported as 16.7 ± 0.93 in the medium-scale production system. A high laying percentage of 85.47 ± 5.01 was recorded in the medium-scale and the highest mortality 23.5 ± 8.8 was in semi-intensive. The price of eggs varied by about +38% in November 2019/2020 and negatively changed price by -22% in May 2019/2020. In a ranking exercise, feed cost, feed quality, product marketing, disease, predator, and lack of information and training were ranked top five. Further risk factors were ranked, accordingly, lack of vaccine, poor biosecurity measures, and management were ranked as major causes. **Implication:** The government and private sector should promote improving the feeding habit of the community and improve the management practice. **Conclusion:** The high price of feed ingredients, limited access to veterinary services, poor market linkages in the value chain, poor feeding habits, and poor extension services aggravated by a lack of awareness of producers were the most important challenges affecting commercial production.

Keywords: Poultry farming; Challenges in production; Egg production chain; Production systems.

RESUMEN

Antecedentes: En Etiopía, las granjas comerciales han aumentado en tamaño y la mayoría de las granjas avícolas a gran escala se concentran alrededor de Addis Abeba, la capital de Etiopía. **Objetivo:** Evaluar la producción avícola, mapear las cadenas de valor e identificar los principales desafíos de producción en el norte de Etiopía. **Metodología:** Para fijar el tamaño de la muestra se utilizó una técnica de muestreo multi etapas junto con un método de determinación del tamaño de la muestra proporcional. En consecuencia, se seleccionaron 147, 109 y 64 productores avícolas de granjas semi-intensivas, de pequeña y mediana escala, respectivamente. Se llevaron a cabo nueve debates de grupos focales integrados por partes interesadas relevantes. Resultado: La edad más temprana a la primera puesta de huevos en semanas fue reportada como 16.7 ± 0.93 en el sistema de producción de mediana escala. Se registró un alto porcentaje de puesta de 85.47 ± 5.01 en mediana y la mayor mortalidad 23.5 ± 8.8 fue en semi-intensiva. El precio de los huevos varió alrededor de un +38 % en noviembre de 2019/2020 y cambió negativamente el precio en un -22 % en mayo de 2019/2020. En un ejercicio de clasificación, el costo del alimento, la calidad del alimento, la comercialización del producto, las enfermedades, los depredadores y la falta de información y capacitación se ubicaron entre los cinco primeros. Se clasificaron otros factores de riesgo, en consecuencia, la falta de vacunas, las medidas de bioseguridad deficientes y el manejo se clasificaron como causas principales. **Implicaciones:** El gobierno y el sector privado deben promover mejorar el hábito alimentario de la comunidad y mejorar la práctica de gestión. **Conclusión:** El alto precio de los ingredientes de los piensos, el acceso limitado a los servicios veterinarios, los vínculos de mercado deficientes

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en la cadena de valor, los hábitos alimentarios deficientes y los servicios de extensión deficientes, agravados por la falta de conciencia de los productores, fueron los desafíos más importantes que afectaron la producción comercial.
Palabras clave: Avicultura; Desafíos en la producción; Cadena de producción de huevos; Sistemas de producción.

INTRODUCTION

Poultry production is an important livestock subsector practiced by most rural Ethiopian households (FAO, 2019). In 2020, the national poultry population was estimated to be 57 million where 78.86%, 12.02%, and 9.11% were reported to be indigenous, hybrid, and, exotic, respectively (CSA, 2021), and it plays important role in terms of generating employment opportunities, improving family nutrition, and empowering women (FAO, 2019).

The majority of the poultry production system all over the country is dominated by village or backyard production systems where indigenous chickens contribute largely to the national economy (Moges *et al.,* 2010). In 2017, the livestock sector, in general, contributes up to 40% of agricultural Gross Domestic Product (GDP), nearly 20% of the total GDP, and 20% of national foreign exchange earnings (World Bank, 2017). Meanwhile, indigenous chickens are known for their low production performance due to factors such as slow growth rate, late sexual maturity, and low productivity (CSA, 2021; Simegnew *et al.,* 2015).

As an approach to improve the performance of poultry in Ethiopia, exotic high-performing breeds such as White and Brown Leghorns, Rhode Island Red, New Hampshire, Cornish, and Australorp Light Sussex have been introduced since 1952 including Bovans Brown, Potchefstroom Koekoek, and Sasso (Aman *et al.,* 2017; Simegnew *et al.,* 2015). However, due to the low tolerance of exotic breeds to the local conditions, the program had not scored great success, and farmers have criticized that this distribution of exotic cocks, pullets, and fertile eggs has negatively affected the local poultry's brooding ability and adaptation to low-input feeding systems (Dinka *et al.,* 2010). Nonetheless, the poultry multiplication and distribution centers as an unqualified success, there is evidence that they have helped chicken production in urban and peri-urban areas to become a profitable venture over the last 15 to 20 years, with more families keeping small to medium-size flocks (approximately 50 to 1000 birds) under semi-intensive management (FAO, 2008). Entrepreneurs are also investing in the industry with larger flocks of exotic breeds kept under intensive management (FAO, 2008; Wolde *et al.,* 2011).

Due to the introduction of high-performing improved breeds of poultry and the high demand for poultry products, and the creation of job opportunities in the country, commercial farms have increased in farm size and the number of flocks (Teshome *et al.,* 2017) and close to 45 million table eggs are produced and marketed per annum at the national level, of which close to 15 million table eggs are produced by the commercial sector (Gezahegn and Karl, 2020). The majority of large-scale commercial farms are mainly concentrated near Addis Ababa, the capital city of Ethiopia, while there is an immense increment of medium-scale and small-scale commercial farms in big to small cities of the country (Fisseha *et al.,* 2010; HAPP, 2012).

Likewise, in Northern Ethiopia, commercial poultry production is motivating and many youths are involved in the sector (Teshome *et al.,* 2017). However, the average household in Tigray consumes less than 0.3 eggs per person per week and egg prices in Tigray are highly seasonal with monthly deviations from the annual average ranging between -16 and +13 percent. Egg prices are higher during the Meher harvest season in September and October, about 10 percent above the annual mean. They decrease during December and in March and April, months containing long Orthodox fasting seasons when demand for eggs plummets. During this period, egg prices are about 15 percent below the annual mean (Kalle Hirvonen, 2020). These endeavors are, however, faced with a number of challenges and obstacles as causes to limit the success of commercial poultry production which include disease, biosecurity, feed, poor housing, and low inputs of veterinary services (Tadesse *et al.,* 2017; Teshome *et al.,* 2017). The existing studies on poultry production are focused on one or limited production systems; such as semi-intensive, backyard, and pullet growers, but there is no compiled information or conducted research so far on the production performance of poultry and its value chain in northern Ethiopia under different commercial production systems. Therefore, the aim of the study was to assess commercial poultry production and map value chains for eggs from different commercial poultry production systems and identify their major production challenges. The results will assist policymakers in understanding the challenges that commercial poultry production at different production systems face in Northern Ethiopia.

MATERIAL AND METHODS

Description of Study area

The study was carried out in Tigray, Northern Ethiopia. It covered 13 districts namely, Tahtay-Koraro, Wukro-killite-Awlaelo, Laelay-Machew,

Hawzen, Raya-Azebo, Hintalo-Wejerat, Tahtay-Adyabo, Tselemti, Kafta-Humera, Tsegede, Enda-Mekoni, Ofla, and Ganta-Afeshum. Tigray is located at the northern limit of the central highlands of Ethiopia. The landform is complex and composed of highlands (with an altitude range of 2300-3200 meters above sea level, lowland plains (with an altitude range of <500-1500 masl), mountain peaks (as high as 3935 masl), and high to moderate relief hills (1600-2200 masl).

Sampling Design

In this research, a multistage sampling technique was employed. First, the study area is classified into three agro-ecological zones Highland, Midland, and Lowland. Four districts from highland, six districts from midland, and three districts from lowland were selected purposively based on their commercial poultry production practices. In each district, the production practices were stratified into three production systems as Medium-scale, Small-scale, and Semi-intensive production systems based on the number of poultry kept on the farm (FAO, 2019; Wondmeneh *et al.,* 2017). In each of the selected poultry farms, households were selected randomly. The number of districts in the study area within the agro-ecological zone, poultry producers per district, and producers per farm sizes were selected using a proportionate sample size method to make sure that sampling sites with large populations have the same probability of getting into the sample as those in smaller sites, and vice versa as described in Cochran (1963). Accordingly, 147, 109, and 64 poultry producers were selected from semi-intensive, small-scale, and medium-scale, respectively, making a total of 320 poultry producers used in this study.

Data collection method and tools

Survey

A structured and semi-structured questionnaire was used to generate both qualitative and quantitative data from the poultry producer.

Observation

Direct observation was conducted by using a checklist to triangulate the validity of the data obtained through the questionnaire.

Focus group discussion

To triangulate the data obtained through interviews thirteen focus group discussions (one group per study district) were held. Nomination of discussants was made together with the bureau of agriculture staff based on their knowledge and role in the commercial poultry production system. A total of nine participants (five male and four female) from the bureau of agriculture, restaurants, poultry producers, egg traders, and veterinarians were invited for a focus group discussion (FGD). The date for discussion was set jointly and a reminder invitation was sent to them one week before the date. Discussions were held in one of the government halls of the towns in each study district. The time taken per FGD was a minimum of 120 minutes and a maximum of 150 minutes per FGD. During the FGD different questions were discussed such as characteristics of commercial poultry production, poultry value chain functions, and major production challenges. Unique observations during the discussions were recorded in writing by the researcher during the discussions.

Production parameters measurement

Feed intake (FI), egg production (EP), egg weight, and mortality were estimated using the farm recorded data of the farms. While feed conversion ration per mass and per dozens of eggs was estimated using feed intake over the average egg weight using the following equations:

$$\text{Feed conversion ration} = \frac{\text{Mean daily feed intake (g)}}{\text{Mean daily egg mass (g)}}$$

Data Management and Analysis

Data collected through questionnaires were analyzed using ANOVA, Chi-square, and descriptive statistics of R programming software package R i386 3.4.2.

One-way ANOVA was employed to analyze the initial stock, existing stock, age at first egg laying, laying percentage, egg weight, feed conversion rations, and mortality. The model is expressed as:

$$\boldsymbol{Yij = \mu + Fi + eij}$$

where,

Y_{ij} is Response variables, $\boldsymbol{\mu}$ is overall mean, F_i is effects of farms where i = 1 medium-scale, i = 2 is small-scale, and **i** = 3 is semi-intensive, and $\boldsymbol{eij}$ is random errors with normal distribution. The comparison between the means was performed by Tukey's test.

Chi-square was used to analyze the following parameters: chicken breeds, housing system, water sources, egg collection, and egg price trending were analyzed by descriptive statistics.

Ranking Index

The method of ranking was used for production challenges, disease risk factors, and veterinary service challenges in the study areas as employed by Musa *et al*. (2006):

$$Index = Rn * C1 + Rn - 1 * C2 \ldots . + R1 * Cn / (\mathbf{\Sigma Rn * C1 + Rn - 1 * C2} \ldots . \mathbf{+ R1 * Cn})$$

Where; Rn= Value given for the least ranked level (for example if the least rank is 8th, then R_n = 8, Rn-1= 7, Rn-2=6, Rn-3=5, Rn-4=4, Rn-5=3, Rn-6=2, Rn-7=1), C_n = Counts of the least ranked level (in the above example, the count of the 8th rank = Cn, and the count of the 1st rank = C1).

Mapping the Poultry egg market chain

This was carried out in qualitative and quantitative terms through graphs presenting the key poultry eggs market channels, various actors of the chain, their linkages, and all operations of the chain from input supply to egg supplementation. It was processed using *Microsoft office visio 2007 software.*

RESULTS

Poultry Farm Characteristics

The majority (66%), all (100%), and again all (100%) of the respondents keep exotic Bovans brown chicken breeds in semi-intensive, small-scale, and medium-scale production systems, respectively Table 1. The housing system was statically different ($p<0.05$) across the production systems. In all production systems of semi-intensive, small-scale, and medium-scale chicken production systems, 49.7% (n = 147), 36.8% (n = 109), and 62.5% (n = 40) of respondents reported that they use deep litter housing systems, respectively.

The egg collection frequency shows a statically significant difference ($p<0.05$) among the production systems. The majority (100%) of the respondents on the medium-scale and 58.7% (n = 64) of respondents on small-scale farms collect eggs three times a day, while about 41.3% (n = 45) of them on small-scale, and 16.6% (n = 24) in semi-intensive farms collect dropped eggs any time of the day. In addition, the adopted lighting system across the production systems shows a statically significant difference ($p<0.05$). Except for the medium-scale production system all semi=intensive and small-scale poultry producers 147 (100) and 109 (100), respectively adopted natural lighting systems in their poultry farming while the majority of 53 (82.8%) medium-scale poultry farmers adopted both artificial and natural lighting systems.

Poultry Production Performance

According to the respondents in the study area, the mean average production cycle from the initial to existing stock was 35 to 42 weeks. Moreover, the average age of birds in production is expected to stay for 58 weeks across the production system. Accordingly, the mean average initial and existing stock among the production system shows a statically significant difference ($p<0.05$). The initial stock of the different farms was recorded to be about 813. ± 377.6, 394 ± 99.7, and 84 ± 34.9 in medium-scale, small-scale and semi-intensive farms, respectively, while the existing stock was 739 ± 342.5, 344 ± 89.2, and 63.4 ± 24.3 in medium-scale, small-scale and semi-intensive farms respectively. Age at first egg-laying (AFEL) shows a statistically significant difference ($p<0.05$) among the different production systems. The earlier AFEL in weeks was reported as 16.7 **± 0.**93 in the medium-scale production system followed by small-scale (17.2 ± 1.0), and semi-intensive production systems (19.31 ± 1.57). Other related performance reports showed that a high laying percentage (85.47 ± 5.01%/day) was recorded in the medium-scale farms followed by small-scale farms (82.3 ± 4.7%/day), whereas the lowest laying percentage (65.88 ± 6.2%/day) was reported in semi-intensive farms. Accordingly, the egg-laying percentage per day among farms shows a statistically significant difference ($p<0.05$). In relation to egg production, the egg weight of laying hens across the production system was significantly different ($p<0.05$). The highest mean egg weight (grams) was recorded for medium-scale farms (59.81 ± 1.11) followed by small-scale (59.01 ± 1.44) and semi-intensive farms (53.94 ± 3.34). The feed conversion ratio was shown statistically not different ($p>0.05$). The feed conversion ratio was highest (2.41 ± 0.10) for layers in medium-scale farms and lowest (2.27 ± 0.53) for layers in small-scale farms. Mortality among the production systems showed also a statically significant difference ($p<0.05$). The highest mortality was recorded in semi-intensive farms followed by small-scale farms (12.8 ± 5.2). Whereas a relatively lower mean mortality percentage (9.6 ± 3.8) was registered from medium-scale farms.

Poultry Product Value Chain Mapping

The value chain of the poultry production sector in Northern Ethiopia is relatively simple. As shown in Fig. 1 it includes six main chain actors; namely: input suppliers who control the supply of day-old chicken, pullets, feed, vaccine, and drugs. Poultry producers (accountable for egg and broiler production at different production systems). Chicken product marketers, traders (buy eggs, broilers, and spent layers from the chicken producers and sell to the consumers), and consumers (use the chicken products bought from the

traders or producers to feed themselves. Most medium-scale and small-scale farms in the study area obtained day-old chicks (DOC) from commercial hatcheries, mainly from Ethio-Farms which is located in the capital of the Tigray region, Ethiopia. Whereas, some of the small-scale farms and most of the semi-intensive farms obtained foundation stocks from neighboring pullet grower farms.

Results showed that the majority of commercial layer farms in the medium-scale production systems sell their eggs to large-scale collectors, local shops, and directly to consumers at the farm gate, while those from small-scale sold eggs to their neighbors for private consumption, local shops, egg hawkers, restaurants at farm gate, and sometimes directly on the open market. Semi-intensive chicken producers sell their eggs to hawkers, local shops, neighbors, bakeries, and open markets. Spent laying hens from commercial layer farms on medium-scale and small scales are sold to brokers and sometimes directly to consumers during holidays, but in a semi-intensive farm, these were sold to neighbors, gave them as gifts to visitors, in the local open market, and used them for home consumption. Broilers are mainly reared in a few medium and small-scale farms in addition to their regular layers of farm activities. Broilers from commercial farms are sold to restaurants, and neighbors, in local open markets, and directly to consumers on holidays.

Table 1. Poultry farm characteristics based on different variables.

Variables	Semi-Intensive	Small-scale	Medium-scale	Total	Test	
	N (%)	N (%)	N (%)	N (%)	X^2-Value	p-value
Chicken Breeds						
Exotic	97 (66.0) [a]	109 (100) [b]	64(100) [b]	270 (84.4)	69.7	0.000
Mixed	40 (27.2) [a]	0 (0) [b]	0 (0.0) [b]	40 (12.5)		
Cross	10 (6.8) [a]	0 (0) [b]	0 (0.0) [a,b]	10 (3.1)		
Indigenous only	NA	NA	NA	NA		
Housing System						
Deep Litter	147(100) [a]	109(100) [a]	40(62.5) [b]	296(92.5)	103.784	0.000
Battery Cage	0(0) [a]	0(0) [a]	24(37.5) [b]	24(7.5)		
Half litter half slot	NA	NA	NA	NA		
Water Source						
Tap	105(71.4) [a]	98 (89.9) [b]	0 (0) [c]	203 (63.4)	177.359	0.000
Borehole	11(7.5) [a]	0(0) [b]	0(0) [a,b]	11(3.4)		
Both	31(21.1)	11(10.1)	64(100)	106(33.1)		
Egg Collection						
One time a day	10 (6.8) [a]	0 (0) [b]	0 (0) [a,b]	10 (3.1)	191.672	0.000
Two times a day	78 (53.1) [a]	0 (0) [b]	0 (0) [b]	78 (24.4)		
Three times a day	35 (23.8) [a]	64 (58.7) [b]	64 (100) [c]	163 (50.9)		
Any time	24 (16.3) [a]	45 (41.3) [b]	0 (0) [c]	69 (21.6)		
Lighting system						
Natural	147 (100) [a]	109 (100) [a]	11 (17.2) [b]	267 (83.4)	254.08	0.000
Artificial	0 (0) [a]	0 (0) [a]	0 (0) [a]	0 (0)		
Both	0 (0) [a]	0 (0) [a]	53 (82.8) [b]	53 (16.6)		

Note: N (%) = the number or percent of respondents; [a,b,c] = numbers connected by different letters are statistically significant.

Table 2. Production parameters of Bovans Brown breed across the production systems.

Variables	**Semi-Intensive**	**Small-scale**	**Medium-scale**	**Overall Means**	**Tests**	
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**	**F-value**	**p-value**
Initial Stock (n)	84 ± 34.9	394 ± 99.7	813 ± 377.6	335 ± 328.9	374.8	0.000
Existing Stock (n)	63.4 ± 24.3	344 ± 89.2	739 ± 342.5	294 ± 302.1	395.3	0.000
AFEL (w)	19.31 ± 1.57	17.2 ± 1.0	16.7 ± 0.93	18.1 ± 1.7	125.5	0.000
Laying (%) /day	65.88 ± 6.2	82.3 ± 4.7	85.47 ± 5.01	75.4 ± 10.4	413.3	0.000
Egg Weight (g)	53.94 ± 3.34	59.01 ± 1.44	59.81 ± 1.11	56.84 ± 3.65	80.4	0.000
FCR (g feed g^{-1} egg)	2.33 ± 0.43	2.27 ± 0.53	2.41 ± 0.10	2.33 ± 0.42	1.87	0.154
Mortality (%)	23.5 ± 8.8	12.8 ± 5.2	9.6 ± 3.8	17.1 ± 9.1	125.2	0.000

Note: Age at First Egg Laying (AFEL), Number (n), Week (w), Feed conversion ration (FCR), Gram (g), Percentage (%) Standard Deviation (SD).

Chicken products are transported from producers to collectors and or consumers by carts, carried by human labor, and via public transport. Large volume collectors use mainly Auto rickshaws (Bajaj) for the collection of eggs within the town. The role and services rendered by most value chain supporters were limited to medium-scale and small-scale producers and input suppliers' levels. That means there was no strong support for producers, egg collectors, and processors. In this regard, only the Bureau of Agriculture, Agricultural TVET, University, FEED the FUTURE, REST, and Research Institutes have provided limited training and promotion opportunities.

Egg Marketing and Price Trending

Restaurant owners often gave verbal contracts to commercial layer farms to supply eggs, but neighbors who bought eggs for household consumption preferred to buy directly from farms. Food restaurants had a preference for yellow yolk normal-sized eggs from indigenous chicken farms, while small-sized eggs were sold to brokers who often mixed them with bigger eggs to increase their gross margins. Eggs with weaker shells and those which were cracked were sold to neighbors and hawkers who would use them for home consumption or would boil them and sell them by the roadside. Also, eggs that remained after selling to other traders were sold to hawkers. The peak egg sales seasons are during the time when there is no fasting, particularly among the Orthodox religion followers. During peak season, the price per egg was about 5 ETB (in November 2019) or more, but during the fasting period, especially from February to April (Ethiopian Orthodox longest fasting season) prices could be less than 3 ETB per egg. Figure 2 shows that egg prices in Northern Ethiopia are highly seasonal, with monthly deviations from the annual average ranging between -22% to +38% in 2018/2019 and 2019/2020. Egg prices are higher in September, October, November, and December. They decrease during March and April, months containing long Orthodox fasting seasons when demand for eggs drops. The price change in the two years varied between +38% in November 2019/2020, and -22% in May 2019/2020 compared to the price of eggs in May 2018/2019. The main reason for the negative price change in the area was reported to be drops of demands due to the COVID-19 shutdowns.

Poultry production challenges

Among the constraints, feed cost ranked first across the production systems of semi-intensive, small-scale, and medium-scale with N=27 (index, 0.184), 19 (index, 0.174), and 11 (index, 0.172), respectively (Table 3). The second major production challenge ranked by the semi-intensive farm was poor quality feeds while this was reported as the sixth and fourth production challenge in small-scale and medium-scale production farms, respectively.

The other second production challenge ranked by small-scale and medium-scale production systems was chicken product marketing, while this was ranked fifth production challenge by semi-intensive farms. In small-scale and medium-scale chicken producers the incidence of disease ranked as the third most challenging constraint to chicken production, while it was in the fourth rank in semi-intensive chicken producers. Although individual respondents or individual focus groups could typically identify and describe only a few diseases, overall, the participants, as directed by animal health professionals were able to identify clinical signs for at least 9 diseases and syndromes which include Newcastle disease (ND); diarrhea; chronic respiratory disease (CRD); pasteurellosis; coccidiosis, 'eye disease', endoparasites and fowl pox. In addition, predators were also ranked as the third and fourth major constraints in semi-intensive and small-scale chicken farms, respectively.

Important poultry risk factors and veterinary service challenges

Lack of vaccines, Poor biosecurity, and poor management, was ranked as the most challenging risk factors by all the production systems. Semi-intensive producers identified scavenging (0.224 index (n = 33) as a major risk factor in addition to the lack of vaccines.

Biosecurity measures on most of the farms visited were lacking or likely to be ineffective. Reasons given for the relative lack of biosecurity included both practical concerns (such as the high cost of disinfectants), and beliefs about the disease (such as the perception that biosecurity was only important when chicks were young and more vulnerable to infection). In addition, cleaning and disinfection were uncommon especially in semi-intensive and small-scale farms while introducing replacement stock. During the field observation, it was noted that only a few semi-intensive and the majority of small-scale and medium-scale farms visited had practiced the use of footbath; however, these footbaths were unlikely to be effective on the day of the visit as the solution in one of them was mostly water and the other contained high levels of organic material.

During the ranking exercise of veterinary service challenges, inadequate vaccines and veterinary service inaccessibility were ranked first and second to be the main constraint by medium-scale and small-scale chicken producers. The inadequate vaccine was also

ranked first by semi-intensive farms in addition to small flock size. However, while inadequate veterinary services were identified as a major challenge by all the production systems, most medium-scale producers hired their own veterinarians, despite the knowledge and skills of the service providers being reported as limited.

Some producers from the different production systems reported that poultry vaccines were only intermittently available. Of the respondents who used vaccines on their farms, most of them carry out the vaccination by themselves, using different schedules and dilution levels contrary to the manufacturer's recommendations. In addition, the administration of tetracyclines (accessed directly from pharmacies) to chickens was reported by some of the semi-intensive and small-scale producers even though their effectiveness was poor. None of the respondents who reported using tetracycline were unaware of the dose and many said that they adjusted it according to the severity of the disease. The use of other human antibiotic preparations, including amoxicillin, was also reported by some respondents. Common ethnoveterinary treatments identified by respondents from semi-intensive farms included the use of a plant locally called 'Melia' (*Melia azedarach*), which was used for a wide range of poultry diseases, and pepper and garlic which were used to treat respiratory infections.

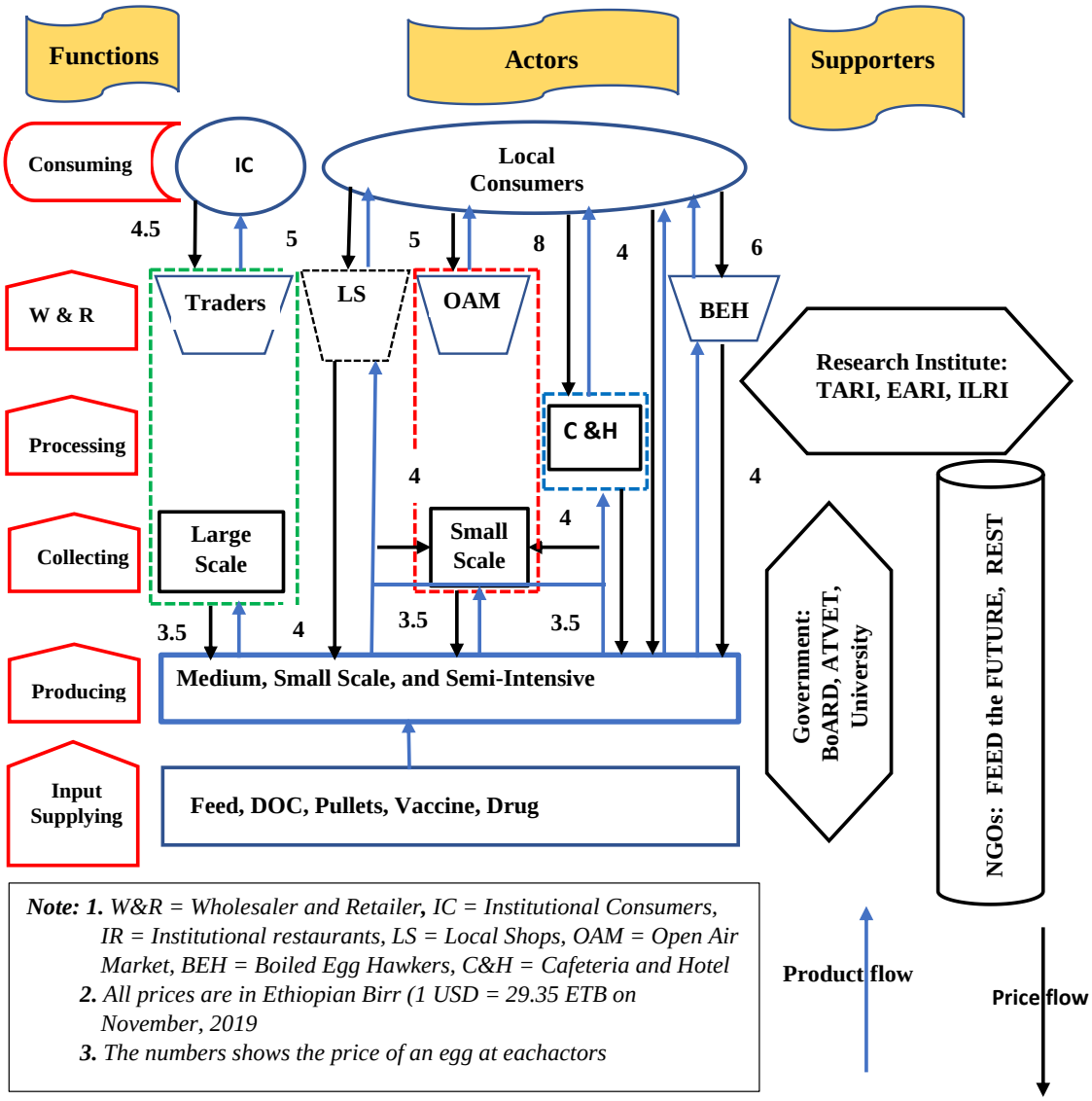

Figure 1. Value chain map for input and products from commercial layer farms in Northern Ethiopia.

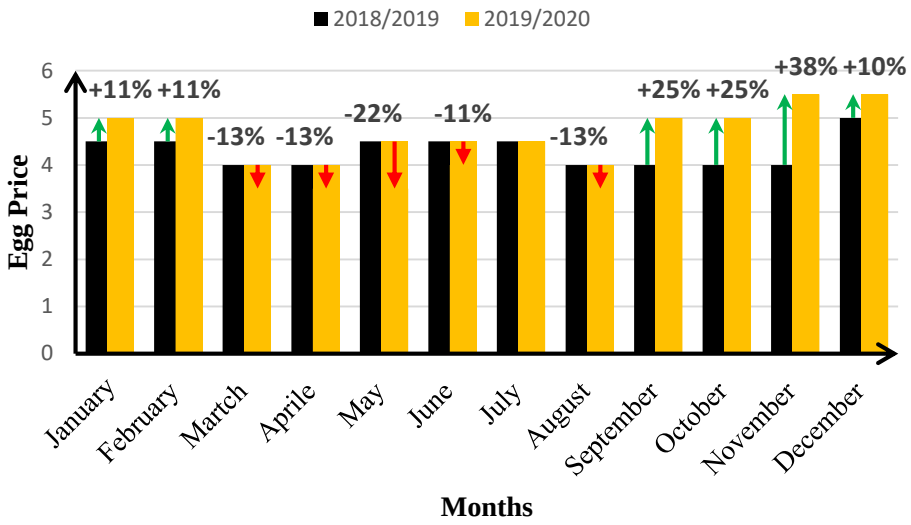

Figure 2. Egg price in ETB trending in Northern Ethiopia at producers' farm gate (Exchange Rate 1 USD = 29.35 ETB in November 2019).

Table 3. Production challenges ranked by individual respondents in Semi-intensive, small-scale, and medium-scale production systems in Northern Ethiopia.

	Semi-Intensive		Small-Scale		Medium-Scale	
Production Challenges	**N (Index)**	**Rank**	**N (Index)**	**Rank**	**N (Index)**	**Rank**
Feed cost	27 (0.184)	1	19 (0.174)	1	11 (0.172)	1
Poor quality feeds	21 (0.143)	2	8 (0.073)	5	6 (0.094)	4
Disease	16 (0.109)	4	14 (0.128)	3	7 (0.109)	3
Lack of veterinary services	6 (0.041)	9	7 (0.064)	6	4 (0.062)	8
Predator	18 (0.122)	3	9 (0.083)	4	3 (0.047)	9
Marketing	15 (0.102)	5	18 (0.165)	2	10 (0.156)	2
Limited land space	7 (0.048)	8	5 (0.046)	9	3 (0.047)	9
Lack of information/training	13 (0.089)	6	9 (0.083)	4	5 (0.078)	5
Water shortage	5 (0.034)	10	2 (0.018)	12	0 (0)	13
shortage of labor	2 (0.014)	13	3 (0.027)	11	2 (0.031)	12
Large capital needs	4 (0.027)	12	6 (0.055)	7	5 (0.078)	5
Sources of Chickens	5 (0.034)	10	5 (0.046)	8	5 (0.078)	5
Poor housing system	8 (0.054)	7	4 (0.037)	10	3 (0.047)	9

(Rank 1 = the major challenge) (Rank 13 = Least challenge)

DISCUSSION

Exotic poultry breeds are major breeds reared in all production systems. Except for a few producers in the semi-intensive production system, most of the commercial poultry producers in all production systems managed exotic breeds. This finding is supported by Wondmeneh *et al*. (2017), and Yared *et al*. (2019) who reported that intensive poultry systems reared specialized exotic poultry breeds. The widely used housing systems in the study area are separate housing practices where the houses are made of corrugated iron with deep litter, with the exception of a few medium-scale farms that are using battery cage housing systems. Most chicken producers have acquired the land for housing their animals from small and micro youth associations, while there are also a few chicken producers who raise their chickens either

on their own lands or on rented land. However, except few medium-scale farm producers who constructed the houses based on the recommended design most of them did not follow the recommended designs. These results are supported by the findings of Desalew *et al.*, (2013), and Aderaw *et al.* (2021) who reported that most commercial poultry houses are made of corrugated iron with deep litter and not constructed based on recommended designs.

Almost all the respondents in the study farms provide water ad libitum for their chickens and they have reported that their water source is tap water and borehole. These findings are in line with the findings of Getu and Birhan (2014) who reported that most of the water sources for chickens in North Gondar, Ethiopia were locally constructed underground water holes with hand-operated pipelines. The majority of poultry producers in the study area collect eggs two to three times a day across the different production systems. They perceived that the longer stay of eggs in the laying nest after it is laid may be exposed to damage and dirty organic matter. The majorly adopted lighting system in the study area is natural. Except, for the medium-production system, a natural lighting system is common. However, an artificial lighting system is a commonly adopted lighting system in medium-scale production systems, especially during brooding times.

The production performance of commercial chicken at different production systems in the study area was assessed. Accordingly, the mean AFEL of Bovans Brown chicken, which currently dominates the different farms in the study area is reported to be 18.1 ± 1.7 weeks. The AFEL in semi-intensive is relatively higher than in small-scale and medium-scale production systems. A slight difference in age at first laying is observed which might be attributed to the feed quality differences and management practices on the different farms. In contrast, the average age of egg at the first laying of Bovans brown chicken was obtained higher at 24.4 weeks under small-scale poultry producers in Eastern Amhara, Ethiopia (Solomon *et al.,* 2018). The slight difference in AFEL might be due to nutrition, lighting intensity, and temperature. When the average age at first laying is low, the economic benefits would be higher.

The average laying percentage in the commercial poultry production in the study area was reported as 75.4 ± 10.4. The medium-scale farms showed relatively better performance in laying percentage followed by small-scale farms. However, in the semi-intensive farm, the laying percentage is low compared to the two production systems in the study area. The finding is supported by Desalew *et al.* (2013), Tomas *et al.* (2017), and Yizengaw *et al.* (2022) who reported that the commercial chicken production sector which uses exotic breeds such as Bovans brown in confinement was astonishing with annual egg production percentage of 73%, 80%, and 73%, respectively. In contrast, (Brhane *et al.,* 2017; Solomon *et al.,* 2018; Aderaw *et al.,* 2021) reported low egg production performance from the same breed. The difference might be due to the husbandry and different feed type supplementation practices.

Table 4. Commonly known poultry disease risk factors and veterinary service challenges reported by respondents.

	Semi-Intensive		Small-Scale		Medium-Scale	
Disease risk factor challenges	**N (Index)**	**Rank**	**N (Index)**	**Rank**	**N (Index)**	**Rank**
Poor biosecurity	29 (0.197)	2	26 (0.239)	3	18 (0.281)	2
Poor management	21 (0.143)	3	31 (0.284)	2	15 (0.234)	3
Scavenging	33 (0.224)	1	0 (0.000)	NA	0 (0.000)	NA
Wet season	20 (0.136)	4	16 (0.147)	4	10 (0.156)	4
Trade of sick birds	11 (0.075)	5	0 (0.000)	NA	0 (0.000)	NA
Lack of vaccines	33 (0.224)	1	36 (0.330)	1	21 (0.328)	1
Vet Service challenges	**N (Rank)**		**N (Index)**	**Rank**	**N (Index)**	**Rank**
Vet accessibility	14 (0.095)	5	27 (0.248)	2	22 (0.328)	2
Lack of expert vets	21 (0.143)	2	25 (0.229)	3	11 (0.164)	4
Lack of vaccines	38 (0.259)	1	31 (0.284)	1	29 (0.433)	1
Ineffective drugs	19 (0.129)	3	11 (0.101)	6	0 (0.000)	NA
Small flock size	38 (0.259)	1	0 (0.000)	NA	0 (0.000)	NA
Cost	17 (0.116)	4	15 (0.138)	5	5 (0.075)	5

(Rank 1 = the major challenge) (rank 5 = Least challenge)

NA – not applicable, as not mentioned (and, therefore, ranked) by any individuals/production systems

As regards the average egg weight, it was reported to be 56.84 ± 3.65 (g). Egg weight varied slightly among production systems, namely small-scale and medium-scale. According to different studies reported from different parts of Ethiopia, the average egg weight of exotic chicken breeds under an intensive commercial production system was 60g (Yirgu *et al.,* 2018; Alemneh and Getabalew, 2019; Yizengaw *et al.,* 2022). A significant difference was observed in the semi-intensive production systems whereas in both small-scale and medium-scale production systems are observed similar egg weight to the previous studies.

The overall average mortality in percent across the different chicken production systems in Northern Ethiopia is reported to be about 17 ± 9.1. The highest mortality rate of 23.5 ± 8.8 percent was observed in semi-intensive farms, whereas about 9.6 ± 3.8 percent mortality rate was reported from medium-scale farms. These findings are in agreement with the results of Tomas *et al.* (2017) who observed about 20.3 ± 2.3% of mortality under the intensive production system by small-scale farmers in Mekelle, Tigray region. In contrast, a slightly lower mortality rate (7.0%) of Bovans Brown in urban areas and 7.8% in peri-urban was observed, and for Sasso T44, it was 3.75% in urban and 3.92% in peri-urban areas (Aderaw *et al.,* 2021). The differences might have come from differences in genotype, production systems, chicken health management practices, and environmental conditions.

The relationship among poultry value chain actors in the study area is very weak and the existing chain in the chicken product market is informal. Most of the actors have no relationships as constant customers and each of the actors focuses only on how to increase their wealth rather than thinking for mutual benefit. According to the focus group discussion, the main reason for the weak relationship among actors was due to a lack of awareness, organizational, and infrastructural problems. These results were consistent with the findings of Goitom *et al.* (2015) who reported that the relationship among poultry value chain actors in the central zone of Tigray, Ethiopia was very weak and the existing chain was informally practiced. However, the study demonstrated that commercial egg-laying birds play a significant role in the provision of eggs to households, food restaurants, collectors, hawkers, and local shops in Northern, Ethiopia. Apart from eggs, these laying birds also provided a source of income from the sale of spent hens and broilers. These are important roles that chickens play in supporting the livelihoods of vulnerable households and creating job opportunities for youths. In a similar study which was conducted in Uganda and Kenya, it was reported that vulnerable households, create job opportunities, and produce income for those who are depended on proceeds from the sale of chicken to support their healthcare, payment of school fees, and purchase other household necessities (FAO, 2009; Joshua *et al.,* 2018).

Chicken products were also marketed through different market outlets, which had significant influences on producers. In the present study, several people had important influences on egg producers. For example, the supply of day-old chicks and poultry feeds was controlled by the hatcheries which were distributed through shops selling agricultural inputs, making them instrumental in the process. Commercial pullet growers purchase exotic day-old chicks and poultry feeds mainly from Mekelle farm having its own parental stock, and feed manufacturing company. However, occasionally they get from Alema farm, Debrezit, Ethiopia, and the distribution of day-old chicks to growers were controlled by the hatcheries even though the number of day-old chicks and the quality of chicks are selected by them (Teshome *et al.,* 2017).

Feed shortage, high feed cost, and feed quality deterioration are among the chicken production challenges agreed upon by most chicken producers. The feed shortage and high cost of feeds result mainly from the ever-increasing price of feed ingredients due to the use of high-cost imported protein sources, such as soybean meal, feed additives, shortage of feed manufacturing plants, supply interruption, and transportation costs. During the group discussion, participants revealed that when feed quality and supply are reduced, they observe a dramatic reduction in egg production, slow growth rate, and susceptibility to diseases. Feed nutrient deficiency and malnutrition weakened the birds and made them susceptible to diseases (Tekalegn et al, 2018). In addition, Emmanuel *et al.* (2015) reported that poor feed quality is identified as a challenge in semi-intensive chicken farm producers. In support of this finding, major constraints of chicken production among poultry producers under an intensive system in Tigray, Ethiopia were lack of information/training to prepare mixed feed, the high price of mixed feed, unavailability of commercial feed in nearby areas, and unavailability and cost of feed ingredients (Tadesse *et al.,* 2017).

Not only feed-related challenges but also, Poultry producers of the medium-scale and small-scale have reported product marketing as the most production constraint. The price of poultry products is determined by the market and most of the time prices of the poultry products are affected during the longest Ethiopian Orthodox church fasting period. In addition, the low feeding habit of the community for poultry products results in difficulties in selling poultry products. The

highest demand for poultry products is reported during holidays. Price instability and marketing difficulties during the selling of poultry products are among the major constraints in the sector (Nebiyu *et al.,* 2016; Yared *et al.,* 2019). On the other hand, in reports in Jigjiga (Somalia region) and Addis Ababa, marketing difficulties are common problems during the selling of poultry products (Mohamed *et al.,* 2016; Nebiyu *et al.,* 2016).

Knowledge of chicken diseases among the participants in this study was poor, and collectively they were unable to name and provide accurate clinical signs for numerous diseases and syndromes except for a few ailments. This is supported by the reports of Pagani and Wossene, (2008) while it is contrary to reports by Emmanuel (2015) who reported that individually and collectively chicken farmers were able to identify numerous diseases and syndromes. This difference may be due to the low and inaccessibility of animal health expertise in the study area.

The challenges identified to affect laying birds in all production systems provide an understanding of differences in problems faced by chicken producers. For example, the medium-scale and small-scale layer farms reported a lack of interaction with government officers and the non-use of veterinarians making these chicken farms vulnerable to disease outbreaks. Similar disconnection with extension services has also been reported for comparable chicken systems in Uganda (FAO, 2009).

CONCLUSION

From the result of this study, it is concluded that the medium-scale poultry production system has a better egg-laying percentage, lower mortality, and relatively better farm performance. The high price of feed ingredients, limited access to veterinary services, poor market linkages in the value chain, and poor extension services aggravated by a lack of awareness of producers were the most important challenges affecting the productivity of the small-scale and medium-scale production systems. The low feeding habit and the two longest Orthodox Tewahedo Church fasting periods 55 days before Easter and the Advent 40 days before Christmas were attributed to poor egg marketing in the study area. There is limited access to veterinary services and producers have limited knowledge of the potential benefits of veterinary services in the study area. The issues that were identified included difficulty accessing veterinarians, low attention from the bureau of agriculture livestock extension for the intensive poultry producers, the cost of their services, and the perception that veterinarians and other animal-health providers lacked expertise in chicken health and production. In addition, poor biosecurity measures and management practices affect on hatching of diseases and high mortality.

Therefore, government and private investors should participate in the establishment of poultry feed processing plants so as to provide feed with standard quality and a minimum price. Feed manufacturing companies should look for locally available alternative feed raw materials that could make a useful contribution to reducing costs. Market linkage creation activities should be made by concerned government and non-governmental bodies to develop a strong poultry value chain in the study area. In addition, awareness creation should actively work to improve egg feeding habits in the study area. Given the current low interaction between the veterinary profession and chicken producers, efforts to increase chicken health and production through veterinary input may need to include both improved training for veterinarians and efforts to demonstrate the benefits of veterinary input to farmers and veterinarians alike. In addition, training should be given on producers' biosecurity measures and their importance. Improve health and medication service/vaccination in the areas by assuring effectiveness and timely service provision by public and private providers.

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Data availability. The datasets generated during the current study are available from the corresponding author on reasonable request (davoma43@gmail.com).

Author contribution statement (CRediT). Dawit Mamo: Conceptualization; Methodology, Data curation; Formal analysis; Investigation; Visualization; Writing original draft and editing. **Mohammed Beyan:** Conceptualization; Data curation; Methodology; Project administration;

Supervision; Visualization and editing. **Wondmeneh Esatu:** Methodology; Supervision; Validation & editing.

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