Economic analysis of egg production in replacing essential amino acids and soybean seed with meat and bone meal in layer rations of exotic chickens

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ABSTRACT

The study was conducted to evaluate the economic analysis of egg production by replacing essential amino acids and soybean seed with meat and bone meal in layer rations of exotic chickens. Ninety Bovan-brown layer hens were randomly selected and allocated to three dietary treatments with two replications using completely randomized design; 15 layers were allocated per replicate. The three dietary treatments were as follows: T1 (control), in which chickens were fed commercial layer ration; T2, in which chickens were fed formulated layer ration with the inclusion of essential amino acids and roasted soybean seeds; and T3, in which chickens were fed formulated layer ration with the inclusion of 10% meat and bone meal. The chickens were fed *ad libitum* for 90 days and the data of feed intake and egg production were recorded for 3 months. Besides, prices of different feed ingredients and commercial layer rations and egg selling prices were taken in July 2020 and February 2024. The economics of egg production were determined using a partial budget analysis that took into account the link between feed intake and egg output. Data were analysed using SAS software package. The treatment means were separated using Tukey's Studentized Range Test. According to the economic analysis of July 2020 and February 2024, T1 had the highest (p<0.001) total gross returns per hen per 90 days (Birr) and followed by T3 while it was the least (p < 0.001) in T2. Besides, both the control and T3 had higher net return (p < 0.001) per hen per 90 days (Birr) than treatment T2. Therefore, it is concluded that alternative and economical layer ration could be formulated with the inclusion of 10% meat and bone meal along with other feed ingredients in layer rations of exotic chickens without using essential amino acids and soybean seed.

Keywords: Economics of egg production; Essential amino acids; Exotic chickens; Layer rations; Meat and bone meal; Soybean seed
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INTRODUCTION

Poultry production plays an important role in Ethiopia's economy. It serves as a significant source of livelihood, food security, nutrition, household income and contributes to the country's economic development (Nigussu *et al.*, 2019). Ethiopia has 59 million chickens

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(CSA, 2021) where poultry farming is deeply embedded in the society and is seen in almost all households from the landless rural poor to the affluent urban population (Hussien, 2023). According to Getnet *et al*. (2022), poultry production provides social and cultural benefits besides its role in family nutrition and income generation. However, the productivity of the chicken is below the expected average. This is mainly due to constraints of quality feed availability and cost of feed ingredients (Shapiro *et al*., 2015). Some of the feed ingredients, particularly those feed sources of the crude protein are very expensive and sometimes inaccessible to the producers (FAO, 2018). Feed is the most important factor which determines the success of poultry business and represents about 70% of the total production costs (Ugwuowo *et al.*, 2019).

In Ethiopia, the price of various commercial formulated poultry rations for different age groups of chickens are increasing at an alarming rate from time to time. The price increase for layer rations in Ethiopia from 2014 to 2021 was greater than 150 per cent. During the same years, however, the price increment for eggs was only 71.4% (own calculation). According to the report of Demissie (2022), the prices increment of layer rations from 2016 to 2021 in Ethiopia was more than 100 per cent. The same author reported that the price of commercial chicken increased by 110.8% within the five-year period. The prices of commercial layer rations have frequently increased, making it unaffordable for Ethiopia's small and medium-scale chicken producers (Tesfa, 2020). Berhane and Tesfaye (2022) had also reported that the prices of various commercially formulated chicken rations have frequently increased making them unaffordable for small and medium-sized poultry producers in Ethiopia and most other nations. According to Seyoum *et al.* (2018), seasonality, shortage and high prices of feed ingredients in Ethiopia were the major challenges for sustainable and affordable delivery of commercial compound feeds. As a result, it is essential to formulate a balanced chicken ration using least cost and protein-rich feed ingredients to reduce the feed costs and enhance the profits obtained from poultry production. Using least cost feeds which are locally available from agro-industrial by-products may help to reduce the feed cost. As feed cost is the major cost from the total costs of chicken production, any attempt to reduce the feed cost may lead to a significant reduction in the total cost of poultry production (Thirumalaisamy *et al*., 2016). Hence, preparing least cost feeds from locally available agro-industrial by-products in chicken rations will help to reduce the total feed cost.

During the rearing and laying periods, chickens should receive enough protein from both plant and animal protein sources to ensure optimum growth and subsequent performance (Berhane and Tesfaye, 2023). Meat and bone meal (MBM) is an important feed stuff in poultry nutrition, due to its high protein content and relatively competitive cost. It has the crude protein (CP) content ranging from 49.5 to 59.4% with a well-balanced amino acids profile including the limiting amino acids of methionine and cysteine for poultry. MBM is also an excellent dietary source for phosphorus and calcium and are known to increase egg shell quality (Hicks and Verbeek, 2016). Likewise, soybean seed (*Glycine max L.*) is an excellent source of protein as it has high content of sulfur amino acid (NRC, 1994), and has an average CP content of about 37-38% and 20% fat on a dry matter basis (Nahashon and Nthenge, 2013). But, the utilization of soybean seed and its by-products (soybean seed cake) are limited due to higher prices. Niger seed (*Guizotia abyssinica*) cake is a protein rich feed with crude protein contents of 22 to 42% (Heuzé *et al*., 2016). Berhane and Tesfaye (2023) also reported that niger seed cake has the CP content of 31.9%.

The use of formulated layer rations for exotic chickens necessitates the replacement of costly feed ingredients, particularly essential amino acids (EAA) and soybean seeds, with more affordable alternatives like meat and bone meal (MBM). This approach is essential for reducing feed costs in layer diets, enabling poultry farmers to achieve higher profits in production. However, there has been limited research on substituting these expensive ingredients with MBM in layer rations. Therefore, the current study aims to evaluate the economic implications of replacing essential amino acids and soybean seeds with meat and bone meal in the diets of exotic layer chickens.

MATERIALS AND METHODS

Description of the study area

The research work was conducted in Ambo University Poultry Farm found in Ambo town, West Shewa Zone, Oromia Regional State, Ethiopia. Ambo town is located approximately between 8^{o} 56'30'' N- 8^{o} 59'30'' N latitude and between 37^{o}47'30" E-37^{o} 55'15" E longitude. It is located 114 km away from Addis Ababa, the capital city of Ethiopia. Ambo town has a mean annual temperature of 18.64 ^{o}C and rainfall of 968.74 mm. The altitude is about 2101 meters above sea level (Gemechu, 2013).

Experimental feed ingredients, feed preparation, and formulated layer rations

The feed ingredients used to formulate experimental layer rations of T2 and T3 were maize, wheat short, niger seed cake, meat and bone meal (MBM), soybean seeds, essential amino acids (EAA) such as methion**in**e, lysine, and dicalcium phosphate, limestone, vitamin premix and salt (Table 1). The layer ration of T2 was formulated with the inclusion of EAA and roasted soybean seeds along with other feed ingredients while the layer ration of T3 was formulated with the inclusion of MBM by increasing the level from 5% to 10% along with other feed ingredients (without the inclusion of EAA and roasted soybean seeds). The MBM content in layer ration of T3 was increased from 5% to 10% to satisfy the requirements of EAA, phosphorus, and calcium. On the other hand, the control commercial layer ration (T1) was purchased from a commercial feed company (Alema Koudijs Feed PLC (AKF) located at Bishofitu in the central Ethiopia.

Before formulating the T2 layer ration, soybean seeds were roasted on a metal pan utilising woody materials as a source of heat energy to inactivate anti-nutritional components such as trypsin inhibitor. Maize, niger seed cake, roasted soybean seeds, and salt were proportionately weighed and crushed with a feed mill to pass through a 5 mm sieve size. In the Feed Processing Unit at Ambo University, the ground feed ingredients and previously ground feed ingredients were added to the mixer machine based on their calculated proportion and then thoroughly mixed. The two formulated layer rations of T2 and T3 had very closer CP content, which were 17 and 16.4%, respectively. Similarly, the energy content of layer rations of T2 and T3 was closer, where the values were between 2890 and 2820 ME kcal/kg of feed, respectively (Berhane Mekete and Tesfaye Engida (2022 and 203).

Table 1.The proportion (%) of feed ingredients used in the formulation of the treatment layer rations

No	Feed ingredients	Proportions of feed ingredients (%)	
		T2	T3
1	Maize grain	54	56
2	Wheat short	8	8
3	Niger seed cake	18	21.4
4	Soybean grains	10	-
5	Meat and bone meal	5	10
6	Methionine	0.1	-
7	Lysine	0.1	-
8	Di-calcium phosphate	0.1	-
9	Limestone	4	4
10	Vitamin premix	0.25	0.25
11	Salt	0.35	0.35
	Total	100	100

* T2 = Treatment 2, formulated layer ration with the inclusion of essential amino acids and roasted soybean seeds along with other feed ingredients. T3 = Treatment 3, formulated layer ration with increasing the level of meat and bone meal from 5% to 10% along with other feed ingredients.

Experimental design and dietary treatments

A total of ninety Bovans brown layers with similar age of 28 weeks and average bodyweight of 1.6 kg were selected from Ambo University Poultry Farm. The selected layers were randomly allocated to three dietary treatments in a completely randomized design (CRD). Each treatment had two replicates comprising of 15 layers per replication and 30 layers per treatment. The three dietary treatments were: T1 (control), chickens of T1 were fed commercial layer ration, whereas chickens in T2 were fed formulated layer ration with the inclusion of essential amino acids and roasted soybean seeds along with other feed ingredients. Treatment 3 (T3), chickens in this treatment were fed formulated layer ration by inclusion of 10% MBM along with other feed ingredients without the inclusion of essential amino acids and roasted soybean seeds (Table 1). The feeding trial was conducted for a period of 90 days.

Management of chickens

The layers were maintained in a deep litter house that was partitioned into six pens using wire mesh and hardboard. Before the trial began, all of the pens and equipment were cleaned, disinfected, and sprayed against external parasites. The concrete floor of each pen was covered with disinfected tef (*Eragrostis tef*) straw at a depth of 10 cm as litter material. The pens were equipped with feeders, waterers and laying nests. The layers were fed weighted amount of feed twice per day both in the morning at 8:30 AM and in the afternoon at 2:30 PM. Clean tap water was always available, and the chickens had free access to it. Generally, the chickens had similar managerial and bio-security practices during the adaptation and experimental period of 90 days. As far as possible, all efforts were made to minimize pain and discomfort for the chickens.

Collection of feed samples and chemical analysis

Representative feed samples from each feed offered and refusals per pen were daily collected and pooled per treatment for the entire experimental period. The samples then were analyzed for dry matter, crude protein, ether extract, crude fiber, and total ash following the proximate method of analysis (AOAC, 1990). The calcium and total phosphorus contents were determined by atomic absorption spectrophotometer and vanado-molybdate method, respectively (AOAC, 1990). The metabolizable energy (ME) content was calculated by indirect method as described by Wiseman (1987**)** as follows: ME (kcal/kg DM) = 3951 + 54.4 Ether Extract (EE) – 88.7 crude fiber (CF) – 40.8 Ash.

Feed intake and egg production

The feed intake of chickens was taken by recording the daily amount of feed offered and feed refusal per replicate. The amount of feed consumed was then determined by deducting the feed refusal from feed offered per replicate. The dry matter intake for each replicate was then calculated by multiplying the feed intake by the respective dry matter percentage of each treatment layer ration. The feed intake of chickens was recorded for 90 days. The layers were adapted to experimental diets for 10 days before the commencement of actual data collection. Eggs produced were also collected both in the morning and evening for each replication.

Economic analysis of egg production

The economics of egg production were analyzed using a partial budget analysis developed by Upton (1979), focusing on the relationship between feed inputs and egg outputs. To assess the impact of feed and egg price fluctuations on profitability, the purchase prices of each feed ingredient and the selling prices of eggs were recorded in July 2020 and February 2024. Net returns were computed at various times.

Feed costs per hen over a 90-day period were calculated by multiplying the feed intake per hen by the prices of the treatment layer rations from July 2020 and February 2024. The costs of layer rations T2 and T3 were determined based on the prices of each feed ingredient during these periods. In July 2020, the calculated prices per quintal for layer rations T2 and T3 were Birr 1372.2 and Birr 1127.2, respectively (see Table 2). At that time, the selling price of the control commercial layer ration per quintal at Alema Koudijs Feed PLC was Birr 1550, while the selling price of one egg in Ambo town was 5 Birr. In February 2024, the prices for formulated layer rations T2 and T3 per quintal rose to Birr 3391.5 and Birr 3135, respectively (see Table 3). During this period, the selling price of the control commercial layer ration at Alema Koudijs Feed PLC was Birr 3990, and the selling price of one egg in Ambo town increased to 12 Birr.

The following formulas were applied for the partial budget analysis:

- Total Gross Return (TGR) per hen over 90 days = Total eggs produced per hen over 90 days × Selling price of an egg (July 2020 and February 2024).
- Net Return (NR) = TGR - Total Variable Cost (TVC), where NR is the net return, TGR is the total gross return, and TVC represents the total variable cost, which in this case is the feed cost.

Table 2.The calculated feed cost for layer ration of T2 and T3 considering the prices of July 2020

No	Feed ingredients	Share of each FI for T2 (%)	Prices per kg (Birr)	Prices for the share of each FI (Birr) for T2	Share of each FI for T3 (%)	Prices for the share of each FI (Birr) for T3
1	Maize	54.0	10	540	56	560
2	Wheat short	8.0	8	64	8	64
3	Niger seed cake	18.0	12	216	21.4	257
4	Soybean seed	10.0	35	350	-	-
5	Meat & bone meal	5.0	20	100	10	200
6	Methionine	0.1	220	22	-	-
7	Lysine	0.1	220	22	-	-
8	Di-calcium phosphate	0.1	120	12	-	-
9	Limestone	4.0	3	12	4	12
10	Vitamin and mineral premix	0.3	120	30	0.25	30
11	Salt	0.4	12	4.2	0.35	4.2
	Total feed cost	100%		1372.2 Birr per Q	100%	1127.2 Birr per Q

* T2= Treatment 2; T3= Treatment 3; FI = Feed ingredient; Q = Quintal. The price of the control commercial layer ration (T1) was taken considering the selling price at Alema Koudijs Feed PLC in July 2020 and it was 1550 Eth.Birr per quintal; and the price of one egg was 5 Birr in July 2020 in Ambo town.

Data analysis

The collected data were analyzed using one-way analysis of variance (ANOVA) and the Statistical Analysis Systems software packages (SAS, 2009). Differences among the treatment means were separated using Tukey's Studentized Range Test (HSD) whenever ANOVA showed significant variation ($p \leq 0.05$) among treatments. The following statistical model was used for the study: $Yij = \mu + Ti + eij$; where: Yij = represents the j^{th} observation in the i^{th} treatment level; the response variable include such as feed intake, economic returns (profitability) etc.; μ = overall mean; Ti = i^{th} treatment effect (feeds) (i= 1, 2, 3); eij = random error.

Table 3.The calculated feed cost for layer ration of T2 and T3 considering the prices of February 2024

No	Feed ingredients	Share of each FI for T2 (%)	Prices per kg (Birr)	Prices for the share of each FI (Birr) for T2	Share of each FI for T3 (%)	Prices for the share of each FI (Birr) for T3
1	Maize	54	33	1782	56	1848
2	Wheat short	8	30	240	8	240
3	Niger seed cake	18	30	540	21.4	642
4	Soybean seed	10	40	400	-	-
5	Meat & bone meal	5	30	150	10	300
6	Methionine	0.1	900	90	-	-
7	Lysine	0.1	550	55	-	-
8	Di-calcium phosphate	0.1	295	29.5	-	-
9	Limestone	4	8	32	4	32
10	Vitamin and mineral premix	0.25	250	62.5	0.25	62.5
11	Salt	0.35	30	10.5	0.35	10.5
	Total feed cost	100%		3391.5 Birr per Q	100%	3135 Birr per Q

* T2= Treatment 2; T3= Treatment 3; FI = Feed ingredients; Q = Quintal. The price of the control commercial layer ration (T1) was taken considering the selling price of at Alema Koudijs Feed PLC in February 2024, and it was 3990 Birr per quintal; and the selling price of one egg was 12 Birr in February 2024 in Ambo town.

RESULTS AND DISCUSSION

Chemical composition of different feed ingredients and layer rations

The results of the chemical analysis of various feed ingredients used in ration formulation, along with the layer rations for each treatment, are presented in Table 4. The analysis revealed that meat and bone meal had the highest crude protein (CP) content at 47.3%, followed by raw soybean seeds (41.9%) and roasted soybean seeds (40.9%). In contrast, maize grain exhibited the lowest CP content at 8.5%. Regarding crude fiber (CF) content, non-roasted soybean seeds had the highest level at 17.7%, followed by Niger seed cake (15.5%) and roasted soybean (14.2%). Maize grain had the least CF content at 4.1%, while wheat shorts and meat and bone meal had CF levels of 5.9% and 6.5%, respectively. This study indicates that roasting soybean seeds effectively reduces CF content. In treatment T2, soybean seeds were roasted before mixing with other feed ingredients to decrease CF levels and mitigate the effects of anti-nutritional factors. Henry *et al*. (2023) noted that roasted soybean performed better than control, boiled, and fermented soybean in monogastric diets. The metabolizable energy (ME) content of different feed ingredients varied from 2250 kcal/kg in meat and bone meal to 3480 kcal/kg in maize grain.

The current study's findings regarding the highest CP content and lowest CF level in meat and bone meal align with those of Hicks and Verbeek (2016), who reported that the CP content of meat and bone meal ranges from 49.5% to 59.4%, although they observed lower CF values, ranging from 1% to 5.1%.

When examining the CP, CF, and energy contents of different layer rations, the CP values ranged from 16.4% in T3 to 17.0% in T2. The CF content was highest in T2 (7.2%) and lowest in T1 (5.2%). The energy content (ME Kcal/kg of feed) of the various layer rations ranged from 2820 in T3 to 2890 in T2 (see Table 4).

The findings regarding CP content in the layer rations (ranging from 16.4% to 17.0%) align with the research of Adeyemo *et al.* (2012), which indicated that chickens fed layer rations with CP contents of 16% and 17% had significantly higher hen-day egg production and a greater number of eggs compared to those fed rations with CP contents of 14% and 15%.

Table 4.The chemical composition (%) of different feed ingredients and layers' rations

Feed ingredients & treatment diets	**DM**	**CP**	**EE**	**CF**	**ASH**	**Ca**	**P**	**ME kcal/kg of feed**
1. Feed ngredients								
Maize grain	92.50	8.52	4.20	4.10	5.80	0.10	0.27	3480
Wheat short	90.53	15.40	4.60	5.85	4.93	0.20	0.34	2640
Niger seed cake	92.10	31.90	6.53	15.50	7.10	0.50	0.30	2460
Soybean (Roasted)	93.20	40.85	8.52	14.15	6.92	0.30	0.50	2560
Soybean (Non roasted)	92.40	41.86	7.45	17.66	6.48	0.35	0.47	2650
Meat and bone meal	93.00	47.30	8.36	6.50	10.70	0.70	0.85	2250
2. Treatment diets								
T1	92.03	16.70	5.43	5.22	10.20	2.18	0.32	2850
T2	90.63	16.95	5.58	7.17	8.53	2.52	0.35	2890
T3	90.83	16.40	5.30	6.40	8.77	3.32	0.37	2820

Note: DM = Dry Matter, CP = Crude Protein, EE= Ether Extract, CF= Crude Fiber, Ca= Calcium and P = Phosphorous. T1= Control, commercial layer ration which was purchased from commercial feed processing unit (Alema Koudijs Feed PLC); T2= Treatment 2; T3= Treatment 3

Concerning the dry matter intake (DMI) and egg production performance of exotic chickens during 3 months experimental period, Berhane and Tesfaye (2022) documented that the average DMI (g/hen/d) was higher (p<0.01) in T3 and T1 (106.8 and 105.2, respectively) than T2 (102.6). Similarly, the average percentage of hen-day egg production (per day per replication) was the highest (p<0.001) in T1 (87.2%), followed by T3 (75.4%) while it was the least (p<0.001) in T2 which was 49.7% (Berhane and Tesfaye, 2023).

Economic analysis of egg production in exotic chickens

The economic analysis of egg production in exotic chickens across different treatments was conducted using a partial budget analysis, focusing on the relationship between feed input and egg output. This analysis utilized feed and egg prices recorded in July 2020 and

February 2024, allowing for an evaluation of how price fluctuations impacted the profitability of egg production over time. The results of this analysis are presented in Table 5

Table 5. Economics of egg production in exotic chickens considering feed prices in July 2020 and February 2024

Parameters	**T1**	**T2**	**T3**	***F*- value**	***p*-value**
Feed consumed per hen per 90 d	$10.3^b \pm 0.1$	$10.19^b \pm 0.1$	$10.6^a \pm 0.1$	11.8	0.001
Feed cost per hen per 90 d, July 2020	$159.5^a \pm 1.0$	$139.8^b \pm 0.8$	$119.2^c \pm 0.6$	616.1	0.001
Feed cost per hen per 90 d, February 2024	$410.5^a \pm 2.5$	$345.6^b \pm 2.0$	$331.6^c \pm 1.7$	404.4	0.001
Number of eggs produced per hen per 90 d	$77^a \pm 0.6$	$49^c \pm 0.9$	$68^b \pm 0.6$	406.0	0.001
Gross returns per hen per 90 d, July 2020	$383^a \pm 3.1$	$246^c \pm 4.3$	$337.7^b \pm 2.7$	406.0	0.001
Gross returns per hen per 90 d, February 2024	$843^a \pm 6.8$	$541.2^c \pm 9.6$	$743^b \pm 6.0$	406.0	0.001
Net returns per hen per 90 d, July 2020	$223.5^a \pm 3.2$	$106.2^b \pm 4.4$	$218.5^a \pm 2.7$	358.2	0.001
Net returns per hen per 90 d, February 2024	$432^a \pm 7.2$	$196^b \pm 9.7$	$411.4^a \pm 6.0$	284.5	0.001

Note:
- Total feed cost and return in Birr; feed consumed in kg; 90 d = 90 days; d = day.
- Total variable cost in this case feed cost per hen per 90 days (Birr) = Total feed consumed per hen per 90 days as such basis (kg) X prices of layer ration per kg in July 2020 and February 2024;
- Total gross returns (TGR) per hen per 90 days (Birr) = Total number of eggs produced per hen per 90 days X prices of one egg in July 2020 and February 2024, which were 5 and 11 Birr, respectively.
- Net income per hen per 90 days (Birr) in July 2020 and 2024 = Total gross returns (TGR) per hen per 90 days (Birr) in July 2020 and February 2024 minus total variable cost (feed cost) per hen per 90days (Birr) in July 2020 and February 2024.
- The price of control layer ration (T1) per kg in in Alema Koudijs Feed PLC (AKF), Bishefitu in July 2020 was Birr 15.50 while it was Birr 39.90 in February 2024.
- The prices of layer ration of T2 and T3 per kg were Birr 13.72 and 11.27, respectively in July 2020; and Birr 33.92 and 31.35 respectively in February 2024.
- The selling price of one egg in July 2020 was 5 Birr while it was 11 Birr in February 2024.

In terms of total feed cost per hen over a 90-day period, T1 had the highest cost ($p<0.001$), followed by T2, while T3 had the lowest cost ($p<0.001$) in both July 2020 and February 2024. Specifically, the total feed costs (in Birr) for T1, T2, and T3 in July 2020 were 159.5, 139.8, and 119.2, respectively, while in February 2024, the costs were 410.5, 345.6, and 331.6, respectively.

Total gross returns per hen over 90 days (in Birr) were highest ($p < 0.001$) for T1, followed by T3, with T2 yielding the lowest returns ($p < 0.001$) in both periods. The net return (profit over feed cost) per hen over 90 days was significantly higher ($p < 0.001$) for both the control group and T3, compared to T2, in both July 2020 and February 2024 (Table 5). The net returns (in Birr) for T1, T2, and T3 were 223.5, 106.2, and 218.5 in July 2020, and 432, 196, and 411.4 in February 2024. This indicates that higher profits were achieved in February 2024, despite increased feed prices, due to higher egg selling prices (Birr 12 per egg) compared to July 2020 (Birr 5 per egg) in Ambo town, West Shewa Zone, Oromia Region, Ethiopia.

The higher net profit for T3 can be attributed to the use of less expensive feed ingredients, such as meat and bone meal and niger seed cake, instead of costly essential amino acids and soybean seeds. Additionally, T3 achieved significantly higher egg production compared to T2, further enhancing its profitability. Conversely, the control group also generated a higher net profit due to the highest egg production levels. T2's lower net profit resulted from both the lowest egg production and higher feed costs, as it included expensive feed ingredients.

These findings align with Gezali (2017), who reported that substituting expensive commercial feed with cost-effective, non-conventional feed can be profitable due to a higher marginal rate of return. Similarly, Wongnaa *et al*. (2023) demonstrated that using locally available feed ingredients improved the profitability of poultry farmers in Ghana by reducing production costs.

CONCLUSION AND RECOMMENDATIONS

Based on the findings of the current study, it can be concluded that the highest total feed cost per hen per 90 days (Birr) was observed in T1, followed by T2, and the lowest in T3. According to the economic analysis of July 2020 and February 2024, T1 had the highest total gross returns per hen per 90 days (Birr), followed by T3, and T2 had the lowest. The net return analysis indicated that the control and T3 had the highest net return (profit over feed cost) per hen per 90 days (Birr), whereas T2 had the lowest net return based on the economic analysis of July 2020 and February 2024. Hence, an alternative and more cost-effective layer ration could be formulated by using 10% meat and bone meal along with other feed ingredients in layer rations of exotic chicken without using essential amino acids and soybean seed. Therefore, the concerned institutions are strongly advised to provide frequent practical training to poultry farmers in the formulation of economical layer rations for exotic chickens with the inclusion of 10% meat and bone meal along with other feed ingredients without using essential amino acids and soybean seeds.

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Ethics approval and consent to participate

Chickens had similar managerial and sanitary conditions during the adaptation and 90 days of the experimental period. As far as possible, all efforts were made to minimize pain and discomfort for the chickens.

Consent for publication

We all authors declare that the manuscript of the article has not been published or submitted for publication in any other journals

Availability of data and material (and sharing data)

The row data related to the article are available with the corresponding author and could be supplied to the chief editor of the journal when requested.

Conflict of interests

The authors declare that they have no competing interests.

Authors' contribution

BM contributed in conceptualization, methodology, data collection, supervision, data analysis, result interpretation, writing the draft article, rewriting, revising and editing the original article. **TE** contributed in data collection, reviewing and editing the original article. **HN and DK** contributed in reviewing and editing the original article. All authors contributed to the article and approved the submitted version.

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