ORIGINAL ARTICLE

Local feed impact on growth, egg yield, and profitability of Potchefstroom Koekoek chicken in Nekemte City, Ethiopia

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ABSTRACT
This study evaluated the feed intake, growth, egg yield and profitability of Potchefstroom Koekoek chicken fed rations formulated from locally available feed sources at Wallaga University. Ninety 42-day-old chicks were used in the study. The dietary treatments for growers includes: Feed 1. 60% crushed maize grain, 27% soybean, 6.5% lupines, 4.5% noug cake, 1.25% limestone, 0.25% salt and 0.5% premix; Feed2. 0% wheat grain, 13% soybean, 15% noug cake, 1.25% lupines, 0.25% salt and 0.5% premix and Feed3. Commercial diet (positive control). Layers ration composed of: Feed-1. 65% crushed maize grain, 20% soybean, 2.5% lupines, 8.5% noug cake, 3.25% limestone, 0.25% salt and 05% premix; Feed2. 75% wheat grain, 10% soybean, 11% noug cake, 3.25% limestone, 0.25% salt and 0.5% premix and Feed3 Commercial ration. A Completely Randomized Design with three replications was used for the experiment. The average feed intake, final body weight and daily weight gain of the grower chicken were significantly ($p < 0.05$) increased from Feed-1 to Feed-3. Chicken fed Feed-2 ration had the highest ($p < 0.05$) efficiency (0.11 of eggs production. Hens consumed Feed-2 diets were the most profitable group with net return of 80.40 ETB, which was more than threefold compared to the commercial ration (23.30 ETB). The commercial ration (Feed-3) was superior in feed intake and in promoting body weight gain of the chicken while Feed-2 has resulted in the highest efficiency of eggs production. Due to highest egg yield and low feed intake of the birds fed on Feed-2 diets, this is the most profitable treatment in the current study. Since Feed-3 was the one most promoted growth of Potchefstroom Koekoek chicken, it may be more useful for meat yield than eggs. Generally, for more egg production and profitability, Feed-2 is recommended for Potchefstroom Koekoek chicken farming

Keywords: Commercial ration, egg production, growth performance, Profitability

INTRODUCTION

Poultry in Ethiopia is raised and kept within a diverse range of production systems, primarily for meat and egg production. Poultry meat is considered a high-quality animal product, boasting lower cholesterol levels compared to beef, pork, and lamb (Lisitsyn et al., 2017). Poultry farming is also a valuable source of income, particularly accessible to women and children due to its manageable nature compared to large ruminants like cattle. Starting a poultry farm requires relatively low initial capital. Additionally, poultry provide manure for crop fertilization and support integrated production systems such as poultry-fish farming.

In Ethiopia, about 78.85%, 12.02% and 9.11% of the total chicken reported were indigenous, hybrid and exotic, respectively (CSA, 2018). Currently, Koekoek chicken is one of the specialized chicken breeds widely distributed and used in the different parts of Ethiopia. It is a dual purpose composite breed developed from the White Leghorn, Black Australorp and Bared Plymouth Rock (Grobbelaar *et al.*, 2010). Being a tropical breed, Koekoek chicken can be considered as one of most important chicken breeds to overcome environmental stress. The chicken breed is known for its brown eggs and for its attractive deep yellow colored carcass (Grobbelaar *et al.*, 2010). According to Serkalem (2019), the number of eggs/hen/clutch and the number of eggs/hen/year for Koekoek chicken were 26.2 ± 4.40 and 138 ± 32.40, respectively. The major constraints of chicken production in most parts of western Ethiopia, including the study areas, are unavailability and high cost of commercial feeds. Feed is one of the major factors that influence the energy and protein requirements of layers (Mello *et al.*, 2012). Most commercial rations are located in and around the capital city of the country, Addis Ababa. Cost of feeds coupled with transportation expense are the most limiting factors for chicken production in the current study area. That means, commercial ration is not accessible to most of chicken producers of the study area.

The current study, therefore, was conducted to address the shortage of chicken ration by using locally available alternative feed sources through evaluation of the different dietary feeds on feed intake, growth and egg laying performances of Koekoek chicken.

MATERIALS AND METHODS

Description of the study area

The current study was conducted at Wallaga University, Nekemte campus located 328 km from Addis Ababa to the west. The geographic location of the area is 10º5` N latitude, 36º33` E longitude. Altitude of the study area is about 2088 meters above sea level.) The average annual rainfall 1780 mm characterized by mono modal rainfall pattern and its annual mean minimum and maximum monthly temperatures of the city lies/varies between 11.05 and 28.65 ºC (Desalegn and Fanta, 2021).

Experimental animal and feeding management

A total of ninety Koekoek chicks at the age of 42-day were purchased from Nekemte Poultry Production Center and grown and used for the experiment until 20 weeks. The chickens were vaccinated for *Fowl typhoid*, Newcastle and Gumburo a day after arrival at the experimental site. After adaptation of one week to the condition of the farm including feeds, the chickens were assigned into two locally formulated rations and one commercial ration that was used as positive control. The commercial ration was purchased from Ethio-chickens plc where the ingredients were not disclosed by the plc.

The chicks were identified with identification number inscribed on their shank using a permanent marker. They were individually weighed using a digital balance that can measure up to 5000g. The chicks were randomly assigned to three treatment diets with three replications using a lottery system based on their initial live weight. A total of 90 chickens (30 per dietary treatment with three replications) were used. The experimental birds were kept in their respective rooms during the whole experimental period. Dietary treatments were provided *ad libitum*, but measured, to all the three treatments twice a day at 8:00 am and 4:00 pm regularly and adjusted at 20% leftover. Feeds were offered in plastic plate and round feeders and waterer were provided in plastic fountains.

Housing and equipment

The experimental chicks were grown in a house roofed with corrugated iron sheet and concrete floor covered with fine wooden shavings. Bedding materials (i.e. wooden shavings) were replaced as necessary. The house was partitioned based on number of chickens per groups per treatment and the group space requirement as recommended by Galobart and Moran (2005). Each room sufficiently accommodated 30 birds. In each room, one 60-watt bulb was suspended at 45 cm over the floor to offer 16 hours. The upper wall of the chicken house was constructed with mesh wire for proper ventilation. The rooms were cleaned using detergents and disinfected with HI-7 disinfectant based on veterinary professional's guide before the chicks were admitted to the house. Different equipment and materials including feeder, waterer, digital sensitive weighing balance, record book, and chicken identification materials were bought and used to measure and record data. Twelve holes on the side of the feeder facilitated the birds to access feed by only inserting their beaks. There was one separate room for isolation of sick chickens in case any sickness occurred. The rooms were closed to avoid intrusion of predators. Laying boxes were prepared from local materials and kept in dark areas in order to protect them from disturbance by people and other animals.

Dietary treatments and feed formulation

The chicken fed on three different dietary treatments from 7 weeks to 12 weeks as growers and from 13 weeks to 20 weeks as layers. This was because 42 days old chicks were bought and hence about 6 weeks elapsed there at the farm of the owner. The dietary treatments for growers were composed of: **Feed-1**. 60% crushed maize grain, 27% soybean, 6.5% lupines, 4.5% noug cake, 1.25% limestone, 0.25% salt and 0.5% premix; Feed-2. 70% wheat grain, 13% soybean, 15% noug cake, 1.25% lupines, 0.25% salt and 0.5% premix and Feed-3 Commercial diet (positive control). Layers ration composed of: Feed-1. 65% crushed maize grain, 20% soybean, 2.5% lupines, 8.5% noug cake, 3.25% limestone, 0.25% salt and 0.5% premix; Feed-2. 75% wheat grain, 10% soybean, 11% noug cake, 3.25% limestone, 0.25% salt and 0.5% premix and Feed-3 Commercial ration. The feed ingredients were purchased from local market, except vitamin premix and the commercial poultry ration which were purchased from Addis Ababa the Ethio-chicks PLC.

In the current study, soybean grain was used instead of soybean meal which is a food processing byproduct limited to cities and less accessible to most farmers. The feed ingredients were first crushed (coarse) and manually mixed according to NRC (1994). The dietary treatments were formulated by taking the nutrient composition of each ingredient and balancing them with nutrient requirements of layers. The measured dietary treatments were provided *ad libitum* to all the three groups of birds twice a day at 8:00 am in the morning and at 4:00 pm in the afternoon and was regularly adjusted at 20% leftover. The experimental rations, both for growers and layers, were formulated using feed win software as cited by Kasech *et al*. (2019) and Bangu (2020).

Crude protein percent (CP%) and energy content in the feed for experimental birds were formulated as follows: 0 to 4, 5 to 8 and 9 to 16 weeks of age, the CP% was 22, 20 and 20, respectively and the energy content in the feed was 3000, 3100 and 3200 energy kcal kg^{-1} ME, respectively. Commercial layers' ration was fed to chicken in comparison with a ration that was formulated from locally available feeds in order that it contains 15 to 20% CP, 2700 to 2900 kcal kg^{-1} ME based on age of birds as suggested by Dawud (2019).

Experimental design

Using the identification numbers given to the chicks and their initial weight, the chicks were randomly assigned into three treatments each with three replications. The weights for the three treatment groups were taken and the results for Feed-1, Feed-2 and Feed-3 were 407g, 407.1g and 407.2g, respectively. Thus, the experimental design employed was a Completely Randomized Design (CRD).

Data Collection and Method

The feed leftover was collected and weighed everyday morning before providing the next meal to use for determination of feed intake of the birds. Body weight of individual bird was recorded every week using a digital balance and eggs were collected every day. Eggs from each treatment groups were weighed every day in the evening using a digital balance that can measure up to 5000 g.

Local feed sample preparation

The locally available feed resources (maize, wheat, lupine (*L. albus*), soybean, ground Noug cake, limestone, salt and vitamin mix) were used to formulate the experimental diets. The lupine grain was not roasted or not imposed to any feed treatment against anti-nutritionals. All these feeds were pulverized using a miller in order to reduce the particle size so that it would pass through 5 mm sieve size before use in the ration. The feed samples were prepared for the three experimental diets. A handful of the feed samples were collected from each treatment on a clean and dry plastic bag every day during provision of daily ration. At the end of the experimental period, the stored samples were thoroughly mixed and a handful of the feed samples were taken and analyzed.

Feed chemical analysis

Chemical composition of individual ingredients (maize, wheat, lupine, ground noug cake and soybean) and all the three experimental rations (Feed-1, Feed-2, and Feed-3) were determined using the procedures described by AOAC (1990) at the Ethiopian National Veterinary Institute, which is located at Bishoftu. Dry matter was estimated by oven drying the samples at 105ºC for 24 hours. Ash content was determined by burning the samples at 500ºC for 72 hours in a muffle furnace. Ether extract was analyzed by exposing the sample in diethyl ether using a solvent extractor and weighing the dried extract. Crude protein (CP) was estimated using the Kjeldahl method which was used to measure the nitrogen (N) content of the sample. The N content obtained was subsequently multiplied by a conversion factor of 6.25

The Crude fiber was determined by the proximate analysis according to AOAC (1990). Approximately, 1g sample (W_0) was weighed into fritted glass crucibles and hydrolyzed with boiling 0.128 M sulfuric acid followed by boiling in 0.223 M potassium hydroxide solution in a hot extractor. The residue was washed in preheated distilled water before being transferred to a cold extractor and washed with acetone. The residue and crucibles were oven dried at 105ºC overnight and weighed (W_1) before being ignited in a muffle furnace at 450ºC for 8 hours. The residual was first put in an oven at 105ºC overnight then cooled to room temperature in desiccators and finally weighed (W_2). The percentage of crude fiber in the sample was calculated as follows:

$$\%\mathrm{CF} = \frac{W1 - W2}{W0} \times 100$$

Metabolizable energy (ME) of the experimental diets was estimated using predictive equations from the proximate analysis data of the treatments as ME (Kcal kg-1 DM) = 3951 + 54.4 EE – 88.7CF – 40.8 Ash following Wiseman (1987).

Feed intake

Feed refused from each pen was collected and recorded every morning before the daily ration was offered. The amount of feed consumed was determined as the difference between the amount of feed offered and refused. To calculate the mean daily feed intake of each bird the amount consumed was divided by the number of birds'.

$$Average\ daily\ feed\ intake\ (g)\ = \frac{Daily\ feed\ offered\ (g) - daily\ feed\ refused\ (g)}{Number\ of\ chickens'\ present\ X\ Experimental\ days}$$

Body weight measurements

The initial weights of chicks were recorded during their assignment into their respective treatments. Thereafter, they were weighted every week until the end of the experimental period (16 weeks). The weight taken at 20 weeks for layers was considered as final body weight. Average body weight gain/chick/day was determined as the difference between the final and initial body weight divided by the number of experimental days as indicated in the following formula.

$$Average\ daily\ body\ weight\ gain\ (g)\ = \frac{Final\ body\ weight\ gain\ (g) - Initial\ body\ weight\ (g)}{Number\ of\ experimental\ days}$$

Feed conversion efficiency

Feed conversion efficiency (FCE) was determined by dividing the total eggs production (g) with feed intake during laying period indicated below. There were no any death cases of the pullets, which were used for eggs production due to mainly careful handling and proper health care. For this reason FCE was calculated on group bases than per single hen.

$$\mathrm{FCE}\ = \frac{Total\ eggs\ yield\ (g)}{\text{Feed intake (g)}during\ laying\ period}$$

Profitability analysis

Profitability analysis was done in order to evaluate the feasibility of feeding for egg yield of Koekoek (for 20 weeks) and employed following Upton (1979). Feed transportation and labor costs incurred for each treatment group was considered for calculation of the profitability analysis. Each treatment feed cost was calculated by summing up the cost of feed consumed (kg) from each treatment. Revenue from egg produced was calculated as a product of total egg produced by price of one egg considering the market price (ETB/egg) of egg at the time of production (Upton 1979). The net income of feeding layers' diet to the experimental hens was determined as: NR = TR-TVC

Where: NR = net return; TR= total return; TVC = total variable cost. Then, the profitability of each treatment was analyzed and compared based their net return.

Data analysis

Feed intake, body weight change, feed conversion efficiency and egg yield were analyzed using the Generalized Linear Model (GLM) Procedure in the Statistical Analysis System (SAS, 2008). Means were compared using Tukey's Standardized Range Test (HSD), and the significance was declared at $\alpha < 0.05$. Profitability of feeding the chicken with different diets was tested as described by Upton (1979). The statistical model fitted was:

$$Yij = \mu + T_i + e_{ij};$$

Where, Y_{ij} = response variable (i.e., feed intake, bodyweight gained, egg yield, and FCE) of the treatments, μ = over all means, Ti = i^{th} treatment effect (feeds), and E_{ij} = error term.

RESULTS AND DISCUSSION

Chemical composition of feed ingredients

Nutrient compositions of the different dietary ingredients are shown in Table 1. The ingredients included in the experimental diets were selected based on the nutrient requirements of chicken. The dry matter (DM) content of the different ingredients was in the range of 88.4 g kg^{-1} for maize to 98.9 g kg^{-1} for limestone. The least DM content of the maize grain might be due to the residue of moisture left in the grain after sun drying whereas the highest DM contained by the limestone was associated to the fact that it was purchased in packs from the factory.

In the current study, the CP value of soybean was highest (380 g kg^{-1}) followed by Noug seed cake (374.6 g kg^{-1}) and lupine (322 g kg^{-1}). Wheat contains lower values (135g kg^{-1}) of CP whereas the least was for maize (88 g kg^{-1}). While the average CP value for soybean meal was about 450g kg^{-1} (Panagiota *et al.*, 2014), the current figure (380g kg^{-1}) was lower because whole grain was used in the ration formulation. The proportion of CP in the full fat (whole grain) soybean is lower than the CP in soybean meal (Dei, 2011). The EE composition was highest for soybean grain (148.3 g kg^{-1}) followed by noug seed cake (92.6 g kg^{-1}), but the least was for wheat grain. Soybean contained highest EE unlike the rest dietary ingredients due to the highest oil content of the whole grain soybean. Despite its potential oil content in the seed of noug cake, its EE composition was lower than that of soybean grain due to the fact that oil was extracted from it. The metabolisable energy (ME) compositions were highest for soybean grain followed by Maize grain but the least was for noug cake.

The highest EE content for soybean grain had contributed to its highest ME values compared to the other ingredients in the diets. The ME content of maize grain with highest carbohydrates, which followed that of soybean with highest EE, was in agreement with the fact that energy values of lipids was about twice that of carbohydrates (McDonald et al., 2002). The variation in nutrient composition of all the above feed ingredients was mainly due to variation of species or varieties (Sajib *et al.,* 2014). With regard to ash content, limestone was the highest followed by noug cake, but maize was the least. However, maize was the highest in calcium content followed by wheat, but noug cake was the least (Table 1).

The chemical composition of the different rations used for grower was given in Table 2. The DM content of treatments Feed-1 and Feed-2 were almost similar, however that of Feed-3 was lowest compared to Feed-1 and Feed-2. This may be due to the fact that both treatments were composed of similar ingredients with slight differences of quantity, except maize and wheat, major ingredients where either of them used in either treatment. For instance, proportion of maize in Feed-1 ranges from 60 – 65% in both the growers and layers rations and proportion of wheat ranges from 70 -75% in growers and layers ration. Almost related trend was obtained for crude fiber (CF). Highest value of CP was recorded for Feed-1 followed by Feed-3, whereas Feed-2 was the lowest. The highest CP content in Feed-1 might be due to relatively higher proportion of soybean in the ration. The proportion of Ether extract (EE) was highest for Feed-3 (commercial ration) and lowest for Feed-1. The mineral contents such as Ca, P and ME (kcal/kg) were in similar trend with the EE composition.

The DM proportions of Feed-1 and Feed-2 in the layer ration were lower compared to that of Feed-3, which was in the reverse trend of growers' ration (Table 3). The treatments, Feed-3 and Feed-1 had got the lowest values of CF compared to Feed-2. This also holds true for CP. The lowest value of CF for Feed-1 could be an attribute of its maize content whereas the main energy ingredient in Feed-2 was wheat. This is because maize grain contains an average of 2.21% CF (Nibret et al., 2022) whereas that of wheat was 7.3% (Hagos Hailu, 2018). The Ca content consistently increased from Feed-1 to Feed-3. On the other hand, Feed-1 and Feed-2 were almost similar in P content and they contained higher P than that of Feed-3. The ME and EE values increased from Feed-1 to Feed-3. This showed that EE was the dominating energy nutrient in all the rations.

Table 1. Chemical composition of ingredients used in the ration (g kg^{-1} on DM basis)

Ingredient	Maize	Wheat	Soybean	NC	Lupine	Ls	Premix	Salt
DM	884	898	906.3	940	942	989	-	950
CP	88	135	380	374.6	322	-	-	-
EE	48.9	44.7	148.3	92.6	70.8	-	-	-
CF	33.9	46.8	46.3	181.2	128.8	-	-	-
Ca	66.3	27.8	18.6	8.9	12.6	15	-	-
Ash	13.9	31.18	40.82	89.72	41.13	969	-	-
ME	3858.9	3652.5	4169.3	2481.3	3025.9	-	-	-

DM=dry matter; CP=crude protein; ME=metabolizable energy; EE=ether extract; CF=crude fiber; Ca = Calcium; NSC = Noug cake; LS= limestone

Table 2. Chemical composition of different rations (g kg^{-1}) for chickens at different life stage

Chemical composition	Grower stage (g kg^{-1})			Layer stage (g kg^{-1})		
	Feed-1	Feed-2	Feed-3	Feed-1	Feed-2	Feed-3
DM	943	937	890.6	888	895	945
Ash	137	128	139	150.4	132	150
CF	35	37	30.6	28	37	27
CP	188	179	185	162	176	167
EE	43	44	54	57	58	59
Ca	33	34	65	29	33	38
P	9	19	27	18	18	12
ME/kcal/kg	3333	3339	3408	3397	3397	3420

DM=dry matter; CP=crude protein; ME=metabolizable energy; EE=ether extract; CF=crude fiber

Feed intake, body weight change and feed conversion efficiency

The initial weight of the Potchefstroom Koekoek (KK) chicken in the grower phase and for the entire phase did not show significant difference ($P > 0.05$). However, the weight at which the hens started laying eggs i.e., weight at laying phase differed significantly ($P < 0.001$) among the treatments (Table 3). The average Feed intake, final body weight, and average daily gain of chickens were consistently increased from Feed-1 to Feed-3 throughout the growing phases. Chickens (grower and layer) fed on Feed-3 diet (commercial ration) attained significantly (*P* <

0.001) highest growth performance while those fed on Feed-1 were the least. The highest growth performance of Feed-3 was mainly due to highest energy content of the ration among the other treatments while the CP content is almost similar to Feed-1 and Feed-2.

The likely reason for the difference in growth performance between those consumed Feed-1 and Feed-2 diets could be two folds. First, it may be the presence of some essential amino acids in wheat grain, which helped those chickens fed Feed-2 diets perform more than those fed on Feed-1. Secondly, the existence of anti-nutritional factor such as Raffinose, phytate and polyphenols in lupine (Kefale et al., 2022) that was included in Feed-1 diet, might have suppressed growth of the chickens by affecting the mineral utilization of the birds that fed on Feed-1 and by causing flatulence and abdominal discomfort (Rajarshi et al., 2023).

The highest Feed intake reported for birds fed on Feed-3 ration, despite its highest energy content (3407.5k cal/kg), was mainly attributed to two factors. Firstly, their relatively higher weight gain might have led the chicken to require more diets and hence consumed the highest volume of ration. Secondly, the least fiber content (30.6 g kg^{-1}) of the ration in Feed-3 also contributed to the highest level of feed intake of the chicken.

The chicken feed intake in this study was lower than 102 g and 115g reported for KK chicken breed (Roberts and Gunaratne,1992; Kitalyi, 1999) . Such differences might be due to Feed related factors and weather conditions under which the chickens were managed.

The chickens with highest average daily feed intake (Feed-3) has attained the highest (P<0.0001) value of average body weight gain. The dietary treatments Feed-2 and Feed-3 had relatively similar CP content; chickens fed both rations had achieved best growth performances compared to Feed-1. The average final body weight of KK was lower but that of the layer stage chickens in the current study was higher than the findings of Desalew *et al.* (2013) who reported 1.55 kg final body weight for KK chicken in East Shewa, Ethiopia. However, the final weight of layer stage from the current study was higher than 1.2kg reported for KK chickens at same age (Aman *et al.*, 2016) in the southern part of Ethiopia. And the final weight at grower stage in the current study was lower than 1.2kg the final body weight reported for KK (Desalew, 2013).

Table 3. Feed intake and growth performance of Koekoek chickens fed the treatments

Parameters	Treatments			
Grower stage (g)	Feed-1	Feed-2	Feed-3	SL
IBW	407.3 ± 21.9	407.1 ± 21.8	407.1 ± 21.8	NS
FBW	756.2^{b} ± 30.7	844.1^{a} ± 34.2	890.8^{a} ± 36.1	***
TWG	349.2^{b} ± 18.5	437.0^{a} ± 23.2	483.7^{a} ± 25.7	****
ADG	9.97^{b} ± 7.83	12.48^{a} ± 9.79	13.82^{a} ± 10.9	****
ADFI	73.53^{b} ±0.15	76.86^{b} ± 0.16	95.63^{a} ± 19	****
Layer stage(g)				
IBW	756.20^{b} ± 21.9	844.1^{a} ± 21.8	890.83^{a} ± 21.8	***
FBW	1799.3^{c} ± 7.2	1874.9^{b} ± 7.5	2105.13^{a} ± 8.4	****
TWG	1043.1^{c} ± 0.87	1030.8^{b} ± 0.9	1214.3^{a} ± 1.01	**
ADG	9.930^{c} ± 0.35	9.80^{b} ± 0.34	11.56^{a} ± 0.41	*
ADFI	94.50^{c} ± 0.035	96.60^{b}±0.034	117.34^{a} ± 0.04	****

*Mean values in a row with different letter superscripts are significantly (P<0.05) different. IBW = initial body weight; FBW = final body weight; NS= non-significant; TWG = Total weight gain, ADG = Average daily gain, ADFI = Average daily feed intake, FCE = feed conversion efficiency, SEM = standard error of the mean; SL=significance level; T= treatment

Egg yield of the chickens

The egg production performance of Koekoek chickens, as evaluated in the study and shown in Figs. 1 and 2, revealed significant differences. The total egg yield, egg yield per month per treatment, and egg yield per month per bird varied significantly (P<0.01) among groups of hens fed different treatments.

The highest egg yield was obtained from the locally formulated ration (Feed-2) followed by those group of birds fed on Feed-3, which was commercial ration. The feed conversion efficiency (FCE) of the chickens was not differed (P > 0.05) for those chickens fed the different dietary treatments. The likely explanation for the highest egg yield obtained from birds fed on Feed-2 was mainly due to the higher protein content of Feed-2 as compared to the other two treatments. Despite the anti-nutritional content of some lupines used as ingredient in the ration, which was formulated from locally available ingredients, the secondary metabolites were not those, which bind proteins. In line with this, Gunawardana *et al.* (2017) reported that protein had significant effects on egg production, egg weight, percentage of eggshell components, yolk color, and albumen weights. Džomba *et al*. (2020) also reported that increased level of protein had positive effect on egg weight and albumen proportion.

Of the two locally formulated rations (Feed-1 and Feed-2), chickens fed on Feed-2 were superior to those fed on Feed-1. The likely reason for the difference may be the presence of some essential amino acids such as glutamic acid, lysine, threonine and phenylalanine that are common in wheat grain (Xiao-ling *et al*., 2008). The lower egg yield obtained from chickens fed on Feed-1 may be due to the existence of lupine (*L. albus*), which contains alkaloids. Alkaloids represent the main ant-nutritional factor in lupins (Katarzyna *et al*., 2016). It was also reported in other literatures (Jeroch *et al*., 2016) that the effect of dietary protein sources in the ration depends on the level of anti-nutritional factors contained in the ration. Hence the Feed-2 ration in the present study was observed to support egg yield of Koekoek chickens to the best among the groups.

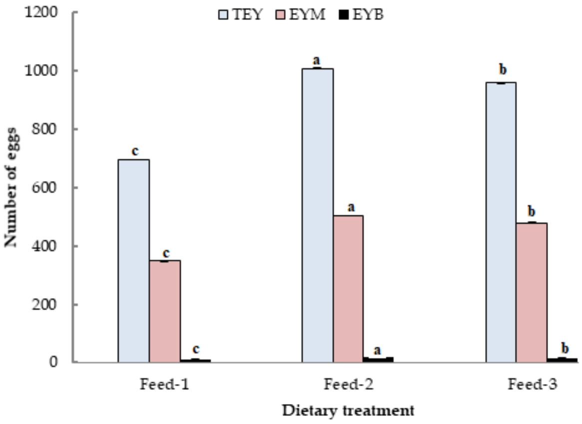

Figure 1. Effect of dietary treatments on egg production of Koekoek Chickens. TEY = Total egg yield per treatment in two months; EYM = egg yield per treatments per month; EYB = average egg yield/bird/treatment/ month; NS= non-significant; SL= significance level

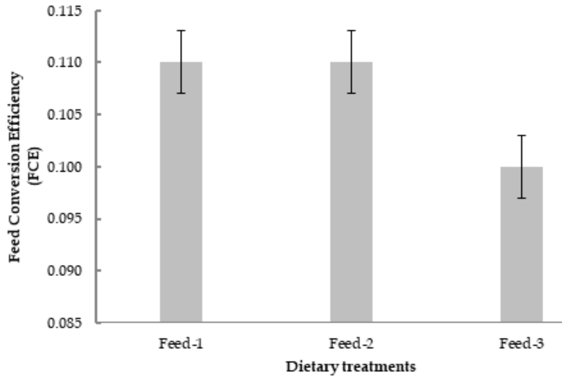

Figure 2. Effect of different dietary treatments on feed efficiency of Koekoek Chickens

Profitability analysis

The profitability analysis of the birds fed on Feed-1, Feed-2 and Feed-3 were resulted in 56.20, 80.40 and 28.30 net return in Ethiopian birr, respectively from sale of eggs within two months eggs laying period (Table 4). From these, hens consumed Feed-2 diets laid the most profitable eggs followed by Feed-1 and Feed-3 rations. This showed that rations formulated from locally available Feed sources resulted in the most profitable eggs compared to the commercial ration, which was costly and imposed more transportation cost, particularly in the study areas where there are no feed processing plants. Among the rations formulated using local feeds, those birds fed wheat as energy ingredient (Feed-2) had fetched the highest ($P<0.0001$) profit. This was so happened because wheat has improved egg yield since it contains more amino acids compared to the ration that used maize as energy ingredient (Feed-1). Moreover, the marginal rate of return indicated that chicken fed on Feed-2 resulted in better marginal rate of return as compared to chicken fed on Feed-1 and Feed-3. Birds reared under Feed-3 consumed more feed than the birds reared under Feed-1 and Feed-2. Therefore, the highest feed cost incurred for birds fed on commercial ration (Feed-3) and this resulted in the least profitability of the group.

Table 4. Profitability of Koekoek hens consumed the experimental Feeds

Parameters	Treatments			
	Feed-1	Feed-2	Feed-3	SL
Total variable cost (TVC)¥	$59.80^{c} \pm 0.59$	$87.60^{b} \pm 0.85$	$131.70^{a} \pm 1.29$	****
Total return (TR)¥	$116.00^{c} \pm 2.15$	$168.00^{a} \pm 3.11$	$160.00^{b} \pm 2.96$	****
Net return (NR)¥	$56.20^{b} \pm 0.34$	$80.40^{a} \pm 4.01$	$28.30^{c} \pm 1.41$	****
Marginal rate of return (MRR)	$0.93^{b} \pm 0.02$	$0.97^{a} \pm 0.03$	$0.20^{c} \pm 0.01$	****

¥Ethiopian Birr; SL= significant level; NB: the total variable costs include feed cost, transportation cost, labor and medication costs.

CONCLUSION

The commercial diet (Feed-3) was superior in feed intake and promoting body weight gain of Potchefstroom Koekoek chickens, while the diet formulated from locally available ingredients (Feed-2) resulted in the highest efficiency of feed utilization for egg production. Due to the highest egg yield and low feed intake of the birds fed on the locally formulated diet (Feed-2), the eggs produced were the most profitable. Since the commercial diet (Feed-3) used in this experiment promoted the growth of Potchefstroom Koekoek chickens, it may be more useful for farmers owning dual-purpose or broiler chickens than layers. For more egg production and profitability on Potchefstroom Koekoek chicken farms, a diet formulated from locally available ingredients (Feed-2) is recommended according to the current study.

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