



EFFECT OF SUBSTITUTING MAIZE WITH NEWLY RELEASED SORGHUM VARIETIES ON LAYING PERFORMANCE AND EGG QUALITY OF BOVANS BROWN

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Abstract

Rising maize prices and increasing competition caused by rising human food demand are forcing poultry producers to seek alternative energy sources. Newly released grain sorghum varieties in western Ethiopia may serve as a viable substitute, but their effects on laying hen performance and profitability need assessment. To assess the effects of replacing maize with a recently introduced sorghum variety (Assosa-1) on feed intake, body weight change, feed conversion efficiency, egg production, egg quality, and economic return in Bovans Brown laying hens. A 90-day feeding trial was conducted at Assosa Agricultural Research Station using a Completely Randomized Design with three treatments (also called as trials) and three batches. A total of 180 Bovans Brown layers of similar age and an average initial body weight of 1,678.35 g were randomly assigned to three diets: maize-based diet in the control group (T1), the group with diet based on sorghum Assosa-1 completely replacing maize (T2), and the group that received a diet with 50 % maize and 50 % Assosa-1 (T3). Data were collected on dry matter intake, body weight, egg production performance, feed efficiency, egg quality traits, and partial budget calculation. Dry matter intake and body weight change did not differ between the groups T1 and T2. Hen-day egg production and feed conversion efficiency favored the sorghum diet (T2) over the control group. Yolk weight was higher in the group T2, while albumen weight was highest in the group T3. Economic analysis showed that T2 provided the greatest financial return. The improved grain sorghum variety Assosa-1 can effectively replace maize in diets of Bovans Brown layers without negative effects on feed intake, body weight, or egg quality, while improving egg production performance and feed conversion efficiency. Using the locally released sorghum varieties as a maize substitute can reduce feed cost, improve profitability, and support sustainable livestock and food production in maize-challenged regions.

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Introduction

The poultry sector has the potential to provide relatively cheap animal-originated protein to the population and improve nutritional status, create both rural and urban employment, and generate income in the periods of economic issues. In Ethiopia, the total chicken populations estimated to be about 56.06 million heads; among this quantity, indigenous breeds account for 88.19 %, exotic 6.45 %, and hybrid for 5.36 % [1]. Chicken food products, the most widespread, play a crucial role in providing affordable animal protein for human consumption and can serve as cash income for any rural family [2].

The major constraints of poultry production are insufficient availability of feed sources in terms of both their quality and quantity, and the high cost of feed ingredients, regardless of their production system or geographical location. The rural poultry obtain their food by scavenging in and around the homesteads. Their food source consists

of household wastes, anything edible found in the immediate environment, together with a small amount of grain supplements provided by the master's household [3]. But modern poultry production needs formulated feed based on the availability of ingredients from the local area. Those available feed resource bases and feeding modes in the local area are defined to promote the rational use of the locally available feed resources.

The demand for energy and protein feedstuffs, and the related high costs, particularly for the protein supplements, is now a serious issue for poultry production. In Ethiopia, in the past years, there appeared the private owners, youth, and women's groups organized by governmental and non-governmental organizations have entered the poultry business of medium and large scales. However, due to the lack of formulated poultry feed, poor quality and quantity, feed cost and its unavailability, those poultry farms are now out of business. Specifically, in the last five years, due to the

long transportation costs and security problems in West Ethiopia, poultry production was highly affected.

In those areas, to solve feed-associated problems, identifying and formulating feed from locally available ingredients for each chicken variety class is very important. The major feed ingredients for poultry are maize and sorghum. These two cereals are dominantly produced in West Ethiopia. Specifically, Benishangul Gumuz regional state, apart from the area cultivated for sorghum, accounts for 31.79 % of the region's grain production [4]. Assosa Agricultural Research Center developed and introduced the *Assosa-1* sorghum variety in 2015. The variety was released through the collection, characterization, and purification of land races from West Ethiopia.

Cereal grains are the main energy source in poultry diets, with maize commonly included at 50–70 % of the ration due to its high energy content, low fibre level, good palatability, and provision of natural pigments and essential fatty acids [5]. However, the major problem with incorporating maize into poultry feed in West Ethiopia is lower production and the costs increases. So, replacing the productive and available grain in the areas with something comparable is very important for poultry producers. However, new varieties of sorghum were introduced as poultry feed, yet they had not been evaluated previously. Results show that in other areas of Ethiopia, the newly released varieties of sorghum prove to be a good source of energy for poultry as compared to maize [6,7]. The success of sorghum substitution depends on the specific sorghum variety being used [8]. In Ethiopia, newly released sorghum is a promising substitute for maize for poultry diets, as improved low-tannin varieties provide high energy, adequate supply of crude protein, balanced essential amino acids, essential vitamins and minerals while reducing anti-nutritional tannin effects [6].

Moreover, in the western part of Ethiopia, there is no availability of a formulation of poultry feed from locally available feed ingredients. The only source of formulated feed from Addis Ababa, Ethiopia, has a high cost per quintal of feed due to transportation costs. Therefore, to minimize the cost of transport and feed, the research on locally available and higher-quality ingredients is critically required. Focusing on locally available feed ingredients, poultry farmers in West Ethiopia can potentially reduce dependence on expensive transported feed, develop more sustainable and cost-effective feeding practices, and improve the health and productivity of their chickens. So, the present study aims to determine the nutritional value of egg-layers' diets formulated with the newly released *Assosa-1* sorghum variety and to develop the best-cost rations for egg-layer chickens in the region.

Objects and methods

Description of the studied area

The feeding experiment was conducted in 2023/2024 at Assosa Agricultural Research Center in Benishangul Gumuz Regional State, West Ethiopia. Assosa town is lo-

cated 670 km to the west from Addis Ababa. It is situated between 10°30' N latitude and 034°20' E longitude at an altitude of 1565 meters above sea level. The minimum mean temperature varies between 16.8°C and 20.6°C, and the maximum mean temperature ranges from 27°C to 35.1°C. In the Midlands, both crop cultivation and livestock production are mutually integrated, and pastoralism is practiced in the lowland areas of the region. Major crops grown include sorghum, maize, teff, soybean, groundnut, finger millet, wheat, rice, and sesame. The *Assosa-1* sorghum variety, released in May 2015 by the Assosa Agricultural Research Center in Ethiopia, is a high-yielding cultivar adapted to the conditions of the lowland humid areas. It features white seeds and has a flowering period that starts within the period ranging from 138 to 144 days. On-farm average harvest yields for *Assosa-1* range between 27.6 and 41.3 quintals per hectare [9]. Research has shown that white sorghum varieties generally possess minimal tannin content, with some varieties containing as little as 0.02 % [10].

Experimental feed preparation

The *Assosa-1* sorghum varieties were produced in the Assosa Agricultural Research Center in collaboration with the Assosa Agricultural Research Center crop breeder team. The Noug seed cake (NSC) and Wheat Bran (WB) were purchased from Assosa Farmers Multipurpose Cooperative Union and Assosa private wheat milling and processing factory, respectively. However, for this experiment, the limestone and the egg-layer food premix were purchased from Addis Ababa poultry feed suppliers. The maize and soybeans were purchased from the Assosa area local market. Whole soybeans were roasted with a traditional open-pan dry heat method adopted from Andrade [11] to improve their nutritional value through the inactivation of anti-nutritional factors such as trypsin inhibitors and lectins, which can impair protein digestion in poultry. A clean, heavy-bottomed iron pan was preheated over an open flame. A single thin layer of whole soybeans was scattered over the pan to ensure uniform heat distribution and to avoid overcrowding. The beans were continuously stirred with a wooden paddle to prevent charring or uneven roasting. Roasting continued for approximately 15–30 minutes, until the beans turned golden brown and began to effuse a signature nutty aroma. Some beans started to crack or pop, thus indicating completion of the process. The roasted beans were then cooled at room temperature, ground to a coarse meal with a hammer mill, and admixed into the experimental diets. This process was repeated in small batches to ensure consistent roasting and avoid over-processing, which could reduce nutrient availability. All feed ingredients were ground before mixing into the formulation to ensure uniform particle size and improve nutrient digestibility for the egg-layers. Grinding at a 4 mm sieve screen was carried out using the following procedure described by Abdollahi et al. [12].

Experimental diets

Three experimental poultry feeds were formulated: for T1 (control group) based on maize, and the group T2 and group T3 where the maize was substituted with *Assosa-1*, at share of 100 %, and 50 %, respectively (Table 1).

Table 1. Proportion (%) of ingredients to be used in formulating the experimental rations

Ingredients	T1	T2	T3
Maize	44	0	22
<i>Assosa-1</i> sorghum (100 %)	0	44	0
<i>Assosa-1</i> sorghum (50 %)	0	0	22
RSB	15	15	15
NSC	17	17	17
WB	17	17	17
Layers premix	0.50	0.50	0.50
Lime	6	6	6
Salt (NaCl)	0.5	0.5	0.5
Total	100.00	100.00	100.00

Layers premix (0.5 %) manufactured by INTRACO Ltd., the company added per kg: vit A=440000 lu, vit D=240000 lu, vit E=1000 mg, Vit K=90 mg, vit B1=60 mg, vit B2=240 mg, vit B3=400 mg, vit B6=200 mg, vit B12=0.8 mg, folic acid=40 mg, nicotinic acid, and choline=1200 mg, chloride=14000 mg, biotin=4 mg; Trace elements added per kg: iron=1800 mg, copper=600 mg, manganese=2400 mg, zinc=2800 mg, iodine=80 mg, selenium=16 mg; Colorants added: beta apo carotenic acid ethyl ester=100 mg, canthaxanthine=160 mg; Additives added: super antioxidant blend and phytase enzyme; Raw materials included: vegetalprotein, lysin, methionine, dicalciumphosphate, salt, vitamin and mineral premix, antioxidant, RSB=Roasted soybean, NSC=noug seed cake, WB=Wheat bran.

Experimental birds and management

A total of 180 Bovans Brown pullets with an average initial body weight of 1,678.35 g and an age of 171 days were used for the experiment. The pullets used in the study were obtained from Assosa private chicken growers' poultry farm. The experiment was conducted from weeks 25th up to 37th. The pullets were vaccinated against Newcastle, Gumboro, and Fowl Typhoid diseases using the appropriate vaccine according to the manufacturer's recommendation. Then the pullets come to the Assosa Agricultural Research Center poultry farm. Before placing the hens into the experimental house, the experimental pens, watering and feeding troughs, and laying nests were thoroughly cleaned, disinfected, and sprayed against external parasites. Each pen was equal in size (1.32 m²) and equipped with individual laying nests, covered with crop straw. The hens were randomly divided into three dietary trials groups in a completely randomized design (CRD). Each group contained 3 batches of 20 hens each. Each group received one of the experimental diets in Table 1. After laboratory analysis of the nutrient composition of each ingredient, the formulated rations were developed with iso-caloric and iso-nitrogenous feed containing 16 % crude protein (CP) and 2700 kcal/kg metabolizable energy (ME) in dry matter (DM) during the egg-laying phase [13]. Before the actual data collection, the hens adapted to the diets for 7 days. The experiment lasted for 12-week period of the study, and the hens were also subjected to similar manage-

rial and sanitary conditions at the time of the experiment. Feed and water were unobstructedly available at any time.

Data collection

Body weight change was measured using a sensitive balance every week starting from 25 weeks of the hens' age. Weighed quantities of diets were given on an *ad libitum* basis to the poultry, and the foods intakes were recorded daily. The eggs were collected thrice daily at 8.00 a.m., 13.00 p.m., and 17.00 p.m. The sum of the three collections and the number of hens alive in each pen were recorded. The rate of lay was expressed as the average percentage of hen-day and hen-housed egg production based on the average values from each batch, following the method of Jahan [14] as follows:

$$\begin{aligned} \% \text{ Hen-day egg production (HDEP)} &= \\ &= \frac{\text{Number of egg collected}}{\text{Number of hens present that day}} \times 100, \end{aligned} \quad (1)$$

$$\begin{aligned} \% \text{ Hen-housed egg production (HHEP)} &= \\ &= \frac{\text{Sum daily egg quantity}}{\text{Number of hens housed originally}} \times 100. \end{aligned} \quad (2)$$

The egg mass was computed by multiplying the average egg weight by the quantity of eggs for each batch, as described by Jahan [14].

$$\begin{aligned} \text{Egg mass (g/hen/day)} &= \\ &= \frac{\text{Total eggs produced in period} \times \text{Mean egg weight (g)}}{\text{Number of hens} \times \text{days in period}} \times 100. \end{aligned} \quad (3)$$

Feed conversion efficiency (FCE) was determined by dividing the egg weight by the weight of feed consumed in dry matter.

$$\begin{aligned} \text{FCE (egg g feed)} &= \\ &= \frac{\text{Egg weight (g/hen/day)}}{\text{Dry matter intake (g/hen/day)}} \times 100. \end{aligned} \quad (4)$$

Egg quality measurements

Sampling and sample size

Egg quality measurements were performed weekly throughout the 12-week trial. From each batch (20 hens/batch), four eggs per batch per week were randomly selected for quality assessment (i.e., 12 eggs per trial per week). Eggs selected for measurement were fresh (collected the same day) and represented all collection times (8.00 a.m., 13.00 p.m., and 17.00 p.m.) to avoid bias due to diurnal lay patterns.

Handling and storage before analysis

Selected eggs were labeled with the trial data and batch codes and stored at ambient laboratory temperature (20–25 °C) for no longer than 24 h before measurement to avoid changes in albumen dimensions and weight due to evaporation as per Bulut and Aygun [15].

External measurements

Each egg was weighed with an approximation to the nearest 0.01 g using an electronic analytical balance (WT10002G (0.01 g Sensitive Balance), WANT Changzhou, China) (readability 0.01 g) that was calibrated daily using certified standard calibration weights before measurements were taken. Egg length (L) and egg width (W) were measured using a digital caliper (accuracy ± 0.01 mm). Length was measured along the longitudinal axis from the blunt end to the pointed end; width was measured across the maximum transverse diameter perpendicular to the length.

Shape index

The egg shape index (SI) was calculated for each egg as:

$$\text{Shape index (SI)} = \frac{\text{Egg width (mm)}}{\text{Egg length (mm)}} \times 100. \quad (5)$$

Eggs were classified according to Duman et al. [16]: sharp ($SI < 72$), normal/standard ($SI = 72\text{--}76$), and round ($SI > 76$).

Shell weight and shell percentage

After external measurements, each egg was broken carefully on a clean surface. Shells (including shell membrane) were separated, rinsed with distilled water to remove adhering albumen, air dried for 2–3 hours at room temperature, and then weighed with approximation to the nearest 0.01 g using the laboratory balance WT10002G, WANT Changzhou, China. Shell percentage was calculated as:

$$\text{Shell \%} = \frac{\text{Shell weight (g)}}{\text{Sample egg weight (g)}} \times 100. \quad (6)$$

External egg parameters were measured, including sample egg weight, egg length, egg width, and shell weight. The egg length and width were measured using digital calipers, and the shape index was calculated as the ratio of width to length multiplied by 100. Four eggs were broken weekly from each batch of the hens, and the egg contents were separated into the yolk, albumen, shell, and its membrane. All the parts were weighed using the laboratory balance WT10002G (0.01 g Sensitive Balance), WANT Changzhou, China.

Separation and weighing of internal components

After breaking, the egg contents were poured into a clean container, and the yolk was carefully separated from the albumen by hand with gloved fingers. The yolk was blotted lightly on filter paper to remove surface albumen and weighed using the laboratory balance WT10002G, WANT Changzhou, China. Albumen weight was obtained by subtracting yolk + shell weight from the whole egg weight, or by direct weighing of the albumen in a tare-weighed vessel. Yolk and albumen percentages were calculated as:

$$\text{Yolk \%} = \frac{\text{Yolk weight (g)}}{\text{Sample egg weight (g)}} \times 100, \quad (7)$$

$$\text{Albumen \%} = \frac{\text{Albumen weight (g)}}{\text{Sample egg weight (g)}} \times 100. \quad (8)$$

Chemical analysis

Sub-samples were taken from the egg materials in triplicate for chemical analyses. The DM of the feed was determined by drying the samples at 65 °C in a forced air oven (BOV-T50F, Biobase, Shandong, China) until a constant mass was achieved (AOAC, 1990)¹ at Assosa Agricultural Research Center. After drying, the samples were ground through a 1 mm screen (Thomas-Wiley mill) for chemical analyses, which were conducted at Assosa University Animal Science Laboratory. The total nitrogen (N) content of the samples was determined by the Kjeldahl method (AOAC, 1990)¹, and then crude protein (CP) content was calculated as $N \times 6.25$. The ash content of the samples was determined by complete burning in a muffle furnace (BWF-12/07, Brother Furnace Co., China) at 600 °C for 3 hours (AOAC, 1990)¹. The ether extract (EE) was measured by extracting a known mass of dried feed with an organic solvent (petroleum ether) that dissolves the lipid fraction. Then the solvent was removed, and the residue (crude fat) was weighed. The procedure follows standard Soxhlet extraction techniques (AOAC, 2005)². Fiber analysis was performed by the device Fibertec® (Tecator, Hoganas, Sweden) [17,18].

The metabolizable energy (ME) content of the feed ingredients was also determined indirectly by the Wiseman [19] formula.

$$ME \text{ (Kcal/kg DM)} = 3951 + 54.4EE - 88.7CF - 40.8Ash. \quad (9)$$

Cost-benefit analysis

Partial budget analysis developed by Upton [20] was applied to estimate the cost benefits of each trial ratio. The market price of each feed ingredient was recorded at the time of purchase, and the cost of the feed consumed by the poultry was calculated by multiplying the ingredient cost by the feed consumed. Total return (TR) value was calculated as the quantity of the total eggs produced multiplied by the price of the egg at the Assosa area local market during the experiment period. Net return was obtained from the difference between feed cost and the eggs produced and sold. Net return (NR) was calculated as the difference between the total return (TR) and the total variable cost (TVC), where the feed cost was considered the only variable cost. The change in total variable cost (ΔTVC) was determined by subtracting the total feed cost of the control diet from that of each Assosa-1 sorghum-based treatment. Similarly, the change in total return (ΔTR) was calculated as the difference between the total income generated from each sorghum-based treatment and that of the control treatment. The change in net return (ΔNR) was obtained by subtracting the net return of the control treatment from that of each sorghum-based treatment. The marginal rate of return (MRR) was used to evaluate the additional net

¹ AOAC International, 1990. Official Methods of Analysis of AOAC International. The 18th ed. Gaithersburg, MD: AOAC International.

² AOAC International, 2005. Official Methods of Analysis of AOAC International. The 18th ed. Gaithersburg, MD: AOAC International.

return obtained for each additional unit increase in variable cost.

$$\text{Net Return (NR)} = \text{Total Return (TR)} - \text{Total Variable Cost (TVC)}. \quad (10)$$

$$\Delta \text{TVC} = \text{TVC}_{\text{treatment}} - \text{TVC}_{\text{control}}. \quad (11)$$

$$\Delta \text{TR} = \text{TR}_{\text{treatment}} - \text{TR}_{\text{control}}. \quad (12)$$

$$\Delta \text{NR} = \text{NR}_{\text{treatment}} - \text{NR}_{\text{control}}. \quad (13)$$

$$\text{MRR} = \frac{\Delta \text{NR}}{\Delta \text{TVC}}. \quad (14)$$

Statistical analysis

The data were subjected to statistical analysis using R software (R 4.1.1), following a one-way analysis of variance procedure. When the F-test indicated significant effects of the trials ($P < 0.05$), mean separation was performed using Fisher's Least Significant Difference (LSD) test at the 5% probability level. Additionally, egg-laying trends were visualized using ggplot2. The model used was as follows:

$$Y_{ij} = \mu + T_i + e_{ij}, \quad (15)$$

where Y_{ij} represents a j^{th} observation (experimental unit) taken under trial i ; T_i = feed effect; μ = all means; e_{ij} = random error

Ethical statement

The authors confirm that the ethical standards outlined in the journal's author guidelines have been fully adhered to. Ethical approval for the animal experiment was obtained from the Research Ethics Committee of Hawassa University, Ethiopia. Although a formal approval number is not available, the study was conducted under the supervision of the committee, and all procedures involving animal management complied with institutional and international guidelines to ensure their welfare and minimize distress.

Results

Chemical composition

The protein content of the sorghum grain varieties was higher than in maize (Table 2). The analysis indicates the ether extract (EE) value of maize is greater than that of sorghum grains, which shows that maize contains higher metabolizable energy (ME). However, the higher content of crude fiber (CF) in Assosa-1 sorghum explains its slightly lower ME compared to maize.

Table 2. Chemical composition of the feed ingredients (% in DM)

	DM	CP	EE	Ash	CF	ME (Kcal/kg DM)
Maize	89.23	9.41	8.84	6.68	8.35	3418.16
Sorghum (Assosa-1)	90.51	11.38	3.95	8.22	12.61	2711.69
RSB	93.71	31.39	17.71	12.17	9.08	3612.32
NSC	93.22	25.56	4.48	14.63	28.93	1031.62
WB	91.75	14.58	2.79	11.18	24.40	1481.51
T1	92.04	16.07	5.84	16.18	8.46	2737.45
T2	92.08	16.81	6.43	14.28	9.57	2725.55
T3	91.97	16.57	5.35	15.96	7.03	2745.74

DM = dry matter, CP = crude protein, EE = ether extract, CF = crude fiber, RSB = roasted soybean meal, and NSC = noug seed cake, WB = wheat bran, T1 = maize based, T2 = 100 % maize replaced by sorghum (Assosa-1 variety), T3 = 50 % maize replaced by sorghum (Assosa-1 variety)

Egg production and feed conversion performance

Significant differences were observed in dry matter intake (DMI), hen day egg production (HDEP), feed conversion efficiency (FCE), and egg weight among the egg-layers fed with different diets. The DMI was higher in 100 % maize and 100 % sorghum diets compared to the group that received 50 % replacement. HDEP and egg weight were highest in the 100 % sorghum group. These results show a significant performance advantage for the full sorghum diet and an egg-laying performance decrease when sorghum was only partially substituted. This suggests that diet uniformity and ingredient-specific nutrient interactions may influence egg-laying performance.

The weekly trends in hen-housed egg production (HHEP%) for the three dietary trials over the 12-week experimental period showed a clear divergence in egg production patterns (Figure 1). The group T2 (100 % Assosa-1 sorghum) consistently maintained the highest HHEP values across nearly all weeks, starting strong in the first week and sustaining a gradual upward trend, peaking midway through the trial before stabilizing. The T1 (maize-fed control group) showed intermediate HHEP throughout the trial, with moderate fluctuations and a slightly declining trend toward the final weeks. However, the group T3 (50 % maize + 50 % Assosa-1 sorghum) showed the lowest HHEP for most of the trials, with more pronounced week-to-week variability and no sustained peak performance. The T2 FCE matches or exceeds the top range reported in Ethiopian-controlled trials. The advantage in the group T2 may be due to the better amino acid digestibility in Assosa-1 sorghum, stable feed intake, and absence of anti-nutritional factors.

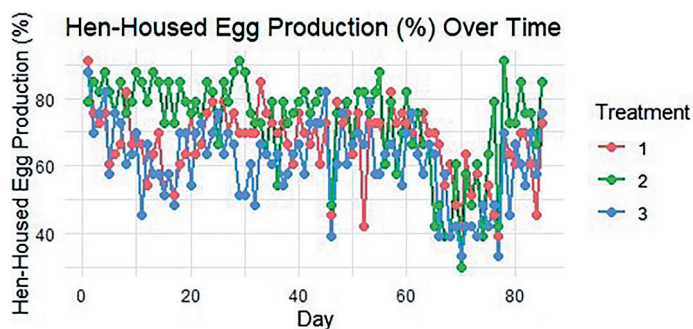


Figure 1. Hen-housed egg production (HHEP) expressed as a percentage

Table 3. Egg-laying performance of Bovans Brown layers fed with rations containing a newly released sorghum variety by replacing maize with 100 % and 50 %

	T1	T2	T3	SEM	P-value
DMI, g/hen/day	113.30 ^a	113.52 ^a	105.75 ^b	0.89	0.00
Initial BW, g	1662.58	1718.08	1654.37	25.26	0.55
Final BW, g	1708.31	1769.43	1723.95	24.35	0.15
Weight changes, g/day	45.73	51.35	69.58	26.40	0.35
HDEP, %	67.94 ^b	73.47 ^a	64.11 ^c	0.61	0.00
HHEP, %	67.03	72.84	61.69	2.03	0.076
Egg weight, g	57.87	58.27	58.12	0.29	0.38
Egg mass, g/hen/day	39.03 ^b	42.78 ^a	35.67 ^c	0.37	0.00
FCE, egg/g feed	0.35 ^b	0.38 ^a	0.34 ^b	0.004	0.005
Mortality rate, %	2.00	—	4.00	—	—

^{abc} means in the same row without common superscript differ at $p < 0.05$, BW = body weight, HDEP = hen day egg production, DMI = dry matter intake, T1 = maize based, T2 = 100 % maize replaced by Sorghum (Assosa-1 variety), T3 = 50 % maize replaced by sorghum (Assosa-1 variety)

Weight change was not significant among the trials groups. Mortality rates remained within normal limits, although higher in the 50 % sorghum-fed group.

Egg quality

The 100 % sorghum-fed group showed higher yolk weights, and the 50 % maize-replaced fed group featured the highest albumen weight. No significant differences were observed in eggshell weight or overall egg weight. Egg shape index was highest in the 100 % sorghum-fed group, falling within the range of round eggs.

Partial budget analysis

Sorghum-based diets reduced feed costs compared to maize-based ones. Net return was highest in the 100 % sorghum-fed group (26885 Ethiopian Birr), followed by

the maize-fed group (23246 Birr), and lowest in the 50 % maize-replaced fed group (21147 Birr). The marginal rate of return showed better profitability with full substitution of maize with sorghum.

Discussion

The present study validates the potential of the newly released *Assosa-1* sorghum variety to fully replace maize in layer diets without compromising dry matter intake, egg production, feed conversion efficiency, or egg quality. The proximate analysis (Table 2) showed that *Assosa-1* sorghum featured higher crude protein but lower ether extract and metabolizable energy compared to maize. The higher CP content supports its potential as a protein-rich energy source for egg-layers, which comes in agreement

Table 4. Egg quality from hens fed the newly released sorghum variety

	T1	T2	T3	SEM	P-value
Sample egg weight, g	60.29	60.68	60.60	0.41	0.92
Eggshell, %	9.77	9.73	10.21	0.33	0.28
Egg yolk, %	26.13 ^b	28.02 ^a	26.70 ^b	0.61	0.009
Albumen, %	57.29 ^b	57.23 ^b	61.19 ^a	1.55	0.02
Egg length, mm	5.68 ^a	5.54 ^b	5.58 ^b	0.02	0.01
Egg width, mm	4.35	4.35	4.35	0.01	1.00
Shape index	76.16 ^b	78.71 ^a	78.07 ^{ab}	0.34	0.03

T1 = maize based, T2 = 100 % maize replaced by sorghum (*Assosa-1* variety), T3 = 50 % maize replaced by sorghum (*Assosa-1* variety)

Table 5. Economics of feeding *Assosa-1* (100 and 50 %) to Bovans Brown as a replacement for maize

	T1	T2	T3
Total feed consumed/ treatment, kg	571.03	572.14	532.98
Total feed cost/ treatment, Birr	18045.78	18079	16832.95
Total variable cost/ treatment, Birr	18045.78	18079	16832.95
ΔTVC, Birr	—	33.22	-1212.83
TOTAL REVENUE			
Total eggs produced (No.)/ treatment	3441	3747	3165
Total return (TR), Birr	41292	44964	37980
ΔTR, Birr	—	3672	-3312
Net return (NR), Birr	23246	26885	21147
ΔNR, Birr	—	3639	-2099
MRR, %	—	10948	173

ΔTVC = change in total variable cost; ΔTR = change in total return; NR = net return; ΔNR = change in net return; MRR = marginal rate of return; Birr = Ethiopia's unit of currency: US 1.00 = birr 56.00; Egg sale = 12 birr/egg. T1 = maize based, T2 = 100 % maize replaced with sorghum (*Assosa-1* variety), T3 = 50 % maize replaced with sorghum (*Assosa-1* variety)

with earlier reports on improved sorghum varieties [6,21]. A study showed that sorghum contains less fat than maize and provides approximately 90 to 100 % of the metabolizable energy of maize, with energy value also influenced by tannin content, starch digestibility level, and cultivar differences [22]. Sorghum also contained more crude fiber (12.61 %) than maize (8.35 %), which, while potentially affecting digestibility, which still remained within acceptable limits for layer diets.

Dry matter intake was similar between the groups T1 and T2, indicating that feed palatability was not adversely affected by full sorghum inclusion. However, the group T3 recorded lower feed intake and poorer performance. In line with this study, feeding sorghum under certain feeding systems reduced egg production and altered feed intake in egg-laying hens. However, the effect was linked to feeding strategy and energy level rather than simply a 50 % maize replacement [23]. The comparable body weight changes among the treatments indicate that observed performance differences were not caused by live weight variation.

Laying performance results (Table 3) indicated that hens fed with the 100 % *Assosa-1* sorghum diet (T2) achieved the highest hen-day egg production (73.47 %), egg weight (42.78 g/hen/day), and feed conversion efficiency (0.38), significantly outperforming both the maize-based-fed control group (T1) and the group fed with 50 % maize replaced diet (T3). The superior performance of the group T2 suggests that full substitution with *Assosa-1* sorghum can provide adequate energy and protein to sustain high productivity, consistent with findings by [6] and [24] that properly selected low-tannin sorghum varieties can successfully replace maize in egg-layer diets without compromising laying performance, nutrients digestibility, or egg quality.

The enhanced FCE in the group T2 may be attributed to better amino acid digestibility and the absence of anti-nutritional factors in *Assosa-1*, as reported by [10].

Egg quality parameters (Table 4) showed that hens fed with 100 % *Assosa-1* sorghum diet (T2) produced eggs with significantly higher yolk percentage (28.02 %) and a greater shape index (78.71) compared to the maize-based control group (T1). The increased yolk proportion in T2 aligns with previous findings by Abera et al. [6], who reported enhanced yolk deposition in layers fed sorghum-based diets, potentially due to improved amino acid utilization and balanced energy-to-protein ratios.

In contrast, the group fed with 50 % maize replaced diet (T3) yielded the highest albumen percentage (61.19 %), which may be associated with altered nutrient partitioning when both maize and sorghum are combined. No significant differences were recorded for eggshell percentage, egg weight, or egg width across treatments, thus indicating that replacing maize with sorghum did not negatively affect shell quality or overall egg size. A study by Ochieng et

al. [25] showed that 50 % and 100 % replacement of maize with low-tannin sorghum maintained egg weight and physical egg quality.

The observed shape indices in the groups T2 and T3 fall within the “round” category [16], which is generally preferred for eggs handling and packaging. These results suggest that complete maize replacement with *Assosa-1* sorghum can enhance certain internal quality traits, particularly yolk proportion, without compromising shell integrity or egg size, thereby maintaining market acceptability of these eggs.

Economic evaluation (Table 5) revealed that the 100 % *Assosa-1* sorghum-based diet (T2) achieved the highest net return (26,885 Ethiopian Birr) and a marginal rate of return (MRR) of 10.948 %, thus indicating superior profitability over the maize-based control diet for the group (T1) and the 50 % replacement diet (T3). The higher returns in the group T2 were driven by increased egg production and comparable feed costs, demonstrating that full maize substitution with sorghum can improve economic efficiency. In contrast, the eggs of the group T3 generated the lowest net return (21,147 Birr) and MRR (173 %), largely due to reduced egg output despite lower feed costs. These findings align with Gebeyew et al. [26], who reported that using locally available cereals like sorghum can reduce production costs and enhance profitability in broiler production.

The overall results confirm that complete maize replacement with *Assosa-1* sorghum can improve egg production efficiency while maintaining feed intake and body weight, thus supporting its potential as a sustainable and cost-effective energy source for egg-layers.

Conclusions

The present study demonstrated that replacing maize with the newly released *Assosa-1* sorghum variety in the diets of Bovans Brown laying hens had no adverse effects on feed intake, body weight, egg weight, egg quality, or mortality. Hens fed the 100 % *Assosa-1* sorghum diet exhibited higher hen-day egg production, greater egg mass, and improved feed conversion efficiency compared with those fed the maize-based diet. Furthermore, the use of *Assosa-1* sorghum reduced feed costs and resulted in a higher net economic return than the conventional maize-based diet. These findings indicate that the newly released *Assosa-1* sorghum variety can completely replace maize as the primary dietary energy source in layer diets without compromising productive performance or egg quality while improving the profitability of egg production. Therefore, the use of *Assosa-1* sorghum provides a practical and cost-effective alternative to maize for poultry feed formulation, particularly in West Ethiopia, where sorghum is readily available and maize is relatively expensive.

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Completely prepared the manuscript and is responsible for plagiarism.

The author declares no conflict of interest.