Substitution Effect of Maize (Zea Mays) with Grain Milling By-Products on Egg Production and Hatchability of Eggs in White Leghorn Layer Hens

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Abstract
The substitution effect of maize grain with grain milling by-products (GMP) was investigated on egg production and fertility parameters in White Leghorn layer hens. To this effect, four treatment (T) diets were formulated to contain GMP (g/kg) at zero (T1), 100 (T2), 150 (T3) and 200 (T4) by partially replacing the maize grain. One-hundred forty four White Leghorn layer hens were allocated randomly to the treatment diets, replicated thrice consisting of 12 hens each. The experiment was conducted for 20 weeks. The results indicated that the hen-housed egg production and daily egg mass output was higher ($p<0.001$) in hens fed with T1 and T2 diets than those of T3 and T4. Birds fed with T1 diet produced heavier ($p<0.001$) eggs than those reared in T2, T3 and T4 diets, the former being significantly different with the latter two. The daily feed intake differed significantly among treatment diets being higher ($p<0.001$) in birds fed with T1 and T2 than that of T3 and T4 diets, which had similar values. No significant difference was observed in hen-housed egg production, daily egg mass output, and daily feed intake among hens fed with T1 and T2 diets. Similarly, no significance difference was observed in egg weight, total and daily feed intake between hens fed with T3 and T4 diets. The feed conversion ratio (FCR, kg feed/kg egg mass) were different among treatment diets in which the lowest value being observed in those chickens reared in T1 followed by T2 diets. Birds fed with T4 diet had the highest FCR as compared with the rest of the treatment groups. Fertility and hatchability of eggs set were similar among chickens reared in T1 and T2 diets; but were higher ($p<0.05$) than those of T3 and T4 which had similar values. However, hens fed with T4 diet had lower ($p<0.05$) value in hatchability of fertile eggs than the rest of other treatments. In conclusion, the substitution of maize grain with 10% GMP showed similar effect with that of the control group in all studied performance parameters. Thus, GMP could be safely incorporated in replacement of maize for layer hen diets up to 10%.
Keywords: egg fertility; egg production; grain milling by-products; maize grain; White Leghorn chicken
DOI: 10.7176/JBAH/10-9-02
Publication date: May 31st 2020

1. Introduction

In most of the rural parts of Africa, poultry plays an important role in improving the nutritional requirement of rural community through consumption of poultry products such as egg and meat. Moreover, it serves as major income generation for most rural women (Melesse 2014). Nevertheless, a dynamic increment in the cost of cereal grains and human competition impose a great challenge on economic viability of the sector coupled with limited accessibility of land to produce maize for poultry feed (Shapiro *et al.* 2015). With increasing demand for livestock products as a result of rapid growth in the world economies and shrinking land area, future hopes of feeding the animals and safeguarding their food security will depend on the better utilization of other feed resources which do not compete with human food (Melesse *et al.* 2013, 2019). As a result, searching for cheap and easily accessible plant protein sources for possible inclusion in poultry feeds becomes imperative option to offset the scarcity and high cost of conventional poultry feeds. In this regard, unconventional feeds could partly fill the gap in the feed supply, decrease competition for food between humans and animals, reduce feed cost, and contribute to self-sufficiency in nutrients from locally available feed sources.

Among the unconventional feedstuffs, by-products from cereal grain milling processing plants that have been evaluated for use in livestock and poultry nutrition. The most commonly used cereal grain milling by-products in poultry nutrition are maize bran, wheat bran, and different forms of rice bran (Aliakbarpour *et al.* 2004; Boros *et al.* 2004; Maina *et al.* 2013; Martínez *et al.* 2015). The nutritional values of the by-products may vary depending upon the types of grains cultivated in a given location. As a result, in the change in proportions of fibrous and nonfibrous carbohydrates, the energy values for the mill feeds are lower than the parent grains. In contrast, the protein contents of the mill feeds are generally higher than the parent grains. (https://courses.ecampus.oregonstate.edu/ans312/two/milling_trans.htm).

In Ethiopia, there are plenty of small-scale local flour millers in many cities of the country, which produce unknown volume of grain milling by-products year round. Most of these by-products are leftovers after milling multiple types of grains. Tef (*Eragrostis tef*), maize, sorghum, lentils, wheat, barley, peas and chickpeas are the most common multiple grains that are consumed by the community in many places of the study area (personal observations). It is thus expected that most of the milling products could be composed of these major grains. They are plentiful, inexpensive and have potential to be successfully incorporated into poultry feeds. This signifies the availability of such useful by-products, which could be used as alternative animal feed resources in the urban and per-urban areas. However, to the author's knowledge, there is no adequate information on the nutritive and feeding values of grain milling by-products as a source of poultry feed in Ethiopia. Thus, this study was designed to investigate the effect of feeding grain-milling by-products as a partial replacement of maize on egg production performances of White Leghorn chickens.

2. Materials and methods

2.1 Describing the experiment site

The study was conducted at Ella Kebella Women's Association Poultry Farm located at Humbo district in North Omo. The research site is situated in the rift valley at the latitude of 6°39' North and longitude of 37°49' East with an altitude of 1450 meters above sea level. The annual rainfall ranges between 460 and 740 mm with a mean of 670 mm. The mean maximum and minimum temperatures are 28.6°C and 20.4°C, respectively.

2.2. Preparation of feed ingredients

The feed ingredients used in the formulation of the experimental rations contain maize, roasted soybean, grain milling by-products (GMP), whole fishmeal, cotton seed cake, limestone and salt. Maize, raw soybean, cotton seed cake, fishmeal, limestone, and salt were purchased from the nearby markets. Grain milling by-products were purchased from nearby small-scale local flour millers. The soybean seed was roasted for 5 minutes to deactivate the trypsin inhibitor (Rocha et al. 2014) and then milled in sieve size of 5 mm separately. All other feed ingredients were milled with similar sieve size and mixed together. Alfalfa was grown at the backyard of the poultry farm and fresh leaves were provided to all experimental birds ad libitum.

2.3. Experimental design

After having results on chemical and mineral analysis of each feed ingredients, four iso-nitrogenous and iso-caloric experimental diets were formulated to contain the control and experimental diets. The control diet (treatment 1, T1) contained no GMP and diets containing GMP at the levels of 100 g/kg (treatment 2, T2), 150 g/kg (treatment 3, T3) and 200 g/kg (treatment 4, T4) by partially substituting the maize in the control diet (Table 1). One hundred and forty four White Leghorn layer hens were distributed according to a completely randomized experimental design into 4 treatment diets with 3 replicates of 12 birds each.

Table 1. Experimental design of the feeding trial with White Leghorn layer hens

Treatment diets	Substitution level of maize with GMP (g/kg)	Number of replicates	Hens per replicate	Hens per treatment diets
T1	0	3	12	36
T2	100	3	12	36
T3	150	3	12	36
T4	200	3	12	36
Total (N)				144

2.4. Management of chickens

Before the arrival of experimental birds, pens, drinkers, and feeders were properly cleaned and disinfected. Two hundred and forty White Leghorn pullets and 40 cocks were obtained from the College of Agriculture of Hawassa University and transported to the poultry house. The concrete floor of the poultry house was covered with wood shavings at a depth of about 5 cm. Natural lighting system, which was relatively constant over 12 hours per day, was used. This was provided through open sides of the house and chicken wire mesh in place. The open sides also provided adequate ventilation.

All chickens were vaccinated against major poultry viral and bacterial diseases including Marek's disease, Newcastle, infectious bursal disease (Gumboro), fowl typhoid and fowl pox diseases. After arrival at the experimental site, pullets were leg-tagged, weighed and randomly distributed to the pre-prepared experimental pens with a dimension of 3 m^2 (2 x 1.5 m) per replicate. The pullets were fed with pullet commercial rations until the age of 19 weeks. They were then fed with the formulated experimental rations starting from the 19th weeks of age until end of the experiment (Table 2). Feeds were provided to all birds in the form of concentrate. Clean fresh water was provided *ad libitum* throughout the experimental period. Feeders and drinkers were cleaned daily to remove contamination from feed particles and the litter. Similar management conditions (light, temperature, and ventilation) were provided to all birds throughout the experimental period.

Table 2. Feed ingredients (g/kg) and nutrient compositions (g/kg DM) of the control diet and diets containing different levels of grain milling by-products of the layer ration

Feed ingredients	T1	T2	T3	T4
Maize	650	550	500	450
Soybean seed (roasted)	170	165	175	170
Grain milling products	0	100	150	200
Cotton seed cake	65	70	70	70
Fish meal	45	35	25	25
Limestone	65	75	75	80
Common salt	5	5	5	5
Alfalfa (green leaf)	*Ad libitum*	*Ad libitum*	*Ad libitum*	*Ad libitum*
Total	1000	1000	1000	1000
Calculated values (g/kg)				
ME (kcal/kg DM)	2702	2791	2771	2741
Ash	31.4	40.5	57.7	30.0
Crude protein	173	180	183	187
Crude fiber	51.9	59.5	64.2	67.7
Crude fat	101	90.3	85.2	80.7
Calcium	27.8	30.9	30.3	32.2
Phosphorous	4.80	4.70	4.50	4.60

2.5. Data collection protocols

2.5.1. Feed intake and egg production

Chickens were fed on replicate basis and each day a measured amount of feed was offered in the morning (between 7.00 and 8.00 am) and late afternoon (between 5.00 and 6.00 pm) and feed refusals were collected and weighed in the morning of the following day before feed is offered. Feed intake on replicate basis was then computed by subtracting the feed refusal from that of feed offered. Eggs were collected daily and egg production rate was calculated on hen-housed basis by considering the number of hens that were housed initially. Egg weight was determined on biweekly basis and the average egg weight was calculated. Total egg mass was computed by multiplying the average egg weight with total number of eggs produced per hen. Daily egg mass per hens was computed through dividing the total egg mass by the number of hens that were initially housed and total number of days in which the hens were in lay. Feed conversion ratio was calculated as a ratio of kg feed to kg egg mass output. The duration of the experiment was 150 days.

2.5.2. Egg fertility and hatchability

Three weeks before the end of the experiment period, two White Leghorn cocks per replicate were introduced to determine the fertility and hatchability of the eggs. At the end of the experiment, 15 eggs were collected for three consecutive days from each replicates totaling 180 eggs. The eggs were then placed in an incubator and were candled on the 18th day of incubation. After candling, the number of fertile and unfertile eggs was recorded. Average fertility of eggs was then computed by dividing the total number of eggs found fertile after candling with the total number of eggs set. Hatchability was then obtained from hatchability of fertile eggs and hatchability of eggs set. Accordingly, hatchability of eggs set for incubation was determined by dividing the total number of chicks hatched with that of total eggs set. Hatchability of fertile eggs was computed by dividing the number of chicks hatched to the number of fertile eggs after candling. It is would be worthwhile to note that each result was multiplied by 100 to get the percentage values.

2.6. Chemical analysis

Analyses of proximate nutrients were performed as outlined by AOAC (2005). Samples of feed ingredients were analyzed for dry matter (DM, method 950.46), ether extract (EE, method 920.39), crude fibre (CF, method 962.09) and ash (method 942.05). Neutral detergent fiber (NDF) was analyzed using the method of Van Soest et al. (1991) in an ANKOM® 200 Fiber Analyzer (ANKOM Technology Corp., Fairport, NY, USA). The crude protein (CP) was assessed using Kjeldahl procedure (method 954.01) and the nitrogen content was multiplied by 6.25 to obtain the CP. Calcium (Ca) was determined by atomic absorption spectrophotometer and phosphorus (P) by colorimetrically methods as described by AOAC (2005). The metabolizable energy (ME) of diets was estimated based on the feed composition tables of tropical feeds for poultry. The NDF content of samples of was analyzed at the Nutrition Laboratory of Hawassa University while the other nutrients were analyzed at Holeta Agricultural Research Center, Ethiopia. All samples were analyzed in duplicates in both laboratories.

2.7. Statistical analysis

Data on feed intake, body weight, body weight gain, feed conversion ratio, egg weight, hen-housed egg production, egg mass output and egg fertility and hatchability parameters were subjected to one-way ANOVA by fitting treatment diets as fixed effects. The ANOVA procedures of Statistical Analysis System (SAS, 2012, ver. 9.4) were used to analyze the collected data and treatment means were compared using Tukey's Studentized Range (HSD) test. Comparisons with $p<0.05$ were considered as significant. The following statistical model was used to analyze the data:

$Y_{ij} = \mu + A_i + D_j/A_i + e_{ij}$, where:

Y_{ij} = observed values of the dependent variables (feed intake, egg production, egg weight, egg mass)

μ = overall mean of the response variable

A_i = the effect of the i^{th} grain milling by-products (i = 1, 2, 3, 4) on the dependant variables

D_j/A_i = the effect of the j^{th} replicate (j =1, 2, 3) within the level of the i^{th} grain milling byproduct

e_{ij} = residual error due to random effects

3. Results

3.1. Chemical composition

Chemical composition analysis of feed ingredients used in this experiment has been presented in Table 3. As expected, the highest ash content was observed in fishmeal followed by alfalfa grass while the least was found in maize and GMP. The CP content was highest in fishmeal followed by cottonseed cake and roasted soybean seed. The analyses further indicated the GMP to be low in fat, high in crude fiber, and moderately high in protein and ash. The fat (EE) content was highest in soybean but lowest in cotton seed cake, which had the highest CF and NDF contents. The highest Ca and P contents were found in fishmeal.

Table 3. Chemical composition of different feed ingredients used in formulating the treatment diets (g/kg DM)

Ingredient	Ash	CP	EE	CF	NDF	Ca	P	ME (kcal/kg)
Maize	16.1	100	45.0	43.0	20.3	0.50	3.00	3300
Soybean seed (roasted)	42.0	343	130	60.2	111	2.46	0.41	2557
Grain milling by-products	20.3	212	25.6	120	130	0.9	6.0	2939
Fishmeal	227	569	60.0	-	-	63.5	34.1	2720
Cotton seed cake	68.6	389	7.30	150	390	1.80	10.8	2350
Fresh alfalfa grass	151	240	13.3	250	454	9.34	3.24	-

CP = crude protein; EE = crude fat; CF = crude fiber; NDF = neutral detergent fiber; Ca = calcium; P = phosphorous; ME = metabolizable energy (calculated values)

3.2. Feed consumption and egg production parameters

The hen-housed egg production was higher ($p<0.001$) in hens fed with T1 and T2 than those reared in T3 and T4 diets (Table 4). The total and daily egg mass production followed the same pattern as that of hen-housed egg production being higher ($p<0.001$) in birds fed with the T1 and T2 diets than that of T3 and T4. The corresponding values were higher ($p<0.001$) in chickens fed with T3 than those of T4. Birds fed with T1 had higher ($p<0.001$) egg weight than those reared in T2, T3 and T4 diets, in which the former being significantly different with the latter two treatment diets. The total and daily feed intake differed significantly among treatment diets being higher ($p<0.001$) in birds fed with T1 and T2 than that of T3 and T4 diets, which had similar values. However, no significance difference was observed in hen-housed egg production, egg mass output, and feed intake among hens fed with T1 and T2 diets. Similarly, no significance difference was found in egg weight, feed intake between birds fed with T3 and T4 diets. The FCR values were significantly different among treatment diets in which the lowest value being observed in those chickens reared in T1 followed by T2 diet. Birds fed with T4 had the highest FCR as compared with the rest of the treatment groups.

Table 4. The replacement effect of maize grain with different levels of grain milling by-products on feed intake, egg production, and feed conversion ratio

Parameters	T1	T2	T3	T4	SEM
Hen-housed egg production (%)	65.0^a	64.2^a	51.3^b	45.5^c	4.83
Average egg weight (g)	60.0^a	57.8^b	57.1^c	56.7^c	0.74
Egg mass/hen (kg)	10.9^a	10.4^a	8.24^b	7.25^c	0.87
Egg mass production per hen/d (g)	38.9^a	37.2^a	29.5^b	25.9^c	3.10
Total feed intake/hen (kg)	27.8^a	27.4^a	24.6^b	24.4^b	0.90
Feed intake/hen/d (g)	99.5^a	97.7^a	87.9^b	87.3^b	3.20
FCR (kg feed/kg egg mass)	2.55^a	2.63^b	2.99^c	3.37^d	0.19

^{a,b,c} Means with different superscript letters across treatment diets are significant ($p < 0.05$)

SEM = standard error of the mean; FRC = feed conversation ratio

3.3. Fertility and hatchability of eggs

Fertility of eggs was greater (p<0.05) for T1 and T2 than T3 and T4 diets (Table 5). Hens reared in T3 and T4 diets had similar values in the proportion of fertile eggs. Hatchability of eggs from the eggs set also followed similar pattern to that of fertility being higher (p<0.05) in hens fed with T1 and T2 diets than that of T3 and T4 which had similar values. No significant difference was observed among the first three treatment groups (T1, T2 and T3) in hatchability from fertile eggs. However, hens fed with T4 diet had lower (p<0.05) value in hatchability of fertile eggs than the rest of the other treatments.

Table 5. Fertility and hatchability (%) of eggs collected from the experimental diets

Parameters	T1	T2	T3	T4	SEM
Fertility of eggs after candling	92.8[a]	88.6[a]	79.7[b]	76.5[b]	3.79
Hatchability from total eggs set	76.6[a]	74.8[a]	71.9[b]	69.7[b]	1.53
Hatchability from fertile eggs	80.5[a]	81.6[a]	79.8[a]	74.4[b]	1.60

[a,b,c] Means with different superscript letters across treatment diets are significant ($p < 0.05$)
SEM = standard error of the mean

4. Discussion

4.1. Feed utilization and egg production

The present findings indicated that the analyzed CP content of GMP was higher than reported for wheat bran (212 vs. 163 g/kg DM) (Melesse *et al.* 2019). The high level of CP in GMP might be due to the presence of milling feed by-products that have been produced from protein rich grains.

The variations in CF content across treatment diets could be due to the presence of different constituents of the GMP, type of milling machine, and climate variation. The EE content of GMP in T1 appeared to be slightly higher than required for layer hens (NRC 1994), which could be attributed to the high proportion of fish meal which had the highest fat content after the roasted soybean seed.

Feed intake of chickens considerably reduced with increased levels of GMP. The low feed intake in T3 and T4 could be possibly be attributed to relatively high levels of CF due to increased proportion of GMP and cotton seed cake in the treatment diets. Dietary fiber has been traditionally considered as diluents of the diet and, often, an anti-nutritional factor. However, moderate amounts of fiber might improve the development of organs, enzyme production, and nutrient digestibility in poultry. Some of these effects are a consequence of better gizzard function, with an increase in gastroduodenal refluxes that facilitate the contact between nutrients and digestive enzymes (Mateos *et al.* 2012). These effects often result in improved growth and animal health, but the potential benefits depend largely on the physicochemical characteristics of the fiber source. On the other hand, it should be noted that higher levels of CF in layer's ration might affect the normal feed consumption resulting in reduced production performance of chicken (Varastegani and Dahlan, 2014). Moreover, high levels of dietary fiber may increase digestible energy loss, reduce mineral utilization, and negatively affect the performance of birds (González-Alvarado *et al.* 2007). In this regard, Mateos *et al.* (2012) reported that the effects of dietary fiber are related to its physiochemical characteristics, inclusion levels, feed physical form, and animal species and class.

To the author's knowledge, there are no reports on the performance of layer hens fed with milling feed by-products produced from a combination of different grains. Most works have reported on the utilization of milling by-products from a single grain such as wheat, maize, or rice bran in various farm animals (Boros *et al.*, 2004; Farooq *et al.* 2011; Maina *et al.* 2013; Martínez *et al.* 2015).

Consistent to our findings, Aliakbarpour *et al.* (2004) reported that increase in the level of broken rice substitution significantly decreased feed intake. It also decreased body weight and FCR of experimental groups though the effects were not significant. In another study, Maina *et al.* (2013) reported that layer hens fed on the commercial layer diet and the maize soybean diet gained more body weight and produced more eggs than those fed on test diets based on rice milling by-products. Nevertheless, when economic returns were considered for the same, it was found that gross margins were higher with rice milling by-products based diets than with the commercial based diets.

Egg weight is one of the important phenotypic traits that influence egg quality and reproductive efficiency of the chicken parents (Melesse *et al.* 2011). The observation of the current study indicated that chickens fed on increased GMP levels had lower hen-housed and egg weight than those chickens reared on control diet without affecting their liveability. In good agreement with the present findings, Cho *et al.* (2004) reported that increasing levels of dried leftover food in the diet of layer hens decreased egg weight and egg mass compared to control diets. Reduction in the weight of eggs, percentage of the egg production and reduced feed intake in the treatment groups might be attributed to the poor quality of nutrients supplied by the GMP particularly that of essential amino acids. There is no information available in the literature on the amino acid composition of GMP. It has been reported that grain-based by-products are typically high in non-starch polysaccharides, which are poorly utilized in poultry and are low in metabolizable energy (Melesse *et al.* 2019). It might also be due to the presence of other unidentified anti-nutritional factors in GMP that might have resulted in general performance depression among the experimental hens fed with increased levels of milling feed by-products. Apart from this, the reduced feed intake in T3 and T4 diets might have negatively affected the egg production potential of experimental birds.

Hascik *et al.* (2010) reported that a low FCR (g feed/g gain) is a good indication of high quality feed with least cost benefit for poultry producers. The finding of this study showed that chickens reared on the control diet had comparatively a lower FCR than those fed with the treatment diets. This indicates that hens in the control diet had efficiently converted the feed they consumed into egg products. Contrary to the present findings, Farooq *et al.* (2011) reported that FCR in broiler chicken had improved on dietary replacement of 25, 50, 75 and 100% of maize with broken rice. Similarly, Bala *et al.* (2017) reported a lower FCR in broiler chickens fed with the experimental diet containing 50% and 75% maize replacement with a mixture of pearl millet and broke rice than those fed with the control diet.

4.2. Fertility and hatchability of eggs

Fertility and hatchability are two major parameters that highly influence the supply of day-old chicks. Many factors of which nutrition, sex ratio, age, egg weight and storage duration are the most important ones could affect fertility and hatchability of eggs (Praes *et al.* 2014; Uğurlu *et al.* 2017). For the hatchability traits, breed has little effect on hatchability of poultry eggs, although light breeds like White Leghorn have been reported to have high fertility and hatchability (King'ori 2011).

The observed low fertility and hatchability of eggs in T3 and T4 diets might be attributed to the increased intake of the anti-nutritional substance gossypol from relatively high level of cotton seed cake in both treatment diets. It has been reported that gossypol has anti-fertility effects in cocks by damaging the germinal epithelium that would lead to a reduced sperm production. It also decreased sperm motility due to specific mitochondrial damage in spermatozoa tail (Randel *et al.* 1992). Another possible explanation for reduced fertility and hatchability values with increased levels of GMP could be the CP content of the experimental diets. Hocking & Bernard (1997) and Graaf *et al.* (2018) reported that broiler breeder males fed 12% CP had higher sperm concentration than those fed on 16% CP diet. Similarly, Uğurlu *et al.* (2017) reported that fertility and hatchability rate of total eggs in pheasants tended to decrease with increasing levels of CP in the diet. In the present study, cocks were fed with the same diet of the hens that had high levels of CP than their requirements (13-14% vs. 18.3-18.7%). Moreover, although diets were formulated to be iso-nitrogenous, the CP content of T3 and T4 diets was slightly higher than that of T1 and T2.

Early studies conducted by Daghir & Shah (1973) and Patel & McGinnis (1977) reported that excess dietary protein in layer hens increased the requirement of Vitamin A, Biotin, Vitamin B12 and calcium that negatively influenced the hatchability of eggs. On the other hand, Vo *et al.* (1994) reported higher hatchability in brown-egg layers fed with high protein diets. It is thus difficult to establish specific effects of maternal dietary energy intake on fertility and hatchability.

Wilson *et al.* (1980) found that broiler breeders on litter floor had normal hatchability with 0.31% phosphorus in their diets, which implies that birds on litter floors appear to recycle considerable amounts of phosphorus by coprophagy. Thus, excess phosphorus intake through a combination of dietary (0.44% in T3 and 0.45% in T4) and coprophagic sources might have reduced the shell quality and, indirectly, decreased the hatchability of the eggs.

5. Conclusion

The grain milling by-products (GMP) had moderately high protein and ash contents. The hen-housed and daily egg mass egg production and feed intake was significantly higher in hens fed with the control diet (T1) and with 10% substituted maize by GMP (T2) group than those reared with 15% (T3) and 20% (T4) GMP replaced diets. No significance difference was observed in these parameters among hens fed with T1 and T2 diets. The feed conversion ratio (kg feed/kg egg mass) was significantly lower in hens fed with T1 and T2 diets than the rest of the treatment groups. Fertility and hatchability of eggs was significantly greater for chickens fed with the control and T2 diets. The substitution of maize grain with increased levels of GMP significantly reduced most of the performance parameters. However, the substitution of maize with 10% had similar effect with that of the control group in all parameters and could be recommended as a viable substitution option. However, considering the advantage of reducing high costs of maize grain a substitution rate of 15% and perhaps higher could be justifiable under smallholder production settings. Thus, using inexpensive and easily accessible grain milling by-products in the layer rations presents a positive alternative to substitute the relatively expensive maize grain in layer rations.

Suggested future works include testing the effect of substitution of maize with various levels of grain milling byproducts on egg quality parameters (both external and internal) in layer hens. Future research is also recommended to investigate the substitution effect of maize or other conventional feed resources with grain milling byproducts on the growth performance and carcass traits of broiler chickens along with cost benefit analysis.

Acknowledgments

The author gratefully acknowledges the financial support received from FARM Africa. The author further acknowledges the Animal Nutrition Laboratory at Holleta Agricultural Research Center for their kind collaboration to analyze the feed ingredients. Moreover, the assistance received from Dr. Mohammed Beyan to follow-up the research activity in the absence of the researcher is highly appreciated.

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