Effect of Replacing Maize (*Zea mays*) with Barley (*Hordeum vulgare*) on Broilers Performance and Carcass Characteristics

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Abstract: A study was conducted to investigate the effect of feeding barley as a replacement for maize on the growth performance and carcass characteristics of Cobb 500 broiler chickens. One hundred and sixty-eight day old chicks were randomly assigned to four treatment diets with three replicates, having 14 chicks in each replication, in a completely randomized design. The treatment diets were maize 100% (T_1) and maize substituted with barley at 33.3% (T_2), 66.7% (T_3) and 100% (T_4). Similar amount of concentrate mix was added to all treatments. The experiment was conducted for a total of 56 days, with the first 1-21 days being the starter phase and the finisher phase lasted up to 56 days following the end of the starter phase. Feeds offered and refused was recorded every day, while body weight was recorded on a weekly basis. At the end of the experiment, two chickens from each sex were slaughtered per replication to evaluate the carcass components. The current results indicated higher crude protein, ash and crude fiber contents in barley than maize, while higher energy content was obtained from maize compared to barley. Starter phase diets gave similar feed intake values among treatments (36.8 - 38.8 g/day), showing a gradually decreasing trend with increasing levels of barley. Weight gains, growth rate and feed conversion ratio were similar up to 66.7% of maize replaced with barley. At finisher phase, daily feed intakes were 134.0-142.3 g with daily gains of 40.4-51.7g. For total period, daily feed intakes were 97.8-103.5 g with daily gains ranged from 31.2-38.8 g. Chicken under T_1, T_2 and T_3 showed similar values of feed intake and growth performance in the finisher and total feeding periods. Carcass yield was also similar for T_1, T_2 and T_3. In conclusion, barley could be used as an alternative source of energy in broiler nutrition by replacing 2/3rd of the maize, especially in areas where maize is not available or less productive or where its price is high.

Keywords: Cobb 500; Feed conversion ratio; Feed intake; Growth performance; Weight gain.

1. Introduction

The current world population of 7.6 billion is estimated to reach 8.6 billion in 2030, 9.8 billion in 2050 and 11.2 billion in 2100, according to the United Nations reports of 2017 (UN, 2017). Driven by population and economic growth, worldwide demand for meat consumption is predicted to increase by 60-70% in 2050 while poultry meat represents around 36% of this global meat production (Makkar *et al.,* 2014). Broiler production is fundamental for rapid and sustainable production of the highly demanded animal source protein in developing countries (Raji *et al.,* 2014). Mahmoudnia and Madani (2012) reported that broiler production has increased rapidly in tropical and subtropical regions in the past and sustained growth are forecasted for the future. However, feed supply and price are the major challenges of the poultry sector in developing countries including Ethiopia. It had been reported that feed expense accounts up to 70% of total cost in commercial poultry production (Hunduma *et al.,* 2010) and energy and amino acids account for more than 90% of this cost (Jayaprakash *et al.,* 2016). Although several researches had been conducting to alleviate feed shortage and price, still further efforts are needed to exploit alternative feedstuffs that can meet the nutrient requirements of poultry (Hunduma *et al.,* 2010).

The principal energy source in broiler diets are cereal grains particularly maize, which remains the sole energy source in most poultry diets. This is due to the fact that the ratio of available energy to gross energy is higher for maize than other cereals because of its high starch and crude fat content (McDonald, 2010). In Ethiopia, maize is a common warm weather cereal crop widely growing between 1500 and 2200 meter above sea level (m.a.s.l.), with a yield of 3.7 t/ha (CSA, 2017). Among the major cereals, maize is the most important staple in terms of calorie intake in rural Ethiopia. The 2004/5

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national survey of consumption expenditure indicated that maize accounted for 16.7% of the national calorie intake followed by sorghum (14.1%) and wheat (12.6%) in descending order (Berhane *et al.,* 2011). Although maize is produced throughout the world, there was stiff competition among human, livestock and industry (Ajebu *et al.,* 2016). These stiff competitions for multiple uses, more than ever the current alternative use of maize for bio-fuel production, would increase maize price in the future; such that any increase in its price will radically affect the price of broiler feeds, especially in maize importing countries. To this effect, investigation of some potential feed resources that are locally available with better comparative nutritional value as energy sources like barely in broiler diets would be justifiable.

Barley (*Hordeum vulgare* L.) is the predominant cereal in the highlands of Ethiopia with an optimum altitude range of 2000 to 3500 masl and covers 14.65% of the land under crop cultivation, with a yield of 2.1 t/ha (CSA, 2017). The total yield of barley has been increased by 4.99% between 2013/2014 and 2014/2015 and also by 5.2% in the year 2015/2016 (CSA, 2017). Barley had an extensive root system that makes it able to compete with weeds and often used to break disease, insect and weed cycles associated with other crops (Karley *et al.,* 2011). It also had higher photosynthetic activity than other cereals, which implies the level of nitrogen fertilizer used for barley production was typically lower than that for maize (Karley *et al.,* 2011). Moreover, barley contains more protein and better amino acid profile than maize, which implies barley-based diets require less protein supplementation (Sadeghi and Habibian, 2016). Although barley is well known to tolerate frost periods and grown successfully in highland areas where maize is less productive with lower price (75% of that of maize in local markets), the use of barley in poultry diets is not well documented under the Ethiopian condition. The current study was thus designed to evaluate the nutritional potential of locally available barley as alternative energy source on growth performance and carcass components by substituting maize in concentrate-based diets of Cobb 500 broiler chickens reared under tropical environment.

2. Materials and Methods

2.1. Study Site

The experiment was conducted at Agarfa A-TVET College poultry farm, located 458 km South East of the capital city, Addis Ababa. It falls between 7°17'N Latitude and 39°49'E Longitude with an average altitude of 2000 masl. The mean annual temperature of the district is 17.5°C. The minimum and maximum temperature are 10°C and 25°C, respectively. The average annual rainfall is 800 ml, whereas 400 ml and 1200 ml were the minimum and maximum rainfall recorded in the Agarfa district, respectively. Barley and wheat are the dominant cereal crops cultivated in the area.

2.2. Experimental Design

The study was a one-factor experiment in a Completely Randomized Design (CRD) with four dietary treatments each replicated three times. In the control diet (T_1) maize was served as the main energy source without barley grain inclusion and in the rest of the treatments maize was substituted by barley (represented hereafter as T_2, T_3 and T_4) weight by weight at 33.3%, 66.7% and 100%. The levels of barley in treatments (T_2, T_3 and to T_4) were 11%, 22% and 33% for the first three weeks of age and 14.5%, 29% and 43.5% for the finishing period of 22 to 56 days. One hundred and sixty eight (168) day old unsexed Cobb 500 broiler chicks were randomly assigned to the four treatment diets with three replicates having 14 chicks per replication. The total experimental period took 56 days. The layout of the experiment is shown in Table-1.

Table 1. Layout of the experiment.

Treatments	Barley substitution level (%)	Maize (%)	Replicates	Number of chicks per replicate	Number of chicks per treatment
T_1	0	100	3	14	42
T_2	33.3	66.7	3	14	42
T_3	66.7	33.3	3	14	42
T_4	100	0	3	14	42

2.3. Ingredients of the Experimental Diets

The experimental dietary rations were composed of maize (white), barley grain, wheat short, soybean meal, Noug seed cake (*Guizotia abyssinica*), limestone, di-calcium phosphate (DCP), vitamin premix, common salt, lysine and methionine. A single batch of barley and maize were purchased from local market, whereas the rest feed ingredients were purchased from Kality Animal Feed Enterprise, Addis Ababa, Ethiopia. All ingredients, except vitamin premix and limiting amino acids, were milled to pass through a 5 mm sieve size. All ingredients were then mixed according to the formulated experimental diets (Table 2) to meet the standard nutrient requirements of broilers as outlined by NRC (1994). Moreover, representative samples from each treatment diets were taken for the determination of chemical compositions.

Table 2. Proportion of feed ingredients used to formulate the starter and finisher broiler chicken rations per 100 Kg (as feed bases).

Feed Ingredients	Treatments			
	T_1	T_2	T_3	T_4
Starter ration				
Maize (White)	33	22	11	0
Barley	0	11	22	33
Concentrate Mix [a]	67	67	67	67
Total	100	100	100	100
Finisher ration				
Maize (White)	43.5	29	14.5	0
Barley	0	14.5	29	43.5
Concentrate Mix [b]	56.5	56.5	56.5	56.5
Total	100	100	100	100

Note: [a] *NSC (Noug seed cake) = 26.7, SBM (Soy bean meal) = 20.3, DCP (Di-calcium phosphate) = 0.75, Wheat short = 17, Limestone = 0.9, Vitamin Premix = 0.5, Common Salt = 0.25, Lysine = 0.35, Methionine = 0.25;* [b] *NSC (Noug seed cake) = 24.4, SBM (Soy bean meal) =11.5, DCP (Di-calcium phosphate) = 0.75, Wheat short =17.6, Limestone = 1, Vitamin Premix = 0.5, Common Salt = 0.25, Lysine = 0.25, Methionine = 0.25;* T_1 *= 100% maize (0% barley);* T_2 *= 33.3% of maize replaced with barley;* T_3 *= 66.7% of maize replaced with barley;* T_4 *= 100% of maize replaced with barley.*

2.4. Management of Experimental Chickens

2.4.1. Housing the broilers

The deep litter experimental house was wire-mesh partitioned in to 12 pens of 1.5 m x 2 m dimensions having a space of 0.5 m between pens and providing sufficient space for finisher birds. The experimental pens were thoroughly prepared, cleaned, disinfected and equipped 15 days before arrival of chicks. The pens were fumigated with formaldehyde gas of 20 g of Potassium per Manganet ($KMnO_4$) powder plus 100 ml of 37% Formaline per m^3 of space. The floor was covered with disinfected sawdust having 4-5 cm depth. The temperature of the experimental house and brooding appliances were adjusted 24 hours before chick's arrival and a careful pre-placement management of feeders and drinkers for each pen; placement of drinkers close to the feeders, but not so close as to cause feed spoilage.

2.4.2. Brooding and health management

A total of 168 day-old unsexed Cobb 500 broiler chicks were purchased from Alema Farms PLC, Debre zeit, Ethiopia. The chicks were then randomly assigned into 12 pens and reared under brooder for four weeks. About 60 watt infra – red lamps were switched on to provide warmth. The initial temperature of the pen was 35°C which was reduced sequentially based on the chick's age until reaching 21°C at day twenty eight. As a bio-security measure, a disinfectant (10% of 37% Formaline) was used as footbath on all entrances. Litter was raked frequently to allow good air circulation. Functionality of drinkers were checked regularly. All chicks were vaccinated against Marek's (day 1), Newcastle (day 7 and 21) and Infectious Bursal diseases (day 14 and 28) as recommended by the veterinarian and mortality was recorded daily. The general health of the chicks and sanitary measures were closely monitored.

2.4.3. Feeding and data collection

Measured amount of feed was offered twice a day (8:30 and 17:30) per pen and refusals were weighed and recorded every day at 8:00 before the daily feed offered. Fresh clean water was provided *ad libitum*. Chicks were fed starter ration for the first three weeks followed by finisher ration till the 8^{th} week. Feed intake was calculated for the same periods and feed conversion ratio was calculated after adjusting feed intake for mortality. Requirements for the starter and finisher phases of chicks were estimated at 0.80 kg and 4.89 kg of feed per chick, respectively. Chicks were weighed on a pen basis initially and every week afterwards before morning meal. Finally, growth rate was calculated using the equation of Larner and Asundson (1932) as $GR = ((LBW2 - LBW1) \times 100)/ (0.5 (LBW1 + LBW2))$. The feed or protein conversion ratio was calculated from the total feed or protein consumed by chicks per unit of body weight gain. At the end of the eighth week, two chicks from each sex close to mean weight were selected per pen. After withholding of feed overnight, each bird was weighed (considered as pre-slaughter weight), humanely slaughtered by severing the jugular vein, allowed to bleed completely and manually eviscerated. The carcass cuts, abdominal fat, edible and non-edible offal components were weighed and recorded. Carcass dressing percentage (CDP) was calculated as: (Carcass Weight/Pre-slaughter Weight) × 100%.

2.5. Chemical Analysis of Feeds

Dry matter, ether extract, crude fiber, crude protein and crude ash were determined following method of AOAC (1995). Crude protein was computed by multiplying N concentration by 6.25. Metabolizable energy was calculated by indirect method of Wiseman (1987) as: ME (Kcal/kg DM) = 3951 + 54.4 EE - 88.7CF - 40.8 Ash. All samples were analyzed in duplicates at Animal Nutrition Laboratory of Haramaya University.

2.6. Statistical Analysis

Data were analyzed using General Linear Model (GLM) procedures of Statistical Analysis System (SAS, 2008). Treatment means were compared using Duncan's Multiple Range Test at P<0.01. The model used was: $Y_{ij} = \mu + T_i + E_{ij}$ Where, Yij = Dependent Variable; μ = Overall Mean; Ti = Effect of the i^{th} treatment diet/ feeding level/sex; Eij = Effect of the random error.

3. Results

3.1. Chemical Composition of Feed Ingredients

The results of laboratory analysis for the major feed ingredients used in the formulation of experimental rations are presented in Table 3. The Chemical analysis results of the current study revealed that DM, CP, CF and crude ash contents of barley grain were found to be higher compared to maize grain with NFE, EE and ME being slightly lower in barley grain.

Table 3. Chemical composition and energy content of feed ingredients.

Ingredients	Chemical composition [a]						
	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	ME (kcal/kg DM)
Maize (White)	90.8	9.8	3.4	2.7	2.7	72.2	3742
Raw Barley	91.4	11.8	2.5	5.3	3.1	68.7	3490
Wheat Short	92.4	17.5	4.3	8.3	4.1	58.2	3281
NSC	93.2	32.8	9.8	17.1	9.2	24.3	2604
SBM	93.8	37.6	10.4	6.3	6.2	33.3	3668

Note: [a] *NSC = Noug Seed Cake; SBM = Soya Bean Meal; DM = Dry mater; CP = Crude protein; EE = Ether extract; CF = Crude fiber; ME = Metabolizable energy; NFE = Nitrogen free extract = DM - (CP + EE + CF + Ash); and Kcal = Kilocalorie.*

3.2. Chemical Composition of Experimental Diets

The results of laboratory analysis for the starter and finisher treatment diets are given in Table 4. The DM, CP, CF and ash levels of the starters and finishers rations showed a slight increase as the inclusion level of barley grain increased while the ME, EE and NFE content slightly decreased as inclusion level of barley grain increased.

Table 4. Chemical composition of treatment diets containing different levels of barley as replacement for maize.

Treatment Rations		Chemical composition [a]						
		DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	ME (Kcal/Kg DM)
Starter rations	T_1	92.6	23.1	6.58	8.31	5.30	49.3	3252
	T_2	92.6	23.3	6.48	8.54	5.35	49.0	3224
	T_3	92.7	23.5	6.38	8.77	5.39	48.6	3196
	T_4	92.8	23.7	6.28	9.00	5.44	48.3	3169
Finisher rations	T_1	92.3	20.1	5.82	7.75	4.85	53.8	3278
	T_2	92.3	20.3	5.69	8.05	4.91	53.4	3241
	T_3	92.4	20.6	5.56	8.36	4.97	52.9	3205
	T_4	92.5	20.9	5.43	8.66	5.03	52.5	3168

Note: [a] *DM = Dry mater; CP = Crude protein; EE = Ether extract; CF = Crude fiber; ME = Metabolizable energy; NFE = Nitrogen free extract;* T_1 *= 100% maize (0% barley);* T_2 *= 33.3% of maize replaced with barley;* T_3 *= 66.7% of maize replaced with barley;* T_4 *= 100% of maize replaced with barley.*

3.3. Nutrient and Energy Intakes of Broilers

The nutrient and metabolizable energy intakes of the experimental chicks are given in Table 5, 6 and 7. The feed, dry matter, ether extract and metabolizable energy intakes of experimental chicks showed a linear decrease with increasing levels of barley in the diets at all stages. However, fiber intakes of chicks were significantly higher for diets T_3 followed by T_4. For the first three weeks, chicks under sole barley diet showed significantly ($p<0.01$) lower dietary protein intake. Chicks fed diets of up to 66.7% maize replaced by barley took more dietary protein. Chicks under sole barley diet (T_4) showed a significant decrease in feed/dry matter, ether extract and energy intake at all stages.

Table 5. Effect of barley replacement for maize on feed and nutrient (g/day) intakes of broilers for the starter phase (1-21d).

Intakes	Treatments					
	T_1	T_2	T_3	T_4	SEM	P
Feed intake	38.82^{a}	38.65^{a}	38.06^{b}	36.78^{c}	0.24	<.0001
Dry matter	35.94^{a}	35.79^{a}	35.28^{b}	34.13^{c}	0.22	<.0001
Crude protein	8.97^{a}	9.00^{a}	8.94^{a}	8.72^{b}	0.03	<.0001
Ether extract	2.55^{a}	2.50^{b}	2.43^{b}	2.31^{d}	0.03	<.0001
Crude fiber	3.23^{c}	3.30^{b}	3.34^{a}	3.31^{ab}	0.01	<.0001
Ash	2.057^{a}	2.067^{a}	2.051^{a}	2.001^{b}	0.01	<.0001
ME (Kcal/day)	116.89^{a}	115.40^{b}	112.75^{c}	108.16^{d}	1.00	<.0001

Note: *Means in the same row without common letter(s) are significantly different at P<0.01 level of significance.*

Table 6. Feed and nutrient (g/day) intakes of broilers for the finisher phase (22-56d).

Intakes	Treatments					
	T_1	T_2	T_3	T_4	SEM	P
Feed intake	142.33^{a}	141.81^{a}	139.94^{b}	134.40^{c}	0.95	<.0001
Dry matter	131.37^{a}	130.89^{a}	129.30^{b}	124.32^{c}	0.84	<.0001
Crude protein	28.61^{b}	28.79^{a}	28.83^{a}	28.09^{c}	0.09	<.0001
Ether extract	8.28^{a}	8.07^{b}	7.78^{c}	7.30^{d}	0.11	<.0001
Crude fiber	11.03^{d}	11.42^{c}	11.70^{a}	11.64^{b}	0.08	<.0001
Ash	6.90^{b}	6.96^{a}	6.95^{a}	6.76^{c}	0.02	<.0001
ME (Kcal/day)	430.62^{a}	424.22^{b}	414.41^{c}	393.84^{d}	4.20	<.0001

Note: *Means in the same row without common letter(s) are significantly different at P<0.01 level of significance.*

Table 7. Feed and nutrient (g/day) intakes of broilers for the overall period (1-56d).

Intakes	Treatments ^{a}					
	T_1	T_2	T_3	T_4	SEM	P
Feed intake	103.51^{a}	103.13^{a}	101.73^{b}	97.79^{c}	0.68	<.0001
Dry matter	95.58^{a}	95.23^{a}	94.04^{b}	90.50^{c}	0.61	<.0001
Crude protein	21.24^{b}	21.37^{a}	21.37^{a}	20.82^{c}	0.07	<.0001
Ether extract	6.13^{a}	5.98^{b}	5.77^{c}	5.43^{d}	0.08	<.0001
Crude fiber	8.10^{d}	8.37^{c}	8.56^{a}	8.52^{b}	0.05	<.0001
Ash	5.10^{b}	5.13^{a}	5.12^{a}	5.00^{c}	0.02	<.0001
ME (Kcal/day)	312.97^{a}	308.41^{b}	301.29^{c}	286.71^{d}	3.00	<.0001

Note: ^{a} *SEM = Polled Standard Error of Mean; ME = Metabolizable energy; T1 = 100% maize (0% barley); T2 = 33.3% of maize replaced with barley; T3 = 66.7% of maize replaced with barley; and T4 = 100% of maize replaced with barley. Means in the same row without common letter(s) are significantly different at P<0.01 level of significance.*

3.4. Effect of Substituting Maize for Barley on Body-Weight Changes

The body weight changes of chicken at different ages are shown in Table 8, 9 and 10. There was no significant ($p>0.01$) difference in body weight among treatment groups at the start of the experimental period. The substitution of maize with barley resulted in reduction of body weight gain and growth performance of chicks, with increasing levels of barley in treatment diets. In the first 21 days, chicken under sole barley diet showed poor performance compared to chicken under sole maize diet. Similar patterns were also observed for the finisher phase.

Table 8. Mean values for body weight changes of broilers for the starter phase (1-21d).

Parameters	Treatments [a]					
	T_1	T_2	T_3	T_4	SEM	P
Initial body weight (g/h)	40.27	40.00	40.07	39.73	0.20	0.8677
Final body weight (g/h)	402.50[a]	398.73[a]	398.27[a]	372.90[b]	3.64	<.0001
Body weight gain (g/h)	362.23[a]	358.73[a]	358.20[a]	333.17[b]	3.59	<.0001
Average daily gain (g/h)	17.25[a]	17.08[a]	17.06[a]	15.87[b]	0.17	<.0001
Growth rate, %	163.62[a]	163.54[a]	163.44[a]	161.48[b]	0.32	0.0141

Note: [a] *SEM = Polled Standard Error of Mean; T1 = 100% maize (0% barley); T2 = 33.3% of maize replaced with barley; T3 = 66.7% of maize replaced with barley; and T4 = 100% of maize replaced with barley. Means in the same row without common letter(s) are significantly different at P<0.01 level of significance.*

Table 9. Mean values for body weight changes of broilers for the finisher phase (22-56d).

Parameters	Treatments [a]					
	T_1	T_2	T_3	T_4	SEM	P
Initial body weight (g/h)	402.50[a]	398.73[a]	398.27[a]	372.90[b]	3.64	<.0001
Final body weight (g/h)	2213.47[a]	2161.53[a]	2049.13[a]	1785.93[b]	52.66	0.0003
Body weight gain (g/h)	1810.97[a]	1762.80[a]	1650.87[a]	1413.03[b]	49.42	0.0005
Average daily gain (g/h)	51.74[a]	50.37[a]	47.17[a]	40.37[b]	1.41	0.0005
Growth rate, %	138.38[a]	137.69[a]	134.89[ab]	130.89[b]	0.99	0.003

Note: [a] *SEM = Polled Standard Error of Mean; T1 = 100% maize (0% barley); T2 = 33.3% of maize replaced with barley; T3 = 66.7% of maize replaced with barley; and T4 = 100% of maize replaced with barley. Means in the same row without common letter(s) are significantly different at P<0.01 level of significance.*

Table 10. Mean values for body weight changes of broilers for the overall period (1-56d).

Parameters	Treatments [a]					
	T_1	T_2	T_3	T_4	SEM	P
Initial body weight (g/h)	40.27	40.00	40.07	39.73	0.20	0.8677
Final body weight (g/h)	2213.47[a]	2161.53[a]	2049.13[a]	1785.93[b]	52.66	0.0003
Body weight gain (g/h)	2173.20[a]	2121.53[a]	2009.07[a]	1746.20[b]	52.60	0.0003
Average daily gain (g/h)	38.81[a]	37.89[a]	35.88[a]	31.18[b]	0.94	0.0003
Growth rate, %	192.84[a]	192.73[a]	192.33[a]	191.29[b]	0.20	0.0005

Note: [a] *SEM = Polled Standard Error of Mean; T1 = 100% maize (0% barley); T2 = 33.3% of maize replaced with barley; T3 = 66.7% of maize replaced with barley; and T4 = 100% of maize replaced with barley. Means in the same row without common letter(s) are significantly different at P<0.01 level of significance.*

3.5. Effect of Substitution on Feed Conversion Ratio

The feed conversion ratios and mortality rates of chicken at different ages are shown in Table 11. The feed and protein conversion ratios expressed as g feed per g weight gain and CP per g weight gain, respectively, were increased with increasing levels of barley at different ages. The total replacement of maize with barley (T_4) resulted in significantly ($p<0.01$) higher feed and protein conversion ratio for the first 21 days of the experiment. Similar pattern was observed for the finisher phase and whole experiment. The overall mortality rate in the entire experimental period was 10.12% with 7.74% and 2.38% for the starter and finisher phases, respectively. Most of the mortality occurred (84%) during the first 10 days of the trial and was not related to treatments. The similar in mortality among treatment groups might indicate optimum balance of nutrients in maize and barley diets.

Table 11. Mean values for feed and protein conversion ratios and mortality rate of broilers.

Parameters [a]	Treatments [b]					
	T_1	T_2	T_3	T_4	SEM	P
Starter phase (1-21d)						
FCR	2.25[ab]	2.26[ab]	2.23[b]	2.32[a]	0.0122	0.0294
PCR	0.52[b]	0.53[b]	0.52[b]	0.55[a]	0.0038	0.0031
M	7.14	7.14	9.52	7.14	1.3785	0.9314
Finisher phase (22-56d)						
FCR	2.76[b]	2.82[b]	2.97[b]	3.33[a]	0.07	0.0018
PCR	0.55[b]	0.57[b]	0.61[b]	0.70[a]	0.02	0.0005
M	2.56	5.81	0.00	2.78	1.19	0.4442
Overall period (1-56d)						
FCR	2.67[b]	2.72[b]	2.84[b]	3.14[a]	0.06	0.0018
PCR	0.55[b]	0.56[b]	0.60[b]	0.67[a]	0.01	0.0005
M (%)	9.52	11.91	9.52	9.52	1.38	0.9314

Note: [a] *FCR = Feed Conversion Ratio; PCR = Protein Conversion Ratio; and M = Mortality.* [b] *SEM = Polled Standard Error of Mean; T1 = 100% maize (0% barley); T2 = 33.3% of maize replaced with barley; T3 = 66.7% of maize replaced with barley; and T4 = 100% of maize replaced with barley. Means in the same row without common letter(s) are significantly different at P<0.01 level of significance.*

3.6. Effect of Substitution and Sex on Carcass Parameters

In the current study, significant difference ($p>0.01$) were not observed in carcass yield and organ weights among chicken under T_1, T_2 and T_3 treatments (Table 12). However, T_4 showed the least values on most of carcass parameters including weight at slaughter, carcass weight, commercial carcass, drumsticks, breast, wing, gizzard, dressing percentage based on carcass CDP and TNEO weights. The carcass yield analysis revealed significantly ($p<0.01$) higher Back bone and AF accumulation values for T_1 and T_3, respectively.

Regarding sex effects, male broilers showed significantly higher values of CDP, CC, thighs and neck compared to female counterparts. On the other hand, both sexes showed similar values for other edible and non-edible carcasses components.

Table 12. Mean values for carcass yield and organ weights in 56-day old Cobb 500 broilers (g).

Parameters [a]	Sex		Treatments [b]					
	Male	Female	T_1	T_2	T_3	T_4	SEM	P
SlWt	2220.42	2103.75	2258.17[a]	2223.83[a]	2210.67[a]	1955.17[b]	34.64	0.0015
Neck	62.73	59.17	62.37	62.92	59.45	59.07	0.92	0.3428
Wings	86.16[a]	74.15[b]	80.67	82.13	86.57	71.25	2.05	0.0460
Drumsticks	227.47	199.14	216.62[a]	223.53[a]	235.25[a]	177.82[b]	6.11	0.0012
Thighs	254.94[a]	217.73[b]	245.57	238.75	245.95	215.08	5.64	0.1716
Breast part	615.55	567.28	617.98[a]	608.33[a]	599.37[ab]	539.98[b]	9.82	0.0115
Back bone	123.51	120.30	150.00[a]	120.90[b]	118.75[b]	97.97[b]	4.90	0.0002
Liver	50.92	46.94	50.25	50.90	49.75	44.82	0.88	0.0459
Gizzard	48.44	45.15	50.32[a]	46.55[a]	48.75[a]	41.57[b]	0.87	0.0002
Skin	104.26	112.73	130.02[a]	110.55[b]	104.18[b]	89.25[c]	3.42	<.0001
AF	11.81	9.54	11.68[b]	8.98[bc]	17.95[a]	4.08[c]	1.25	<.0001
TEO	203.63	204.82	230.58[a]	208.00[b]	202.68[b]	175.63[c]	4.54	<.0001
TNEO	566.37	550.68	580.42[a]	575.02[a]	579.82[a]	498.85[b]	10.66	0.0059
CC	1370.36[a]	1237.78[b]	1373.20[a]	1336.57[a]	1345.33[a]	1161.17[b]	26.54	0.0091
CWt	1573.99	1442.59	1603.78[a]	1544.57[a]	1548.02[a]	1336.80[b]	29.83	0.0024
CDP	70.84[a]	68.50[b]	70.92	69.44	69.99	68.34	0.37	0.0897

Note: [a] *SlWt = Slaughter weight; AF = Abdominal fat; TEO = Total edible offal (Liver, Gizzard and Skin); TNEO = Total non-edible offals; CC = Commercial Carcass (Thighs, Drumsticks, Breast part, Backbone, Neck and Wings); CWt = Carcass Weight (CC and TEO); and CDP = Carcass Dressing Percentage.* [b] *SEM = Polled Standard Error of Mean; T1 = 100% maize (0% barley); T2 = 33.3% of maize replaced with barley; T3 = 66.7% of maize replaced with barley; and T4 = 100% of maize replaced with barley. Means in the same row without common letter(s) are significantly different at P<0.01 level of significance.*

4. Discussion

4.1. Nutrient and Energy Intakes

In this study, sole barley diets decreased feed and dry matter intakes of broilers at different phases of the experiment. A similar study of Friesen *et al.* (1992) showed a reduction in feed intake by using 35% and 70% barley in broiler diets. Jacob and Pescatore (2012) also reviewed that increasing levels of untreated barley reduced feed intake of broilers. The lower feed intake of broilers, especially young chicks, fed barley-based diets might be attributed to the detrimental effects of the non-starch polysaccharides, especially β-glucans found in barley grain (Gracia *et al.,* 2003; Onderci *et al.,* 2008). The β-glucans form gels in the bird digestive tract are not broken down because of the lack of appropriate enzymes and the rapid rate of passage in poultry (Sadeghi and Habibian, 2016). In addition to the limited enzyme production, slow gastrointestinal transit of digesta may reduce feed intake and growth (Gracia *et al.,* 2003). The reduced voluntary feed intake could also be associated with poor palatability of the feed due to barley, which has higher crude fiber content compared to maize. It had been reported that dietary factors, including energy density, deficiency or excessness of nutrient such as carbohydrates, proteins and minerals can also influence feed intake in poultry (Mbajiorgu *et al.,* 2011). In contrast to the current finding, Veldkamp *et al.* (2005) reported that as dietary energy level increased; broiler chickens satisfy their energy needs by decreasing feed intake.

In the current study, the protein, fiber and ash intakes of chicks showed a linear increase with the increasing levels of barley in the treatment diets, which might be attributed to the combination of higher dry matter intake of chickens and the relatively higher protein, fiber and ash contents of barley-based diets. The crude fiber content of the experimental diets varied between 7.75% and 8.66% which is slightly above the maximum CF (7%) requirement of broiler diets (Varastegani and Dahlan, 2014). According to Saki *et al.* (2010), fiber can be included in broiler diets to reduce fat deposits and produce lean meat. Melkamu (2013) also reported the advantage of crude fiber in improving DM intake of chicken by increasing fecal bulk and speed up the passage rate of feed through the digestive tract which keep the health of gastrointestinal tract. Likewise, the trend of reduction of metabolizable energy and EE intakes of broilers fed barley-based diets might be attributed to the low feed intake and low oil content of barley diets. The lipid content of barley is relatively low, only 2 to 3% of the grain (Sadeghi and Habibian, 2016). This, together with high fiber and ash intakes seems to have contributed to the differences in metabolizable energy intake of broilers. It had been reported that the level of inclusion of barley is limited because of its lower metabolizable energy and negative effects on bird performance (Onderci *et al.,* 2008). The addition of fat to poultry diets that rely on barley could thus be another possible explanation, as indicated previously by Sadeghi and Habibian (2016).

4.2. Body-Weight Changes and Growth Performance

In the current study, the final body weight of broilers ranged from 1785.9 g to 2213.5 g at 56 days of age. Similarly Sadeghi and Habibian (2016) reported 2000 to 2100 g for broilers fed barley-based diets with or without enzyme supplementation. However, a study of Abera *et al.* (2018) showed 2203- 2600 g for Cobb 500 broilers reared at Agarfa poultry farm. The average daily gain of 31.2 to 38.8 g also agreed with 40.8 to 42.9g reported by Sadeghi and Habibian (2016) but less than the 47.1 to 57.1 g results obtained by Abera *et al.* (2018). The differences might be due to the differences in nutritional content of the diet, management of birds or the conditions under which the experiment was carried out (Rebolé *et al.*, 2010). Any variation in the environment surrounding the birds resulted in stunted growth and major productive losses (Czarick and Fairchild, 2012). The comparable weight gain and growth of broilers fed sole maize and broilers fed maize/barley diets was consistent with the results obtained by Bennett *et al.* (2002) and Sadeghi and Habibian (2016). It has been reported that broilers can fed up to 35% barley with no overall effects on bird performance (Bennett *et al.,* 2002). Sadeghi and Habibian (2016) observed comparable growth with barley replacement up to 50% of maize in starter diets and up to 100% for older broilers. However, Jacob and Pescatore (2012) did not recommend the inclusion of untreated barley grain, especially in starter broiler diets.

On the other hand, the reduction of body weight changes of broilers fed sole barley diets (T_4) was consistent with previous reports (Mansoori *et al.,* 2011; Ribeiro *et al.,* 2012). It has been reported that feeding high barley diets decreased body weight gain (Mansoori *et al.,* 2011; Ribeiro *et al.,* 2012). According to Shakouri *et al.* (2009), the negative effects of barley on the growth performance of broiler chickens could be related to the altered intestinal morphology, endogenous enzyme activity and gut microflora. It might also be due to shortening, thickening, and atrophy of the villi as well as increase in the number and size of goblet cells as suggested by Onderci *et al.* (2008).

4.3. Feed Conversion Ratio

In the current study, the feed conversion ratios (ranged from 2.67 to 3.14) were better than values of 3.19 to 3.41 reported by Ajebu *et al.* (2016) for Cobb 500 broilers. Feed conversion ratios of 2.08 to 2.44 were obtained by Abera *et al.* (2018) while Sadeghi and Habibian (2016) reported 1.73 to 2.5 in cockerels fed barley-based diets. The differences might be due to barley type or the conditions under which the experiment was carried out (Rebolé *et al.,* 2010). In the current study, feed conversion ratio of broilers were comparable between broilers fed maize-based diet and broilers fed diets of up to 66.7% of maize substituted with barley. Similar confirmation of the suitability of barley was established by the work of Mansoori *et al.* (2011), who observed absence of feed efficiency changes on broiler diet containing 30% barley.

The increasing trend of feed conversion ratio figures with increasing levels of barley in the current study agreed with the reports of Onderci *et al.* (2008), Shirzadi *et al.* (2009) and Sadeghi and Habibian (2016) who observed increased feed conversion ratio by feeding high barley diets. A similar trend was reported by Bennett *et al.* (2002) who observed a temporary loss in early growth and feed conversion efficiency when barley was included at any level above 5% in broiler diets. However, the current finding was not in agreement with the work of Ribeiro *et al.* (2012) who observed a decreased feed conversion ratio when poultry were fed with high barley diets.

4.4. Carcass Characteristics

The similarity in primal carcass parts of broilers fed sole maize and broilers fed maize/barley diets in the current study was consistent with previous reports (Melkamu, 2013; Raji *et al.,* 2014). It was reported by several authors that carcass yields were unresponsive to dietary ME level (Melkamu, 2013; Raji *et al.,* 2014). Etalem *et al.* (2013) reported significant differences on Drumstick weight and drumstick percentage on Hubbard broilers similar with the current study. The breast part and carcass yield were lower in broilers fed diet of 100% barley. Similarly, Moharrery (2006) reported a higher percentage of breast part and carcass yield in broilers fed diets containing 35% barley. The comparable gizzard weight of broilers fed on sole maize and those fed on maize/barley diets indicated presence of adequate energy for birds from those dietary treatments. Similarly, the observed higher abdominal fat of broilers fed 66.7% of barley diet was in agreement with the findings of Rabie *et al.* (2010) who observed accumulation of abdominal fat caused by low energy diets with the reasons being substantiated by the report of Nikolova *et al.* (2007) who indicated abdominal fat being affected by genotype, sex, age and nutrition of the broilers.

In the current study, male broiler chicks were significantly higher for CDP, CC, thighs, wing and neck compared to the females, which suggest the existence of association between these traits in both sexes to express them. This sex difference might be attributed to the presence of sex hormone (androgen) in males which enhanced muscle development compared to the sex hormone (estrogen) in females, mostly responsible for fat deposition rather than muscle tissue development (Abera *et al.,* 2018). On the other hand, in contrast with the findings of the current study, Ajebu *et al.* (2016) reported heavier breast muscle for male chickens compared to females.

5.Conclusions

The effect of replacing maize with barley on feed intake, growth performance and carcass yield characteristics of Cobb 500 broiler chickens was studied for 56 days. Suitability of barley in concentrate-based diets was successful to replace 2/3rd of maize in starter broiler diets. Also at finisher phase sole barley diet resulted in poor performance of broilers. It is thus concluded that replacement of up to 66.7% of maize with barley will not adversely affect growth performance and carcass traits of broilers. The inclusion of barley up to the proportion of 30% of ration can be recommended for feeding of broilers, especially in areas where maize is not available or less productive or its price is high.

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7. References

Aberra Melesse, Cheru Tesfaye and Aster Abebe. 2018. Response of broiler chickens to different levels of Moringa stenopetala leaf meal as a substitute for Noug seed *(Guizotia abyssinica)* cake on growth performance and carcass components. *International Journal of Research in Agriculture and Forestry*, 5: 1-9.

Ajebu Nurfeta, Lidetewold Tsega and Aster Abebe. 2016. Cactus fruit meal as a partial replacement of maize in broiler ration. *Ethiopian Journal of Applied Science and Technology*, 7: 34-43.

AOAC (Association of Official Analytical Chemists). 1995. Official Method of Analysis, 16th Edition. Association of Official Analytical Chemists, Washington DC, USA.

Bennett, C., Classen, H. and Riddell, C. 2002. Feeding broiler chickens wheat and barley diets containing whole, ground and pelleted grain. *Journal of Poultry Science,* 81: 995-1003.

Berhane G, Paulos Z, Tafere K, Tamru S. 2011. Food grain consumption and calorie intake patterns in Ethiopia. IFPRI Ethiopia Strategy Support Program II (ESSP II) Working Paper 23.

CSA (Central Statistical Agency). 2017. The Federal Democratic Republic of Ethiopia, Central Statistical Agency, Agricultural Sample Survey 2016/7 (2009 E.C.),Volume I, Report on Area and Production of Major Crops (Private Peasant

Holdings, Meher Season), Statistical Bulletin 532, May 2017, Addis Ababa, Ethiopia.

Czarick, M. and Fairchild, B. 2012. Relative humidity, the best measure of overall poultry house air quality (poultry housing tips), extension article and cooperative extension service. Vol. 24. University of Georgia, USA. 2p.

Etalem T., Getachew A., Mengistu U. and Tadelle D. 2013. Moringa oleafera leaf meal as an alternative protein feed ingredient in broiler ration. *International Journal of Poultry Science,* 12: 289-297.

Friesen, O., Guenter, W., Marquardt, R. and Rotter, B. 1992. The effect of enzyme supplementation on the apparent metabolizable energy and nutrient digestibilities of wheat, barley, oats and rye for the young broiler chick. *Poultry Science,* 71: 1710-1721.

Hunduma D., Regassa C., Fufa D., Endale B. and Samson L. 2010. Major Constraints and Health Management of Village Poultry Production in Rift Valley of Oromia, Ethiopia, Adama University, School of Agriculture, Adama, Ethiopia.

Jacob, J. P. and Pescatore, A.J. 2012. Barley in poultry diets-A review. *Applied Poultry Research,* 25: 915-940.

Jayaprakash, G., Sathiyabarathi, M. and Arokia, R. M. 2016. Insects- A natural source for poultry nutrition. *International Journal of Science, Environment and Technology,* 5: 733-736.

Karley, A. J., Valentine, T. A. and Squire, G. R. 2011. Dwarf alleles differentially affect barley root traits influencing nitrogen acquisition under low nutrient supply. *Journal of Experimental Botany,* 62: 3917-3927.

Larner, I. M. and Asundson. 1932. Inheritance of rate of growth in domestic fowl. *Poultry Science,* 13(6): 348-352.

Mahmoudnia, N. and Madani, Y. 2012. Effect of Betaine on performance and carcass composition of broiler chicken in warm weather - A review. *International Journal of Agricultural Science,* 2: 675-683.

Makkar, S., Tran, G., Heuzé, V. and Ankers, P. 2014. State-of-the-art on use of insects as animal feed. *Animal Feed Science and Technology,* 197: 1-33.

Mansoori, B., Modirsanei, M. and Nodeh, H. 2011. Alteration of D-xylose intestinal absorption in broilers with high dietary barley intake. *International Journal of Veterinary Research,* 5: 248-254.

Mbajiorgu, C., Ng‟ambi, J. and Norris, D. 2011. Voluntary feed intake and nutrient composition in the chickens. *Asian Journal of Animal and Veterinary Advances,* 6: 20-28.

McDonald, P., Edwards, R. A., Greenhalgh, J. F. D. and Morgan, C. A. 2010. Animal Nutrition, 7th Edition. Pearson Educational Limited, Harlow, UK.

Melkamu Bezabih Yitbarek. 2013. Carcass characteristics of Rhode Island Red (RIR) grower chicks feed on different levels of dried tomato pomace (DTP). *International Journal of Advanced Research,* 1: 17-22.

Moharrery, A. 2006. Comparison of performance and digestibility characteristics of broilers fed diets containing treated hulled barley or hulless barley. *Czech Journal of Animal Science,* 51: 122-131.

Nikolova, N., Pavlovski, Z., Milošević, N. and Perić, L. 2007. The quantity of abdominal fat in broiler chicken of different genotypes from fifth to seventh week of age. *Biotechnology in Animal Husbandry,* 23: 331-338.

NRC (National Research Council). 1994. Nutrient requirements of poultry. 9th Edition. National Academy Press, Washington DC, USA.

Onderci, M., Sahin, N., Cikim, G., Aydin, A., Ozercan, I., Ozkose, E., Ekinci, S., Hayirli, A. and Sahin, K. 2008. B-Glucanase-producing bacterial culture improves performance and nutrient utilization and alters gut morphology of broilers fed a barley-based diet. *Animal Feed Science and Technology,* 146: 87-97.

Rabie, M., Ismail, F. and Sherif, K. 2010. Effect of dietary energy level with probiotic and enzyme addition on performance, nutrient digestibility and carcass traits of broilers. *Egypt Poultry Science Journal*, 30: 179-201.

Raji, M.O., Adeleye, O.O., Osuolale, S.A., Ogungbenro, S.D., Ogunbode, A.A., Abegunde, P.T., Mosobalaje, M.A., Oyinlola, O.O., Alimi, I.O. and Habeeb, A.A. 2014. Chemical composition and effect of mechanical processed of African Yam bean on carcass characteristics and organs weight of broiler finisher. *Asian Journal of Plant Science and Research,* 4: 1-6.

Rebolé, A., Ortiz, L.T., Rodríguez, M.L., Alzueta, C., Treviño, J. and Velasco, S. 2010. Effects of insulin and enzyme complex, individually or in combination, on growth performance, intestinal microflora, cecal fermentation characteristics, and jejunal histomorphology in broiler chickens fed a wheat and barley-based diet. *Poultry Science,* 89: 276-286.

Ribeiro, T., Lordelo, M., Prates, J., Falcão, L., Freire, J., Ferreira, L. and Fontes, C. 2012. The thermostable β-1, 3-1, 4-glucanase from Clostridium thermocellum improves the nutritive value of highly viscous barley-based diets for broilers. *British Poultry Science,* 53: 224-234.

Sadeghi, G. and Habibian, M. 2016. Effects of enzyme supplementation on replacing corn with barley in diet of broiler chicks. *Bioscience and Biotechnology,* 5: 159-165.

Saki, A., Mirzayi, S., Ghazi, S., Moini, M., Harsini, R., Haghighat, M. and Mahdavi, R. 2010. Effect of various level of treated barley on small intestinal content viscosity, litter moisture, uric acid and broiler chicken performance. *Animal Veterinary Advances,* 9: 2627-2632.

SAS (Statistical Analysis Systems). 2008. SAS/STAT® Guide to Personal Computers ver. 9.1.3. Prentice Hall, London.

Shakouri, M., Iji, P., Mikkelson, L. and Cowieson, A. 2009. Intestinal function and gut microflora of broiler chickens as influenced by cereal grains and microbial enzyme supplementation. *Animal Physiology and Animal Nutrition,* 93: 647-658.

Shirzadi, H., Moravej, H. and Shivazad, M. 2009. Comparison of the effects of different kinds of NSP enzymes on the performance, water intake, litter moisture and jejunal digesta viscosity of broilers fed barley-based diet. *Food, Agriculture and Environment,* 7: 615-619.

UN (United Nations). 2017. The World Population Prospects: The 2017 Revision. United Nations Department of Economic and Social Affairs. United Nations, Geneva, Switzerland.

Varastegani, A. and Dahlan, I. 2014. Influence of dietary fiber levels on feed utilization and growth performance in poultry. *Animal Production Advances*, 4: 422-429.

Veldkamp, T., Kwakkel, R., Ferket, P. and Verstegen, M. 2005. Growth response to dietary energy and lysine at high and low ambient temperature in male Turkeys. *Poultry Science,* 84: 273-282.

Wiseman, J. 1987. Feeding of non-ruminant animals. pp. 9-15. *In:* Meeting nutritional requirement from available resources. Butter worth and C. Ltd.