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Research Article

Effects of Dietary Substitution of Ordinary Maize Meal with Quality Protein Maize Meal on the Performance of Broiler Chicken

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Abstract

Background and Objective: Quality protein maize has a high concentration of essential amino acids compared ordinary maize, hence can be exploited in broiler chicken production. We investigated the effects of graded substitution of ordinary maize (NMM) meal with Quality Protein Maize meal (QPM) on the performance of broiler chicken. **Methodology:** About 225 day-old Ross Breeders broiler chicks were randomly assigned to five grower-starter diets (SD1-SD5) wherein QPM replaced NMM at 0, 25, 50, 75 and 100% and fed for 4 weeks. The birds were transferred onto similarly constituted corresponding finisher diets; FD1-FD5. Growth performance, carcass yield and gastrointestinal (GIT) macro-morphometry were determined. **Results:** At 28 days chicks fed QPM-based starter-grower diets were heavier, had higher Body Mass Gain (BMG) and Average Daily Gain [ADG, ($p<0.05$)]. At 56 days birds fed finisher diets FD4 and FD5 were the heaviest with the highest BMG ($p = 0.0002$). From 29-56 days birds fed finisher diets FD4 and FD5 had the highest ($p<0.05$) ADG. Birds reared on SD5 and finisher diets FD5 had the most economic FCR ($p = 0.0002$). Overall, BMG and ADG were highest ($p = 0.0001$) in birds fed starter-grower diets SD4 and SD5 and transferred to finisher diets FD4 and FD5. Despite their high FI ($p = 0.0084$), birds reared on SD5 and transferred to FD5 were the most efficient feed utilizers (FCR = 1.67 ± 0.02, $p = 0.0016$). Dressed mass increased ($p = 0.0001$) with dietary QPM. Feeding starter (SD3-SD5) and finisher (FD3-FD5) diets caused longer GIT ($p = 0.0001$) while feeding starter (SD4-SD5) and finisher (FD4-FD5) diets caused the heaviest livers ($p = 0.0005$). **Conclusion:** The QPM increased the growth performance, feed efficiency and carcass yield of broiler chicken.

Key words: *Zea mays*, quality protein maize, lysine, boiler chicken, growth performance, feed cost, feed utilization efficiency, dressed mass, carcass yield, viscera morphometry

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Chickens have co-existed with mankind for several millennia and are primarily kept as a source food with their eggs and meat supplying quality protein[1]. Odunitan-Wayas *et al.*[2] contend that globally the consumption of poultry products is widespread. Over and above providing high-quality protein, chicken meat and eggs also provide crucial vitamins and minerals[2]. Importantly, poultry meat is regarded as a key source of nutrients especially in developing world where it can help mitigate shortfalls of nutrients[3]. In physiological states that result in an increased demand for calories and protein, for example, pregnancy, lactation and growth (weaning to early adolescence), the consumption of poultry meat contributes to the overall quality of the diet[3]. When compared to red meats, broiler chicken meat has much lower proportion of saturated fatty acids but contains a good proportion of the desirable monounsaturated fatty acids[4]. Compared to red meats broiler chicken meat is thus is considered healthier[4].

Broiler chicken production is one of the fastest animal production systems through which high-quality animal protein for human consumption can be produced in the shortest possible time. In addition to having healthier meat, broiler production has added advantages of a short generation interval, reduced land requirements and economic feed utilization. These advantages could be harnessed to help meet the global increase in the demand of animal products by both the urban and rural populace[5]. Feed cost, which ranges from 65-75% of the total broiler production costs, constitutes the largest input in broiler chicken production[6]. The high feed cost presents a major impediment to the intensification of broiler chicken production. Of the different dietary ingredients for broiler chicken feeds, the protein component is the most costly ingredient[7]. In SSA, soyabean meal (SBM) is the major dietary protein source in animal feeds including broiler chicken[8]. Local production of soyabean in SSA does not meet the region's requirements for human and the livestock feed industry[9]. To meet the SBM requirements for the livestock industry, SSA relies on imports to make good the shortfall from local production[8]. This results in increased feed costs which militate against intensification of broiler chicken production. Lysine and tryptophan are essential amino acids (EAAs) for non-ruminant animals including broiler chicken[10]. Wecke *et al.*[11] contend that studies have confirmed the essentiality of lysine in meat-type chickens. In addition to the need to supply adequate dietary protein in chicken feeds, the availability of amino acids, especially the EAAs lysine, tryptophan and methionine is critical for optimal broiler chicken performance. The processing of soyabean into SBM involves heat treatment to inactivate lectins and trypsin inhibitors followed by solvent extraction to remove excess lipid. Although controlled the heating results in some degree of maillard and browning reactions which cause EAAs, especially lysine, to become unavailable. The processing-induced reduction in the availability of lysine is made good by supplementing diets with synthetic DL-lysine. The latter is very costly particularly for resource-limited small scale broiler chicken producers. The shortages of SBM in SSA coupled with processing-induced reduced lysine availability from SBM make it imperative to find alternatives that reduce the cost of broiler chicken production in SSA. When compared to Normal Maize (NM) grain, Quality Protein Maize (QPM) grain has twice the amount of lysine and tryptophan[6,12]. The bioavailability of lysine and tryptophan from QPM compares favourably with that from casein[12]. In view of QPM's favourable nutritional attributes, the potential of QPM to enhance broiler production needs to be explored under a variety of poultry production systems.

The objective of this study was to determine the dietary effects of substituting NM meal with QPM meal on the growth performance, feed utilization efficiency of broiler chicken and on the macro-morphometry of selected viscera of broiler chicken in a concentrate-maize feeding system.

MATERIALS AND METHODS

Study site: The study was carried out at Rio Tinto Agricultural College in Zhombe district in the Midlands province of Zimbabwe. The area is characterized by clay loamy soils. The mean annual rainfall ranges from 650-800 mm and while the mean maximum temperatures range from 25-35°C[13].

Sources of feed ingredients: The broiler concentrate was bought from National Foods Limited, Zimbabwe. The QPM seed was donated to Midlands State University's (Zimbabwe), Department of Agronomy, by CYMMIT Maize Breeders, Zimbabwe. The Midlands State University, Department of Agronomy supplied the NM meal and QPM meal for the trial.

Dietary treatments: The dietary treatments were based on a broiler concentrate (41% CP) mixed with either NMM meal or QPM meal. While in the starter-grower diets, the broiler concentrate was mixed with the maize meal at a ratio of 2:3 w/w, respectively, in the finisher diets, the broiler concentrate and maize meal were mixed at a ratio of 1:2 w/w, respectively. Five starter-grower diets (SD1-SD5) where QPM meal replaced NM meal at 0, 25, 50, 75 and 100%, respectively

Table 1: Ingredient and chemical composition of the starter-grower diets

Ingredients (g kg^{-1})	Diet 1 (SD1)	Diet 2 (SD2)	Diet 3 (SD3)	Diet 4 (SD4)	Diet 5 (SD5)
Broiler concentrate	400.00	400.00	400.00	400.00	400.00
[a]NM meal	600.00	450.00	300.00	150.00	0.00
[b]QPM meal	0.00	150.00	300.00	450.00	600.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00
Chemical composition (%)					
Dry matter	88.54	88.89	88.71	88.57	88.39
Crude protein	21.74	21.57	21.41	23.36	20.83
Ash	7.07	7.75	6.77	8.86	7.93
Calcium	1.28	1.57	1.21	1.68	1.49
Phosphorus	0.71	0.72	0.63	0.88	0.83
Neutral detergent fibre	15.69	14.39	15.24	15.17	13.94
Acid detergent fibre	5.61	7.46	6.64	7.12	7.55
Gross energy (MJ kg^{-1})	18.31	17.31	17.45	17.24	17.99

NM: Ordinary maize, QPM: Quality protein maize, [a]Lysine content of NM meal = 0.26±0.02%, lysine content of QPM meal = 0.42±0.01%, [b]Tryptophan content of NM meal = 0.06±0.01%, tryptophan content of QPM meal = 0.11±0.03%

Table 2: Ingredient and chemical composition of the finisher diets

Ingredients (g kg^{-1})	Diet 1 (FD1)	Diet 2 (FD2)	Diet 3 (FD3)	Diet 4 (FD4)	Diet 5 (FD5)
Broiler concentrate	333.00	333.00	333.00	333.00	333.00
[a]NM meal	667.00	500.30	333.50	166.70	0.00
[b]QPM meal	0.00	166.70	333.50	500.30	667.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00
Chemical composition (%)					
Dry matter	88.71	88.53	88.20	88.98	88.63
Crude protein	19.69	19.98	20.71	18.96	18.57
Ash	6.30	6.47	6.68	7.42	8.00
Calcium	1.16	1.15	1.15	1.31	1.35
Phosphorus	0.67	0.54	0.63	0.75	0.90
Neutral detergent fibre	14.83	14.75	13.51	13.32	11.88
Acid detergent fibre	5.47	6.15	4.82	5.12	5.67
Gross energy (MJ kg^{-1})	16.66	17.19	16.92	17.31	17.98

NM: Ordinary maize, QPM: Quality protein maize, [a]Lysine content of NM meal = 0.26±0.02%, lysine content of QPM meal = 0.42±0.01%. [b]Tryptophan content of NM meal = 0.06±0.01%, tryptophan content of QPM meal = 0.11±0.03%

and five finisher diets (FD1 to FD5) where QPM meal replaced NM meal at 0, 25, 50, 75 and 100%, respectively were formulated. The diets were formulated to be of similar energy and protein content and to meet the nutritional requirements of broiler chicken at the starter-grower and finishing phases. The lysine and tryptophan contents of the NMM and QPM were determined prior to the use of the meals in diet formulation. The lysine and tryptophan content of the NM meal and QPM meal used in diet formulation and the ingredient and chemical composition of the starter-grower diets and the finisher diets are shown in Table 1 and 2, respectively.

Ethical clearance: The study was cleared by the Midlands State University Research Board. All procedures in regard of handling of the birds used in the experiment were executed as described by the Helsinki Declaration on the humane use of animals in experimentation.

Experimental animals and animal management: Day-old broiler chicks were sourced from Ross Breeders. Routine health management (disease and parasite control: vaccinations and dosing) measures for broiler chicks were undertaken from receipt of the day-old chicks and throughput the experiment. The broiler chicks were housed in a deep litter system. Clean wheat straw was used as bedding. The bedding was replaced twice weekly. Each bird was allocated a flow space of 0.2 m^2 and fed on the starter-grower diets for 4 weeks after which it was then transferred onto the corresponding finisher diet and fed for another 4 weeks. During the two phases of the feeding trial, the birds had *ad libitum* access to their respective diets and clean drinking water. They were weighed once weekly and feed intake was determined on a weekly basis.

Experimental design: Two hundred and twenty five Ross Breeders day-old broiler chicks were used in the trial. The chicks were randomly allocated to the starter-grower dietary treatments such that each diet had 45 chicks split into 3 groups of 15 chicks. Each group of 15 chicks constituted an experimental unit. The chicks were fed on the respective starter-grower diets for 4 weeks and then transferred on the corresponding finisher diets and fed for another 4 weeks. Weekly body masses were determined. Following the 8 week feeding period, the birds were slaughtered and dressed.

Computations: At the end of the 4th week of the feeding trial total Feed Intake (FI), Body Mass Gain (BMG), Average Daily Gain (ADG) and Feed Conversion Ratio (FCR) were computed from the feed intake and body mass data. Similarly at the end of the 8th week of the feeding trial FI, BMG, ADG and FCR for the finishing phase were computed. The overall FI, BMG, ADG and FCR from day 1-56 were also computed.

Terminal procedures and measurements: At 56 days of age (8 weeks), the birds were weighed to get the terminal body mass after which they were slaughtered and dressed. The gastrointestinal tract (GIT) was carefully dissected out and its length determined on a cooled dissection board. The liver and gizzard were then dissected out and their masses determined. The carcasses were then kept overnight in a cold room at 4°C following which the cold dressed mass was determined. The dressed masses were then used to compute the dressing percentage.

Data analysis: Data was analyzed using GraphPad Prism version 5 (GraphPad, USA) statistical software. Except for the data on weekly body masses where a repeated measures ANOVA was used to analyze data, all other data was analyzed using a one-way ANOVA. Mean comparison was done using the Bonferroni *post hoc* test. The level of significance was set at $p \leq 0.05$.

RESULTS AND DISCUSSION

Lysine and tryptophan content of the maize grain meals: The QPM meal used in diet formulation had 50% more lysine and 67% more tryptophan compared to the NM meal (Table 1, legend) and is in agreement with the observations of Panda et al.[6] and Nuss and Tanumihardjo[12].

Performance to day 28: Table 3 shows the effect of substituting NM meal with QPM meal on the productive performance of broiler chicken to day 28 of age. From 1-28 days of age dietary substitution of NM meal with QPM meal resulted in heavier body mass, higher BMG and higher ADGs ($p \leq 0.05$). At 28 days chicks on starter-grower diets SD2, SD3, SD4 and SD5 (25, 50, 75 and 100% QPM meal, respectively) were heavier ($p \leq 0.05$) compared to their counterparts on the control diet. Chicks on starter-grower diets SD4 and SD5 (75 and 100% QPM meal) had significantly higher ($p = 0.0052$) Body Mass Gains (BMG) compared to those on starter-grower diets SD1 and SD2 (0 and 25% QPM meal). At 28 days chicks on diets SD2, SD3, SD4 and SD5 (25, 50, 75 and 100% QPM meal, respectively) registered similar ($p>0.05$) Average Daily Gains (ADG) but that were higher ($p = 0.0052$) compared to the ADG of chicks on the control diet. Feed Intake (FI) increased ($p \leq 0.05$) with increasing dietary QPM meal but there were no statistically significant differences ($p>0.05$) in the economy of feed utilization efficiency from 1-28 days.

Performance from Day 29-56: Table 4 shows the effect of the substitution on the growth performance from day 29-56. From day 29-56, while the substitution of NM meal with QPM meal resulted in heavier body masses, increased BMG and ADG ($p \leq 0.05$); birds fed finisher diets FD4 and FD5 (75 and 100% QPM meal) had the highest ($p = 0.002$) BMG, ADG and FI. However birds on FD5 had the most economical ($p \leq 0.05$) feed utilization.

Overall performance from Day 1-56: The effect of substituting OM meal with QPM meal on overall broiler performance is shown in Table 5. Overall, the substitution of NM meal with QPM meal positively affected BMG, ADG, dressed mass and resulted in more economic feed utilization. Birds fed starter-grower and finisher diets SD4 and SD5 and FD4 and FD5 (75 and 100% QPM meal, respectively) had similar but significantly higher ($p = 0.0001$) BMG and ADG compared to counterparts on starter-grower and finisher diets SD1, SD2 and SD3 and FD1, FD2 and FD3 (0, 25 and 50% QPM meal, respectively). Birds reared on starter-grower and finisher diets SD1, SD2, SD3 and SD4 and FD1, FD2, FD3 and FD4 had similar but lower overall FI ($p = 0.0084$) compared to those reared on diet SD5 and FD5. However birds reared on starter-grower and finisher diets (SD4/FD4 and SD5/FD5) overall had the most economical ($p = 0.0016$) feed utilization followed by those reared on starter-grower diet SD3 and finisher diet FD3 compared to counterparts on starter-grower diets SD1 and SD2 and finisher diets FD1 and FD2. The Cold Dressed Mass (CDM) increased with an increase in dietary QPM meal with birds reared on starter-grower diet D5 and finisher diet FD5 registering the heaviest ($p = 0.0001$) CDM.

Dietary effects of QPM meal on visceral macro-morphometry: Table 6 shows the effect of substituting NM meal with QPM meal on macro-morphometry of selected viscera. Birds reared on starter-grower and finisher diets

Table 3: Effect of graded dietary substitution of ordinary maize with quality protein maize on the growth performance of boiler chicken from day 1-28

	Starter-grower diet					
Parameters	SD1	SD2	SD3	SD4	SD5	p-value
Day 28 body mass (g)	819.33±6.86^{a}	921.00±25.53^{b}	930.33±29.03^{b}	963.33±70.07^{b}	995.33±51.33^{b}	0.0052
Body mass gain (g)	774.33±6.81^{a}	876.00±25.53^{ab}	885.33±29.06^{ab}	918.33±70.06^{b}	950.33±51.63^{b}	0.0052
Average daily gain (g day^{-1})	27.65±0.24^{a}	31.29±0.91^{b}	31.62±1.04^{b}	32.80±2.50^{b}	33.94±1.84^{b}	0.0052
Feed intake (kg)	1.56±0.07^{a}	1.61±0.05^{a}	1.65±0.08^{ab}	1.68±0.12^{ab}	1.73±0.03^{b}	0.0500
Feed conversion ratio	2.02±0.11^{a}	1.83±0.10^{a}	1.87±0.06^{a}	1.83±0.13^{a}	1.83±0.10^{a}	0.1813

^{a,b}Within row means with different superscripts are significantly different at $p \leq 0.05$. Broiler chicks reared on QPM based starter diets were significantly heavier ($p<0.05$) compared to those on the control starter diet. Chicks reared on starter diets SD4 and SD5 had the highest ($p = 0.0052$) body mass gain. Feed intake for chicks on starter diets SD1 to SD4 were statistically similar ($p>0.05$) but chicks reared on starter diet SD5 had the highest ($p<0.05$) feed intake. There were no significant differences ($p>0.05$) in feed conversion ratio from day 1-28. Data presented as Mean±SD, n = 15

Table 4: Effect of graded dietary substitution of ordinary maize with quality protein maize on the growth performance of boiler chicken from day 29-56

	Finisher diet					
Parameters	FD1	FD2	FD3	FD4	FD5	p-value
Day 56 body mass (g)	2263.33±75.06^{a}	2350.00±30.00^{a}	2430.00±117.90^{a}	2786.67±120.97^{b}	2920.00±62.45^{b}	0.0002
Body mass gain (g)	1136.67±25.17^{a}	1140.00±45.83^{a}	1166.67±98.15^{a}	1463.30±135.77^{b}	1540.00±43.59^{b}	0.0002
Average daily gain (g day^{-1})	40.60±0.90^{a}	40.71±1.64^{a}	41.67±3.51^{a}	52.26±4.85^{b}	55.00±1.56^{b}	0.0002
Feed intake (kg)	2.62±0.06^{a}	2.64±0.07^{a}	2.61±0.19^{ab}	3.04±0.28^{b}	3.06±0.09^{b}	0.0086
Feed conversion ratio	2.31±0.05^{a}	2.32±0.09^{a}	2.24±0.06^{a}	2.31±0.04^{a}	2.00±0.02^{b}	0.0002

^{a,b}Within row means with different superscripts are significantly different at $p \leq 0.05$. Broiler chicken finished on finisher diets F D4 and FD5 had significantly different heavier ($p = 0.0002$) body masses at 56 days compared to the rest. Broiler chicken finished on finisher diets FD1 to FD3 had similar body mass gains from day 29-56. Broilers finished on finisher diets FD4 and FD5 had significantly different and the highest body mass gain and the highest average daily gain ($p = 0.0002$) compared to the rest. Feed intake significantly increased ($p = 0.0086$) with an increased in dietary QPM in the started diet. Feed conversion ratio was lowest ($p = 0.0002$) for broiler chicken finished on diet FD5. Data presented as Mean±SD, n = 15

Table 5: Effect of graded dietary substitution of ordinary maize with quality protein maize on the overall growth performance of boiler chicken from day 1-56

	Diets					
Parameters	SD1/FD1	SD2/FD2	SD3/FD3	SD4/FD4	SD5/FD5	p-value
Total body mass gain (g)	2218.33±75.06^{a}	2305.00±30.00^{a}	2385.00±117.90^{a}	2741.67±120.97^{b}	2875.00±62.45^{b}	0.0001
Average daily gain (g day^{-1})	39.61±1.34^{a}	41.16±0.54^{a}	42.59±2.11^{a}	48.96±2.16^{b}	51.34±1.12^{b}	0.0001
Total feed intake (kg)	4.18±0.12^{a}	4.24±0.12^{a}	4.26±0.17^{a}	4.72±0.37^{ab}	4.79±0.09^{b}	0.0084
Feed conversion ratio	1.98±0.11^{a}	1.84±0.05^{a}	1.79±0.04^{b}	1.72±0.07^{c}	1.67±0.02^{c}	0.0016
Dressed mass (kg)	1.57±0.03^{a}	1.73±0.02^{b}	1.79±0.03^{b}	2.12±0.01^{c}	2.41±0.04^{d}	0.0001
Dressing percent (%)	79.06±2.52^{a}	80.25±0.99^{a}	79.91±0.79^{a}	80.38±1.10^{a}	81.40±1.76^{a}	0.5125

$^{a-d}$ Within row means with different superscripts are significantly different at $p \leq 0.05$. Total body mass gain and overall average daily of broiler chicken reared on starter and finisher diets D4 and D5 was significantly different and higher ($p = 0.0001$) compared to those of chicken reared on starter and finisher diets D1 to D3. Total feed intake increased with an increase in QPM meal in the diets but was highest for chicken reared on starter and finisher diet 5. Feed conversion ratio decreased ($p = 0.0016$) with an increase dietary QPM. Dressed mass significantly increased ($p = 0.0001$) increased with an increase in dietary QPM. Data presented as Mean±SD, n = 15

Table 6: Effect of graded dietary substitution of ordinary maize with quality protein maize on gastrointestinal length, liver and gizzard mass of broiler chicken

	Diets					
Parameters	SD1/FD1	SD2/FD2	SD3/FD3	SD4/FD4	SD5/FD5	p-value
GIT length (m)	2.09±0.03^{a}	2.10±0.10^{a}	2.34±0.02^{b}	2.40±0.02^{b}	2.48±0.02^{b}	0.0001
Liver mass (g)	50.00±5.00^{a}	56.67±32.89^{a}	50.00±5.00^{a}	70.00±5.00^{bc}	67.00±3.61^{c}	0.0005
Gizzard mass (g)	50.00±10.00^{a}	60.00±5.00^{a}	60.00±5.00^{a}	60.00±5.00^{a}	70.00±10.00^{a}	0.0723

^{a,b,c}Within row means with different superscripts are significantly different at $p \leq 0.05$. Broiler chicken reared on starter-grower and finisher diets 3, 4 and 5 had significantly longer ($p = 0.0001$) gastrointestinal tracts compared to those reared on starter-grower and finisher diets 1 and 2. Broiler chicken reared on starter-grower and finisher diets 4 and 5 had significantly heavier livers ($p = 0.0005$) compared to their counterparts reared on starter-grower and finisher diets 1- 3. There was a general tendency ($p = 0.0723$) of an increase in gizzard mass with an increase in QPM in the diet. Data presented as Mean±SD, n = 15

(SD3, SD4 and SD5 and FD3, FD4 and FD5) similar ($p>0.05$) but longer ($p = 0.0001$) GIT lengths compared those on diets (SD1 and SD2 and FD1 and FD2). Birds reared on starter-grower diets SD4 and SD5 and finisher diets FD4 and FD5 had the heaviest ($p = 0.0005$) livers when compared to counterparts on starter-grower diets SD1-SD3 and finisher diets FD1-FD3. While the substitution of NM meal with QPM meal had no statistically significant effects on the mass of the gizzards (ventriculus) of the broilers, there was a trend (p = 0.0723) towards an increase in gizzard mass with an increase in dietary QPM meal.

Effects of dietary QPM on growth performance: In their study with layers Panda *et al.*[14] reported that the apparent digestibility of lysine and threonine was increased in White Leghorn layers fed QPM-based diets compared to that of birds fed NM-based diet. Panda *et al.*[14] also observed that the replacement of NM with QPM and or the supplementation of NM-based diet with synthetic lysine increased egg production and feed efficiency but without a concomitant increase in egg weight and or feed intake. However, in a study with laying hens, Celestino *et al.*[15] observed that the use of a QPM-based diet in place on NM-based diet did not confer any advantages with respect to hen-day egg production, egg mass and feed conversion ratio. The observation by Celestino *et al.*[15] on egg production is at variance with the benefits in egg production as reported by Panda *et al.*[14] when QPM is use in place of NM but is in agreement with regards to feed utilization efficiency. In another study, the use of QPM in place of NM in broiler diets allowed for an overall 5% reduction in the cost of production as a result of reduction in the amount of fish meal used in the diet[16]. Onimisi *et al.*[17] reported that while the 100% replacement of NM with QPM resulted in numerical increase in weight of broiler chicks during the starter (brooding) phase and caused significantly better finishing performance compared to that of birds on 0-75% substitution, supplementation of NM-based diet with synthetic lysine gave better results than the 100% substitution of NM with QPM.

In the current study dietary QPM positively impacted on the growth performance (BMG, ADG and overall body mass) of broiler chicken during both the starter-grower and finishing phases. Our observed significant increase in broiler chicken performance during the starter (brooding) phase is at variance with the observations by Onimisi *et al.*[17] who reported numerical but non-significant increase in the starter (brooding) weight of broiler chicks fed 100% QPM-based starter diet. In a maize meal-soyabean meal based feeding system Panda *et al.*[18] observed that the replacement of NM with 50% QPM resulted in the most significant improvement body weight gain and FCR. In this present study, for the brooding phase, most significant increases in growth performance (BMG and ADG) were observed with NM substitution at 25, 50, 75 and 100% while overall (brooding plus finishing) substituting NM with QPM at 75 and 100% gave the most significant improvement in body mass gain while the most significant improvement in FCR was observed from 50-100% substitution of NM with QPM. Thus our findings with regards to growth performance and FCR somewhat vary with those of Panda *et al.*[18]. In another study Panda *et al.*[6] reported that a 50% or higher replacement of NM with QPM significantly improved body weight gain of broiler chicken. The observed significant increase in body weight gain reported by Panda *et al.*[6] is in agreement with our findings, especially during the finishing phase, where the replacement of NM with QPM at 75 and 100% resulted in the highest body weight gain by the broiler chicken. Okai *et al.*[19] observed that the use of Obatanpa, a QPM variety, in the diet of albino Wistar rats did not enhance their growth performance or their feed utilization efficiency when compared to their counterparts fed on white and or yellow NM-based diets. This observation seems to suggest that the beneficial effects of QPM on growth performance may not always be realized and could be possibly dependent on the animal species.

In the current study an increase in dietary QPM resulted in increased BMG, ADG and overall body mass. The observed improvement in growth performance could be harnessed to produce more broiler meat (protein) for human consumption. This improvement in growth performance affords the "untying of pen-space" in a shorter time period thus allowing for the production of more broiler chicken batches per unit time. Panda *et al.*[20] observed higher BMG in broiler chicken when NM was replaced with QPM and in those where NM meal was supplemented with synthetic lysine and methionine. Our findings are in tandem with the observations of Panda *et al.*[20] who reported higher BMG with replacement of NM with QPM in broiler chicken. From the findings by Panda *et al.*[20] and the findings of the current study, it could be inferred that the use of QPM in broiler feeds might remove the need to supplement broiler diets with the costly synthetic lysine and methionine. Thus the use of QPM in broiler feeds could potentially result in cost saving.

Effects of dietary QPM on feed utilization: Feed costs in broiler production account for 65-75% of the total production costs. They thus constitute the largest input in broiler chicken production[6]. Amonelo and Roxas[21] reported that QPM-based diet fed broilers and those fed a NM-based diet but supplemented with synthetic lysine had a lower Feed Intake (FI) compared to birds on unsupplemented NM-based diet. The birds on the QPM-based diet had the best feed utilization efficiency[21]. In this present study, it was observed an increase in FI with an increasing dietary QPM. While our findings are at variance with those of Amonela and Roxas[21], the observed increase in FI by broiler chicken on QPM based diets in current study is in agreement with the reported increase in FI by broilers fed QPM based diets that had the highest intake compared to counterparts on either NM or QPM-based diets but with supplementation with synthetic lysine and methionine[22]. In the current study, although FI increased with an increase in dietary QPM, these results indicate an increase in the efficiency of feed utilization with an increase in dietary QPM. This observation is in agreement with the reported increase in feed utilization efficiency by broilers chicken fed QPM-based diet[21]. In this study, the observed increase in the efficiency of feed utilization compensates for the reported increased FI. Overall, with QPM, less feed was consumed per unit mass of product (broiler meat) produced which has a positive effect on the cost broiler meat production.

Effects of dietary QPM on carcass yield and GIT viscera: In their study Onimisi *et al.*[17] observed that broiler chicken dressing percentage and organ weight were not influenced by a complete (100%) substitution of NM with QPM neither were they affected by the supplementation of NM with synthetic lysine. In this present study we observed an increased in dressing percentage with an increase in dietary QPM. The increase in the dressed mass of the broiler chicken with an increased in dietary QPM pointed to an increase in carcass yield. Current findings are at variance with Panda *et al.*[6] who reported that neither dressed mass nor giblet mass was influenced by replacement of regular maize by QPM or supplementing lysine to regular maize-based diet and those of Onimisi *et al.*[17] who reported similarities in the dressing percentage and organ weight between chicken fed QPM-base and NM-based diets. Similarly our results are at variance with those of Amonelo and Roxas[21] who reported that use of QPM-base diet had no effect on broiler chicken dressing percentage. In this study, a determination of the proximate composition of the carcass would have assisted in elucidating whether the increase in carcass yield was due to muscle (protein) or fat accretion. Panda *et al.*[18] observed that in a maize-soyabean meal feeding system, 50% replacement of NM with QPM resulted in lowered abdominal fat content and increased breast muscle yield in broiler chicken. It could therefore be inferred that the observed increase in carcass yield in broiler chicken fed QPM-based diets in the current study could have been due to increased muscle accretion at the expense of abdominal fat.

The dietary substitution of NM with QPM at 50-100% (start-grower diets SD3-SD5 and finisher diets FD3-FD5) and at 75-100% (start-grower diets SD4-SD5 and finisher diets FD4-FD5) was associated with an increase in the GIT length and an increase in liver mass, respectively. It could be inferred that the feeding of QPM to broiler chicken promoted the growth and development of the GIT and stimulated an accretion of the liver tissue. The increase in GIT length with increasing dietary QPM could have positively affected nutrient digestion and absorption by increasing the surface area for digestion enzyme production and nutrient absorption. The improvement in nutrient digestion and absorption could have resulted in a more efficient channelling of key nutrients to support growth and development as seen in the broilers on QPM based diets that had higher growth and productive performance (BMG, ADG, FCR and carcass yield) compared to those on the control diet. The liver is the metabolic citadel. An increase in liver mass with increasing dietary QPM could have resulted from an increase in the metabolically active cell hepatocytes resulting in an improvement of the functional efficiency of the liver. A more functionally efficient liver would cope better with the increased demand of metabolites critical for supporting growth and development and also increased demand to detoxify and eliminate potentially toxic metabolites.

CONCLUSION

Dietary QPM improved the growth performance (heavier body masses, improved BMG and ADG) of broiler chicken during the starter-grower and finishing phases. The improved growth performance was coupled with an improvement in the economy of feed utilization and increased carcass yields.

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