AMINO ACID PROFILE, ENERGY METABOLIZABILITY AND FEEDING VALUE OF QUALITY PROTEIN MAIZE IN LAYING HENS

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ABSTRACT

The amino acid profile and apparent metabolizable energy (AME) contents of a new quality protein maize (QPM) cultivar were analyzed. A normal maize (NM), which served as a reference, was also subjected to the same determinations. The analyzed values were used in formulating least-cost QPM and NM-based isonutrient diets. A feeding trial using 144 layers (Dekalb, 24 weeks old) were used to assess the effects of the diets on production performance and egg quality for 16 weeks. The birds were assigned to the diets, each with six replications of 12 birds per replication, in a completely randomized design. The concentration of total amino acids was 23% greater in QPM than NM. The AME (as fed basis) of QPM was comparable with that of NM. There was no significant difference on egg production performance of layers fed QPM and NM-based diets. However, subjective yolk color score was lower (P<0.001) in eggs of layers fed the QPM-based diet than those fed the NM-based diet. The findings show that QPM is a promising grain for poultry feeding and can be used to replace NM in layers' diet.

Key words: amino acids, layers, metabolizable energy, quality protein maize

INTRODUCTION

Quality protein maize (QPM), which is adaptable under Philippine conditions, was successfully developed by the Institute of Plant Breeding at the University of the Philippines Los Baños, Laguna using QPM genes from the Centro International de Mejoramiento de Maiz y Trigo (Llaneta, 2009). An open pollinated cultivar which has already passed tests for yield and agronomic characteristics is now being produced and evaluated for its nutritional merits. Initially, the nutritional evaluation of QPM was limited to the analysis of its proximate composition, calculation of amino acids and metabolizable energy based on proximate values and feeding trials in pigs (Rañeses, 2010), broilers (Garcia, 2010), and layers (Soriano, 2010). While literature on the nutritional value of QPM is available (Onimisi *et al*., 2008; Zhai and Zhang, 2007; Qi *et al*., 2004; Sullivan *et al*., 1989), the amino acid composition and energy metabolizability may vary from one cultivar to the other.

Previous studies have also demonstrated that feeding QPM-based diets resulted in improved or comparable production performance compared with feeding

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normal maize (NM)-based diets under varying dietary conditions. When QPM was used to replace NM on a weight-for-weight basis in poultry diet, production performance was improved (Panda *et al*., 2010; Onimisi *et al*., 2009; Subsuban *et al*., 1989). However, when QPM replaced NM in the diet on an isonutrient basis, the performance of broilers (Garcia, 2010; Amonelo and Roxas, 2008; Tyagi Praveen *et al*., 2008) and layers (Soriano, 2010; Osei *et al*., 1999) was found to be generally comparable. Therefore, the present study was conducted to provide a better understanding of the nutritional value of the new cultivar of QPM. The specific objective was to determine the amino acid profile and energy metabolizability of QPM. Using these values, the feeding value of QPM was evaluated in terms of production performance and egg quality of laying hens.

MATERIALS AND METHODS

Test maize and determination of proximate, amino acids and energy contents

The QPM used in the study was grown in the research farm of the Central Luzon State University, Muñoz, Nueva Ecija. The feeding trial was conducted at the Miracle Farm Technologies in Poblacion Sur, Talavera, Nueva Ecija from January to May, 2011. The QPM was harvested in September, 2010. The NM was procured from Miracle Farm Technologies in November, 2010. Representative samples (500 g) of NM and QPM were obtained for proximate and amino acids analysis at the Lipa Quality Control Center in Lipa City and Pacific Lab Services in Singapore, respectively.

The apparent metabolizable energy (AME) contents of NM and QPM were determined based on modified Sibbald method (1976). Two trials were conducted. In both trials, a total of six adult roosters (Dekalb, 60 weeks of age) with an average body weight of 1.65 and 1.96 kg were used in the first and second trials, respectively. Birds were kept in individual cages equipped with a feeder and waterer. After acclimatization to the experimental area, the birds were fasted for 48 h and then individually forced fed with 50 g of finely ground maize. The excreta were quantitatively collected every 8 h within a 48-h period after forced feeding. The excreta collected were dried in an oven at 70℃ for three days. After allowing it to equilibrate with atmospheric temperature and humidity, the excreta were weighed then ground and kept in airtight containers at room temperature. The maize and excreta samples were sent to the Animal Nutrition Analytical Service Laboratory, Animal Nutrition Division, Animal and Dairy Sciences Cluster, University of the Philippines, Los Baños, Laguna for gross energy (GE) determination. The AME (as fed basis) of NM and QPM was calculated as:

$$AME = [(GEm \times Fi) - (GEf \times Ec)]/Fi$$

where:

GEm is the gross energy of the maize, kcal/kg
Fi is the maize input, kg
GEf is the gross energy of the excreta, kcal/kg
Ec is the excreta collected, kg

Formulation of diets and feeding trial

A high-density layer diet containing either QPM or NM (Table 1) was formulated to meet or exceed PHILSAN (2003) nutrient recommendations using the User-Friendly Feed Formulation Done Again software (Pesti and Miller, 1993). The experimental diets contained the same amount of AME, crude protein (CP), total amino acids (lysine, methionine+cystine, threonine and tryptophan) calcium and available phosphorus. The analyzed values for CP, AME, amino acids, crude fiber and crude fat of the two maize were used in the diet formulations. For the other ingredients, values from PHILSAN (2003) were used. The QPM and NM were assigned the same price of PhP 12.50/kg. Diets were in mash form. Feed and water were provided on *ad libitum* basis.

A total of 144 layers (Dekalb, 24 weeks of age) with an average body weight of 1.5 kg were assigned to two dietary treatments using a completely randomized design. Each diet had six replications with 12 hens, in three groups of four layers in adjacent pens, per replication. The layers were housed in half-pyramid, triple deck wire laying cages in stair-step arrangement with trough-type feeders and waterers fitted at the front of the cage. Care and management of the layers were in accordance with the standard practices of Miracle Farm Technologies.

Data collection

Production parameters were determined weekly for a total of 16 weeks. Daily feed intake was calculated as the difference of the feed offered for the week and the feed remaining at the end of the week divided by the total hen-days for the week. Hen-day egg production rate was calculated by dividing the total eggs produced in a week by the total hen-days for the week multiplied by 100. The feed conversion ratio (FCR) was calculated by dividing the mean feed intake by the mean egg production (dozen eggs, kg eggs) for the same period. Egg mass was calculated by multiplying egg weight by hen-day egg production. Percent livability of the layers was calculated as the birds remaining at the completion of the feeding trial divided by the initial number of birds multiplied by 100. Eggs were classified according to sizes set by the Philippine National Standard (2005).

The composition (yolk, albumen and shell) and quality of eggs were determined weekly using two egg samples per replication taken at random. Albumen height was measured using a caliper. The average yolk color was subjectively scored using a DSM yolk color fan (DSM Nutritional Products, 2003). The yolks were separated from the albumen with the aid of tablespoon and glass funnel. Egg shells were weighed after drying them under the sun for a day. Albumen weight was calculated by subtracting the weight of the yolk and the shell from the whole egg weight.

Statistical analyses

The production performance data were summarized on a weekly basis and analyzed using t-test of Statistica (StatSoft, Inc., Version 7). Only the mean for all periods was presented in this report. The same test was employed in the analysis of the AME data. Homogeneity of variances of mean was determined using Levene's test. The statistical model used in the study was:

Table 1. Composition (%) and calculated analysis (as fed basis) of layer diets with normal maize (NM) or quality protein maize (QPM).

Ingredient	NM	QPM
Normal maize	53.67	0
Quality protein maize	0	52.92
Rice bran (D1)	5.28	8.63
Crude coconut oil	2.00	2.00
Soybean meal (US)	24.76	22.19
Poultry by-product meal (65% CP)	3.00	3.00
Limestone (fine)	3.82	3.84
Limestone (coarse)	5.00	5.00
Monodicalcium phosphate	1.30	1.29
DL-methionine	0.17	0.13
Salt	0.50	0.50
Poultry vitamin premix[1]	0.03	0.03
Poultry trace mineral premix[2]	0.15	0.15
Choline chloride (50% Choline)	0.10	0.10
Ethoxyquin	0.02	0.02
Toxin binder	0.20	0.20
Total	100.00	100.00
Cost/kg (PhP)	17.25	16.68
Calculated analysis		
M.E., kcal/kg	2800	2800
Crude fat, %	5.275	5.805
Crude fiber, %	2.438	2.405
Calcium, %	3.800	3.800
Available phosphorus, %	0.450	0.450
Crude protein, %	18.395	18.405
Lysine, %	1.047	1.029
Methionine, %	0.462	0.422
Methionine + Cystine, %	0.790	0.790
Threonine, %	0.704	0.704
Tryptophan, %	0.210	0.210

[1]Each kg of vitamin premix contains: 45,000,000 IU Vit. A, 9,000,000 IU Vit. D_3, 200,000 g Vit. E, 15,000 g Vit. K_3, 150,000 g niacin, 9,000 g Vit. B_1, 30,000 g Vit. B_2, 19,500 g Vit. B_6, 0.15 g Vit. B_{12}, 81,522 g Vit. B_5, 8,000 g Vit B_9 and 0.70 g Vit. H/H_2.

[2]Each kg of trace mineral premix contains: 8.33 g copper, 0.998 g iodine, 66.672 g iron, 33.334 g manganese, 0.202 g selenium, 83.34 g zinc and 0.33 g cobalt.

$$Yqj = \mu + \tau q + \varepsilon qj$$

where:

Yqj is the jth observation in group $q = 1, \ldots\ldots, Q$

μ is the mean

τq is the treatment effect

εqj is the random error.

Significant differences between means were set at 5.0% alpha level.

RESULTS AND DISCUSSION

Proximate, amino acids and energy contents of quality protein maize

When expressed on a DM basis, QPM had 29% and 8% more crude protein and crude fat than NM, respectively (Table 2). In contrast, QPM had 5%, 3% and 34% less crude fiber, nitrogen-free extract (NFE) and crude ash, respectively, compared with NM. These proximate values were similar to those in QPM sourced from IPB and evaluated in previous studies (Soriano, 2010; Amonelo and Roxas, 2008). It must be emphasized though that the CP content of 12.19% for QPM in the present work was much higher than the 10.24% reported by San Andres *et al.* (2011) for QPM grown by the IPB. The differences suggest that certain factors, which cannot be determined in the present work, cause variation in the CP content of QPM.

Table 2. Proximate content of normal maize (NM) or quality protein maize (QPM).

Item	As fed basis (%)		Dry basis (%)	
	NM	QPM	NM	QPM
Dry matter	88.23	87.81	100.00	100.00
Crude ash	2.04	1.51	2.31	1.72
Crude protein	8.31	10.70	9.42	12.19
Crude fiber	2.20	2.08	2.49	2.37
Crude fat	3.56	3.84	4.03	4.37
Nitrogen-free extract	72.12	69.68	81.74	79.35

The QPM had 23% more total amino acids than NM (Table 3). Among individual amino acids, the largest difference was for cystine (50%) and the least for alanine (3%). Lysine, tryptophan and threonine concentrations in QPM were 33%, 44% and 24% greater than NM, respectively. Other indispensable amino acids such as phenylalanine, valine, isoleucine, histidine, arginine and leucine were 18%, 26%, 19%, 41%, 39% and 12% greater in QPM compared with NM, respectively. Likewise, all dispensable amino acids were greater in concentration than those in NM.

The amino acid concentrations in QPM sourced from IPB were generally in good agreement with the reported values for US (Sullivan *et al.*, 1989) and Chinese (Zhai and Zhang, 2007) QPM cultivars. The analyzed amount of lysine (0.375%),

Table 3. Amino acid content of normal maize (NM) or quality protein maize (QPM).

Amino acid	As fed basis (%)		Dry basis (%)	
	NM	QPM	NM	QPM
Indispensable amino acids				
Lysine	0.249	0.329	0.282	0.375
Methionine	0.153	0.158	0.173	0.180
Methionine+cystine	0.351	0.453	0.398	0.516
Threonine	0.263	0.325	0.298	0.370
Tryptophan	0.052	0.075	0.059	0.085
Valine	0.381	0.478	0.432	0.544
Isoleucine	0.267	0.317	0.303	0.361
Leucine	0.894	0.993	1.013	1.131
Histidine	0.246	0.346	0.279	0.394
Glycine	0.304	0.391	0.345	0.445
Phenylalanine	0.341	0.401	0.386	0.457
Dispensable amino acids				
Serine	0.343	0.403	0.389	0.459
Tyrosine	0.273	0.326	0.309	0.371
Aspartic acid	0.484	0.679	0.549	0.773
Glutamic acid	1.435	1.673	1.626	1.905
Arginine	0.367	0.508	0.416	0.579
Cystine	0.198	0.295	0.224	0.336
Alanine	0.536	0.548	0.608	0.624
Proline	0.666	0.875	0.755	0.996
Crude protein	7.460	9.130	8.450	10.390

the first limiting amino acid in maize, was slightly lower than the values reported by these studies (0.41-0.51%). A plausible factor for the difference can be any or combination of the following: cultivar *per se*, cultural management practices and the method employed in amino acid analysis, but none of these cannot be ascertained in the present work.

The AME of NM was close to published values (PHILSAN, 2003; Table 4), which gives confidence that the AME measured in QPM is accurate. The determined AME (3,353 kcal/kg) for QPM was comparable with the AME (3,335 kcal/kg) reported by San Andres *et al.* (2011) but greater than the AME (~3,115 kcal/kg) of a Chinese QPM cultivar (Qi *et al.*, 2004). Despite the greater fat content in QPM, there were no differences (P>0.05) observed in the AME of the two maize sources. This lack of differences in energy value between QPM and NM were also observed in previous studies (Tyagi Praveen *et al.*, 2008; Zhai and Zhang, 2007; Zhai *et al.*, 2002).

Effects of quality protein maize on egg production performance

There were no differences (P>0.05) in any of the production performance parameters measured in layers fed diets containing QPM and NM (Table 5). This

Table 4. Mean (± SEM) apparent metabolizable energy (AME) of normal maize (NM) or quality protein maize (QPM).

Maize	AME (kcal/kg)	
	As fed basis	Dry basis
NM	3,336±70	3,781±79
QPM	3,353±78	3,818±88
Prob.	0.370	0.310

suggests that the nutrient values determined for both QPM and NM were accurate. Moreover, both diets provided the same amount of nutrients used by the birds for maintenance and production. The findings conform with the report of San Andres *et al*. (2011) indicating comparable performance of layers fed diet based on QPM and NM formulated to contain the same amount of nutrients with the present study. An evident advantage of the diet with QPM though was the lower amount of QPM (52.92 vs 53.67%) and soybean meal (22.19 vs 24.76%) used in this diet (Table 1), reflecting the influence of the higher amount of amino acids in QPM than NM. It can be figured out that such is an economic advantage of QPM over NM when used in layers' diet.

Table 5. Mean (±SEM) production performance of hens fed diets with normal maize (NM) or quality protein maize (QPM).

Parameter	NM	QPM	*Prob.*
Daily feed intake, g/day	103.05±1.86	105.99±0.68	0.170
Hen-day egg production, %	91.92±1.81	92.88±1.33	0.675
Feed conversion ratio, kg/dozen eggs	1.35±0.02	1.37±0.02	0.485
Feed conversion ratio, kg/kg eggs	1.86±0.03	1.90±0.02	0.324
Egg weight, g	59.43±0.74	59.14±0.51	0.758
Egg mass, g	54.70±1.45	54.90±0.40	0.894
Livability (16 weeks), %	97.22±1.76	94.44±1.76	0.290

There was no effect (P>0.05) of the type of maize used in the diets on the classification of eggs (Table 6). This indicates that dietary factors such as methionine, dietary energy and linoleic acid concentrations, which affect egg size or weight (Leeson, 2006; NRC, 1994), were comparable between the two diets.

Effects of quality protein maize on egg quality

Layers fed the QPM-based diet had similar (P>0.05) egg shell weight, albumen weight, yolk weight and albumen height compared with those fed the NM-based diet (Table 7). However, subjective yolk color score was lower (P<0.001) for layers fed the QPM-based diet than those fed the NM-based diet. This observation was consistent with those of San Andres *et al*. (2011), who suggested that QPM

Table 6. Mean (± SEM) egg classification of hens fed diets with normal maize (NM) or quality protein maize (QPM).

Parameter	NM	QPM	*Prob.*
Pewee (40-45 g), %	0	0	-
Pullet (45-50 g), %	0.53±0.25	0.20±0.13	0.173
Small (50-55 g), %	9.12±2.65	8.17±1.52	0.249
Medium (55-60 g), %	35.94±5.18	39.79±4.48	0.757
Large (60-65 g), %	38.14±3.52	38.52±1.72	0.141
Extra large (65-70 g), %	14.57±5.01	10.19±2.80	0.226
Jumbo (70 g up), %	1.70±0.88	3.13±1.26	0.457

Table 7. Mean (± SEM) egg composition and quality parameters of layers fed diets with normal maize (NM) or quality protein maize (QPM).

Parameter	NM	QPM	*Prob.*
Albumen weight, g	41.08±0.35	41.07±0.27	0.973
Yolk weight, g	15.70±0.14	15.78±0.15	0.714
Egg shell weight, g	5.90±0.06	5.85±0.05	0.527
Albumen height, mm	10.08±0.13	10.33±0.03	0.082
Yolk color score, DSM units	5.40±0.03	4.47±0.11	<0.001

provided less amount or poorer bioavailability of xanthophylls for yolk pigmentation. However, Zhai (2002) observed the opposite, where layers fed the QPM-based diet had greater subjective yolk color score than those fed the NM-based diet when maize was added at the same inclusion rate. According to Beardsworth and Hernandez (2007), yolk color is primarily determined by the content and profile of pigmenting carotenoids, largely xanthophylls present in the diet. Early works of Mertz *et al*. (1964) have shown poor utilization of carotenes from high lysine maize. The differences noted on the influence of QPM on yolk color suggest variations in the amount and/or bioavailability of xanthophylls in this maize.

CONCLUSION

Quality protein maize had greater concentrations of indispensable and dispensable amino acids but similar AME content compared with NM. Replacing NM with QPM in layer diet formulations did not affect egg production performance and egg quality. However, yolk color was not improved by feeding QPM-based diets. The findings show that QPM is a potential replacement for NM in layer diets.

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