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Abstract: *Quality protein maize (QPM) has increased levels of lysine and tryptophan, limiting amino acids for monogastric animals, so its use in animal feed reduces the need for more expensive high-protein sources. The authors, through the application of a linear programming optimization model with the composition and prices of feed components used at the coast, show that the cost reduction from substituting QPM for regular maize in poultry feed for Kenya is 5% (mainly as a result of a reduction in fishmeal). The optimal ratios based on QPM and regular maize were calculated and formulated, and trials showed that broilers raised with either mixture had the same food intake, mortality and growth. Moreover, when the chickens were fried in the style popular at the coast, there was no difference in the taste of the meat between the two batches. If QPM were to replace regular maize in broiler feed in Kenya, a 5% cost reduction would translate into a gain of US$300,000. If the cost reduction were passed on to the broiler producers as a reduction in feed price, producers would be expected to gain on average US$32 per year. If the cost reduction were not passed on to the broiler producers, it would result in an extra profit for the feed industry.*

Keywords: *maize; quality protein maize; feed; poultry; Kenya*

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Maize is the major food crop and dietary staple in Kenya, with an average annual production of 2.68 million metric tons (tonnes) from 2001–2005 (FAOSTAT, 2007) and consumption of 103 kg per person (Pingali, 2001). It is also a major source of rural income, with a gross marketed production of about US$38 million (Central Bureau of Statistics, 2000). Although maize in Africa is mainly consumed by the human population, it is increasingly used in animal feed. In Kenya, over 68,000 tonnes of maize are used annually in commercial feeds (Mbugua, 1999). Growth in meat and poultry consumption in the developing world has resulted in a rapid demand for maize for livestock feed (Pingali, 2001; Rosegrant *et al*, 2001), but this can be constrained by the high cost of feed – the major cost of production.

The livestock sector plays a vital role in the economies of many developing nations. In Kenya, about 10% of the gross domestic product (GDP) and over 30% of the agricultural GDP comes from livestock (Twinamasiko, 1998). Livestock farmers are increasingly commercially oriented, especially in pig and poultry production in Kenya. The gross market value of poultry production and eggs is estimated at over US$18 million, and US$4 million for pigs (Central Bureau of Statistics, 2000).

Broiler production is the most important intensive animal production activity in Kenya, and is therefore the focus of this study. Improved poultry breeds constitute about a quarter of all poultry in Kenya, and broilers constitute about 60% of the total commercial birds produced (Table 1). Commercial poultry production in Kenya relies on the use of purchased feed, with very little feed produced on-farm. Feed production in Kenya is increasing steadily, and currently stands at 380,000 tonnes per year (Ministry of Agriculture, 2001, unpublished data), more than half of which is poultry feed (Figure 1).

Animal feed in Kenya is produced by several well established feed millers, mostly based in the major cities, using both local and imported ingredients. Their

Table 1. Poultry production in Kenya 1995–2004 (thousands).

Type	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Broilers	3,600	3,830	4,370	4,421	3,500	5,765	5,278	5,654	5,997	4,731
Layers	2,697	2,741	2,883	2,885	2,052	1,824	2,379	2,074	2,540	2,300
Indigenous	20,999	21,761	22,103	21,744	19,802	20,587	19,604	19,999	20,770	21,500
Poultry total	27,296	28,650	29,356	29,050	25,354	28,176	27,261	27,727	29,307	28,531

Source: Ministry of Agriculture, Livestock Division, unpublished data, 2005.

Table 2. Nutrient content of normal maize and quality protein maize (as percentage of whole grain).

Maize type	Source	Conventional maize	Quality protein maize (QPM)
Protein	USDA		8.9–10.2
	Laboratory analysis by Kenya Industrial Research Development Institute (KIRDI), Nairobi, 2002	7.2	9.5
	CIMMYT laboratory (CIMMYT, 2001)	9	11
	Brazil food composition tables (López-Pereira, 1993)	9.7	9.7
Lysine	CIMMYT laboratory (CIMMYT, 2001)	0.23	0.48
	Brazil food composition tables (Lopez)	0.24	0.42
Tryptophan	CIMMYT laboratory (CIMMYT, 2001)	0.05	0.11
	Brazil food composition tables (López-Pereira, 1993)	0.06	0.11
	CIMMYT laboratory (Vasal, 2000)	0.07	0.084–0.103

Table 3. Nutrient composition of the different ingredients used in broiler feed at the coast.

Ingredients	Composition										Price (US$/kg)
	Dry matter (%)	*Metabolizable energy (Mcal/kg)*	*Crude protein (%)*	*Crude fibre (%)*	*Crude fat (%)*	*Calcium (%)*	*Available phosphorus (%)*	*Lysine (%)*	*Methionine (%)*	*Tryptophan (%)*	
Regular maize	89	3.42	7.2	3.36	3.9	0.03	0.04	0.26	0.17	0.05	0.127
QPM	89	3.42	9.5	3.36	3.9	0.03	0.04	0.48	0.47	0.11	0.127
Maize bran	88	2.5	10.6	11.2	0	0.03	0.04	0.28	0.17	0	0.101
Fishmeal	88	2.8	52	2	4	4.2	2.8	4.6	1.8	0.21	0.506
Wheat pollard	89	3.03	15.6	7.1	4.2	0.12	0.4	0.57	0.26	0.8	0.127
Wheat bran	89	1.7	16.1	11.2	4.8	0.1	0.65	0.6	0.1	0	0.076
Cottonseed cake	94	2.8	34	20	6	0.15	0.48	1.4	0.39	0.7	0.177
Prairie meal	90	3.7	60	2.5	2.5	0.1	0.2	0.9	1.43	0.3	0.443
Coccodiostat	100	0	0	0	0	0	0	0	0	0	10.127
Premix	96	0	0	0	0	0	0	0	0	0	3.544
Synthetic lysine	0	0	0	0	0	0	0	100	0	0	2.500
Limestone	100	0	0	0	0	33	0	0	0	0	0.063
Salt	100	0	0	0	0	0	0	0	0	0	0.063
Limits for starter:											
Lower limit	88	2.75	22	–	–	1	0.45	1.1	0.48	0.23	
Upper limit	–	–	–	7	6	–	–	–	–	–	
Limits for finisher:											
Lower limit	88	2.75	20	–	–	0.9	0.4	0.95	0.4	0.23	
Upper limit	–	–	–	7	6	–	–	–	–	–	

manufacturing capacity is estimated at over 600,000 tonnes, but actual utilization is only about 63% (Mbugua, 1999; Technical Center for Agricultural and Rural Development, 1998). Poultry feed constitutes 55% of national feed production, followed by cattle feed (30%) and pig feed (10%).

A major disincentive to animal production is the high price of feed. Increased feed prices without corresponding increases in producer prices have resulted in a dampening of the initial enthusiasm for poultry production by smallholders (Potter, 1987). Major constraints to feed production are the limited availability and high prices of high-protein ingredients such as fishmeal and soybeans, some of which have to be imported. The search for low-cost alternatives is therefore important.

Maize grain is often used as a cheap source of energy in

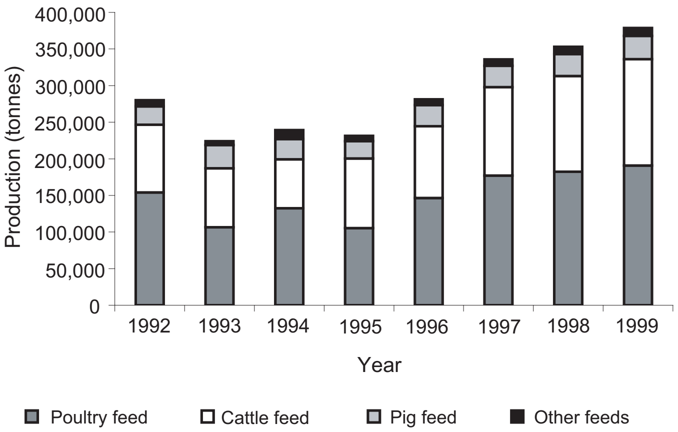

Figure 1. Livestock feed production in Kenya (1992–99).
Source: Ministry of Agriculture, unpublished data (2001).

animal feed, but it is deficient in the essential amino acids tryptophan and lysine (Olson and Frey, 1987) and limits the amount of protein available for monogastric animals such as pigs and poultry. Therefore, it is routinely supplemented with other protein sources such as oilseed cakes, soybeans and fishmeal, or with synthetic amino acids. Oilseed cake is a by-product of the extraction of oil from crops such as soybeans or cottonseed. It contains about 30–40% protein, but is deficient in methionine, which limits its use in poultry diets. Methionine is usually the first limiting amino acid in the standard maize–soybean meal diets used for poultry. Other common protein sources are fishmeal, meat meal, blood meal and bonemeal. If maize is supplemented with fishmeal, lysine becomes the first limiting amino acid (Toride, 2002). In Kenya, the major protein sources for feed are cottonseed cake, prairie meal, wheat pollard and fishmeal. Cottonseed cake is a by-product of oil extraction from the seed, and is high in crude protein (Table 3). Prairie meal, also called maize gluten meal, is a highly digestible protein-rich feed generated from the maize-milling process. Wheat pollard, also called wheat middlings, is a high-energy by-product of the wheat-milling industry and consists of a mixture of shorts and germs. Imported synthetic lysine and methionine are also available in Kenya, at US$2.5 and $3.8 per kg respectively, but are not commonly used because of their cost.

An alternative to adding amino acids from other sources is to breed maize with higher levels of deficient amino acids. Efforts started in the mid-1960s after the discovery in 1963 of the *opaque-2* gene, which results in substantially higher lysine and tryptophan contents in the grain endosperm (Mertz *et al*, 1964). The original opaque-2 cultivars were, however, low-yielding, and the grains were soft with a chalky appearance and susceptible to storage pests, making them unpopular with farmers as well as consumers (Vasal, 2000). Scientists at the International Maize and Wheat Improvement Center (CIMMYT) have since improved and developed the opaque-2 cultivars into 'quality protein maize', or QPM, which overcomes these constraints. The biological value of QPM protein is 90% of that of milk, a standard reference protein, as compared with 40% for conventional maize (National Research Council, 1988). While normal maize has a lysine content of 0.23% of total protein and a tryptophan content of 0.05%, QPM varieties typically contain 0.48% lysine and 0.11% tryptophan (Table 2). Currently, the appearance and taste of quality protein maize are similar to those of regular maize, and yields and pest resistance are comparable (Krivanek *et al*, 2007). Its varieties are widely accepted and grown for food and animal feed in many countries. A meta-analysis of nine nutritional studies showed that consumption of QPM instead of conventional maize leads to a 12% increase in the rate of growth in weight and a 9% increase in the rate of growth in height in infants and young children with mild to moderate undernutrition from populations in which maize is the major staple food (Gunaratna *et al*, 2010). As of 2001, some 730,000 hectares of QPM varieties were sown in the developing world (CIMMYT, 2001), and by 2003, about 200,000 ha had been sown in Africa alone (Krivanek *et al*, 2007).

Feed trials have repeatedly shown that pigs fed with QPM grow twice as fast as those fed with conventional maize (Krivanek *et al*, 2007; CIMMYT, 2001). Some nutritional studies with pig and chicken diets have shown that performance is improved when QPM is substituted for regular maize without an additional protein supplement (Kemm *et al*, 1977; Gous and Gevers, 1982). By using opaque-2 instead of normal maize in pig diets with suboptimal protein content (between 13.3% and 16%), fishmeal can be reduced by 22% without influencing performance (Kemm *et al*, 1977). In broiler diets, the substitution of QPM for regular maize at a rate of 60% substantially reduces the need for soybean meal and, therefore, the cost (Subsuban *et al*, 1990). Similarly, in an experiment with finisher pigs, less soybean meal was needed to maximize performance in diets based on QPM compared with diets using normal maize (Burgoon *et al*, 1992). Beef steers fed on high-lysine maize gained weight significantly faster than those fed on the conventional maize (Slabbert *et al*, 1988).

Thus QPM can reduce the cost of animal feed by decreasing the amount of the more expensive high-protein sources. Linear programming (LP) models allow feed companies to identify the cheapest way of providing the minimum dietary requirements for farm stock. Calculations for pig and poultry rations containing regular maize, QPM, sorghum, soybean meal and synthetic lysine and tryptophan showed that the optimization using QPM instead of regular maize resulted in a cost saving of 2.8% for chicken feed and 3.4% for pig feed (López-Pereira, 1992). The calculations used long-term average prices at that time in the 1990s, which were $120/ton for maize and $2.5/kg for lysine, but were similar to the prices in Kenya at the time of this study. These theoretical results were, however, not used in further animal feed trials to ensure that the theoretical cost gains could be realized without loss of productivity. Although several feed trials compared opaque-2 or QPM with regular maize in Africa (Kemm *et al*, 1977), the diets for these trials did not cover the most economic ratios; neither did they calculate the cost reduction from using QPM.

The present study, therefore, estimates the economic benefits of using QPM in broiler diets, in two stages. First, the economically optimal feed ratios for starter and finisher broiler feed were calculated, using LP, with regular maize and with QPM, allowing the cost reduction from the use of QPM to be estimated. Second, these theoretical results were used to mix broiler feed with and without QPM, and the proportions used were tested in broiler feed trials at the Kenyan coast. The trials tested the hypothesis that broilers fed on QPM-based rations would grow at the same rate as those fed on rations based on regular maize, but at a lower cost.

Methodology

Calculation of most economic broiler feed ratios

An LP model was used to calculate the cheapest broiler feed formulation that met the minimal dietary specifications (López-Pereira, 1993):

$$\textit{Minimize} \quad Z = \sum_{i=1}^{n} P_i X_i$$

$$\textit{Subject to:} \quad A_j \leq \Sigma_i N_{ij} X_i \leq B_j$$

$$C_i \leq X_i \leq D$$

$$\Sigma_i X_i = 1$$

$$X_i \geq 1$$

where:

Z is the total cost per ton of feed for a given animal growth stage, in US$,
X_i is the level of ingredient *i* in the ration (kg),
X_i is price of ingredient *i* (from *1* to *n*), in US$/kg,
N_{ij} is the content of nutrient *j* (from *1* to *m*), in ingredient *i*, in kcal/kg for energy and g/kg for other nutrients,
A_j is the minimum requirement of nutrient *j* in the feed formulation,
B_j is the maximum allowed level of nutrient *j* in the feed formulation,
C_i is the minimum level of ingredient *i* required (kg), and
D_i is the maximum level of ingredient *i* allowed (kg).

Solving this model results in finding the lowest Z, the total cost per ton of feed for a given species and growth stage (first line in the equation). Z is calculated by adding the costs of the different ingredients *i*, each of which is obtained by multiplying their price P_i with their quantities X_i.

For this study, the model was applied to calculate the cheapest broiler starter and finisher feeds, with and without QPM. The list of possible ingredients included those commonly used by the Kenyan poultry feed industry: maize bran, wheat bran, wheat pollard, prairie meal, cottonseed cake and fishmeal (Table 3). Vitamin and amino acid premixes and a coccodiostat were added to the mix. Each ingredient *i* forms a line, while each nutrient *j* forms a column. Each cell N_{ij}, therefore, represents the content of nutrient *j* in ingredient *i*, and together they constitute the content matrix of Table 3.

The total nutrient levels are calculated by multiplying the content matrix N_{ij} by the quantities vector X_i. The quantity of each nutrient *j* then needs to fulfil the minimum requirement A_j, a level that depends on species and stage, but should not exceed a maximum B_j. The minima and maxima for the different nutrients are derived from the industry standards (from (National Research Council, 1984; bottom of Table 3). Furthermore, there are limits to the levels of the different ingredients. Ingredient *i* should be under minimum C_i or should exceed maximum D_i (Table 4). For example, the maize content cannot exceed 40% of the starter ratio or 35% of the finisher ratio, largely because of the fibre content. Similarly, cottonseed cake contains gossypol, a toxic component, so its use needs to be limited to 12%. Prices of the different ingredients were obtained from informal surveys, with the price of QPM assumed to be equal to that of regular maize (Table 5).

Table 4. Minimum and maximum levels of ingredients used in the calculations to optimize the formulations.

Ingredient levels	Starter Min (%)	Starter Max (%)	Finisher Min (%)	Finisher Max (%)
Regular maize	40	40	35	35
QPM	40	40	35	35
Maize bran	–	–	–	–
Fishmeal (omena)	–	–	–	–
Wheat pollard	–	–	30	–
Wheat bran	–	–	–	–
Cottonseed cake	–	12	–	12
Maize gluten meal	–	–	–	–
Coccodiostat	0.05	0.05	0.05	0.05
Premix	0.25	0.25	0.2	0.2
Limestone	–	–	–	–
Salt	0.5	0.5	0.5	0.5

With these specifications, the quantities of different ingredients needed to produce one ton of feed at minimal cost for each growth stage (starter and finisher) were calculated with an LP model (the add-on 'Solver' in Microsoft Excel), using either regular maize or QPM.

Broiler feed trials

The results of the optimization were subsequently used to formulate broiler starter (half a ton) and finisher (one ton) for each of the two treatments (with or without QPM), to be compared in a feed trial. This trial was carried out at four sites in the Kikambala division, Kilifi district: the Kenya Agricultural Research Institute (KARI) station and the Farmers' Training Center (FTC) in Mtwapa, and on two farms. The trials took place in September and October 2002, and involved a total of 660 day-old chicks, raised till six weeks.

At each of the four sites, there were two treatments: (1) broilers fed on a diet formulated using regular maize, and (2) broilers fed on a diet formulated using QPM. At the KARI station, each diet was fed to 10 birds and replicated three times, and the different batches were kept in different cages (60 birds in total). At the FTC and with the two farmers, each diet was fed to 10 birds and replicated 10 times (200 birds each). Birds on each diet were kept together, but each of the 10 batches was identified by different coloured marks on the legs.

Table 5. Most economic formulation for different feeds, with and without QPM, as calculated by the optimization model.

Ingredients	Price (US$/kg)	Starter				Finisher			
		With regular maize		*With QPM*		*With regular maize*		*With QPM*	
		Qty (kg)	*Cost (US$)*	*Qty (kg)*	*Cost (Ksh)*	*Qty (kg)*	*Cost (Ksh)*	*Qty (kg)*	*Cost (Ksh)*
Maize	0.127	400	50.63	400	50.63	350	44.30	350	44.30
Maize bran	0.101	0	0.00	0	0.00	34	3.42	19	1.90
Wheat pollard	0.127	223	30.63	223	28.23	300	37.97	300	37.97
Wheat bran	0.076	40	0.00	40	3.04	32	2.41	75	5.70
Cottonseed cake	0.177	120	21.27	120	21.27	120	21.27	109	19.24
Prairie meal	0.443	82	37.72	82	36.33	46	20.38	45	20.13
Fishmeal	0.506	112	67.59	112	56.96	98	49.49	80	40.76
Coccodiostat	10.127	1	5.06	1	5.06	1	5.06	1	50.63
Premix	3.544	3	8.86	3	8.86	2	7.09	2	7.09
Limestone	0.063	14	0.71	14	0.89	13	0.80	15	0.89
Salt	0.063	5	0.32	5	0.38	5	0.38	5	0.38
Total		*1,000*	*222.66*	*1,000*	*211.57*	*1,000*	*192.55*	*1,000*	*183.29*
Cost saving, US$/ton					11.09				9.26
Cost saving, %					5.24				5.05

Table 6. Number of birds and mortality.

Treatment (feed type)		Start of trial	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Mortality (%)
Regular maize	Number [a]	342	332	330	329	329	329	329	3.80
	Mortality [b]		10	2	1	0	0	0	
QPM	Number [a]	336	332	329	327	326	326	326	2.97
	Mortality [b]		4	3	2	1	0	0	

[a] Number of live birds at the start of the trial and at the end of each week; [b] Number of birds that died during each week.

All four sites were visited weekly, and headcount, feed intake and weight were observed for each batch. At the FTC and the farms, the chicks from the different batches had to be separated before observation. The number of surviving chicks from each batch were collected in a container, counted and weighed. Feed intake was calculated by subtracting the weight of leftovers in the feeders from the feed offered. To analyse the statistical difference between the number of surviving birds, feed intake and weight, a multivariate general linear model was used, with treatment as the main factor and farm as the covariate. This allows for the calculation of F-values for each time period, as well as for a combined time period over the different time periods, while controlling for possible differences between the four farms.

Participatory evaluation

At the end of the six-week feeding trial, when the broilers were ready for marketing, a field day was organized to obtain the views of stakeholders on the trial and the performance of the two diets and to compare the taste of the meat of the two broiler batches. Poultry farmers, agricultural officers and staff from the Ministry of Agriculture, feed manufacturers and feed dealers were invited, and 49 people participated.

Meat from animals from both treatments was fried using the preparation method common at the coast. The participants tasted coded samples of meat from both batches, and evaluated them on different traits (appearance of the raw meat, appearance of the cooked meat, tenderness, taste, flavour and fat content), using standard sensory methods for food evaluation (Watts *et al*, 1989). Participants evaluated each sample on a scale of 1 ('dislike very much') to 7 ('like very much') and marked the score on a specially prepared evaluation sheet. Differences between the scores were analysed using the pairwise t-test on the differences between the mean scores.

Results

Optimization results

The results of the LP model showed that the use of QPM reduces the cost of the broiler feed by 5% (Table 5). For the starter diet, the most economic formulation using conventional maize cost US$223/ton, compared with the formulation with QPM, which cost only US$212/ton, a reduction of US$12/ton, or 5.24%. Similarly, the finisher mix with regular maize cost US$193/ton, compared with US$183/ton with QPM, a cost saving of 5.04%. The cost reduction is mainly the result of reducing the quantity of expensive protein sources, especially fishmeal [*omena*], which is commonly used at the coast. Its use can be reduced by more than 15% when substituting QPM for regular maize.

Feed trial

Different feed batches, with and without QPM, were formulated according to the outcome of the optimization, and fed to broilers on both treatments at the four sites. Every week, all sites were visited to make the necessary

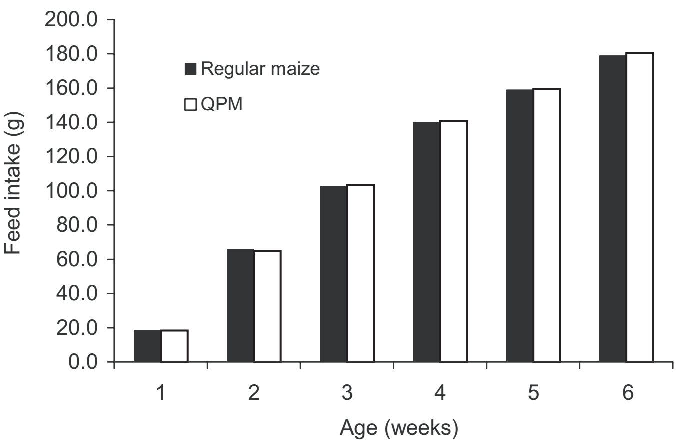

Figure 2. Average feed intake, g/bird/day.

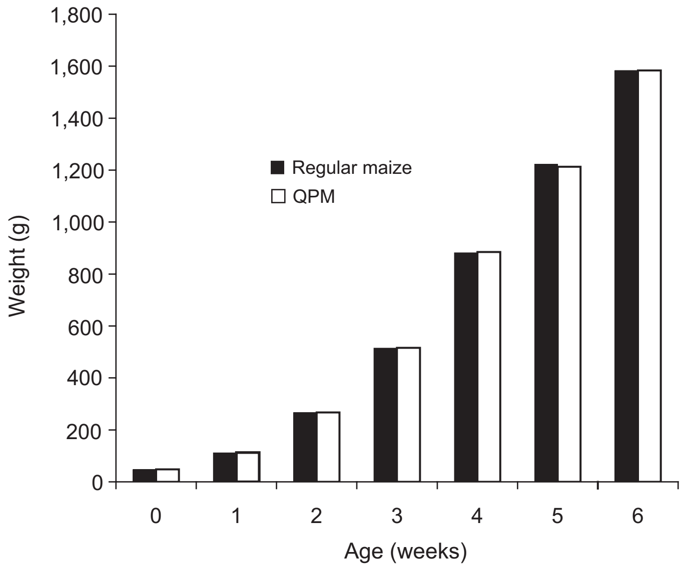

Figure 3. Average weight, g/bird/week.

observations. The results showed no significant differences between the two treatments in mortality, feed intake or weight gain.

The trial started with 342 birds on the treatment with regular maize, 13 (3.8%) of which died, plus 336 birds on the treatment with QPM, 10 (2.97%) of which died (Table 6). No statistical difference was found between the treatments using a general linear model (GLM) while controlling for farm effects (for the multivariate test over all six periods, $F = 1.035$, $p = 0.406$).

Feed intake increased from 18.7 grams/bird/day in the first week, to 179.0 g/bird/day in the sixth week (Figure 2), and tests showed no significant differences between the two diets (at the 5% level). Total intake over the six weeks was 3.38 kg/bird for the broilers on either diet, again with no significant difference between the two diets ($F = 0.265$, $p = 0.994$).

Weight gain over the six weeks averaged 36.17 grams/bird/day for broilers fed regular maize and 36.19 g/bird/day for those fed on QPM diets (Figure 3), and no statistical differences were found (Table 7). Feed conversion efficiency, calculated as the weight gain over the feed intake, was 0.33 for both diets.

The organoleptic test

During the field day at the KARI station in Mtwapa, 49 participants tasted coded samples of fried chicken from each treatment, and scored them for different traits. There were no statistical differences in consumer appreciation for the different traits – appearance of the raw meat, appearance of cooked meat, tenderness, taste, flavour and fat content – between the meat of broilers raised on the formulation using QPM and those raised on the formulation with regular maize (Table 8).

Economic analysis

For the same production, the use of QPM reduces the cost by 5.24% for starter feed and by 5.05% for finisher feed. At the participating farms, with typical small-scale farmers from coastal Kenya, feed costs form about half the production costs. On average, a batch of 200 birds consumes 676 kg of feed, at a cost of US$151. A cost reduction of 5% would increase farmers' profits by US$8 per batch. Therefore, if the gains were to be passed on to the farmers as cheaper feed, these farmers would increase their annual profits by US$32, since they typically raise four batches each year.

The value of broiler production in Kenya is estimated at about US$6 million per year. Savings arising from using QPM instead of regular maize in poultry feeds alone could, therefore, be valued at about US$0.3 million a year. If the cost reduction were not passed on as reduced prices, the gain would be translated into higher profits for the industry. In total, the feed manufacturers could save US$300,000 annually from the poultry feed produced using QPM.

Conclusions

Substituting QPM for regular maize in the production of broiler feed reduces the amount of expensive protein sources used, leading to a cost reduction of 5%. Optimal ratios of QPM and regular maize were calculated and diets formulated, and subsequent trials showed that broilers raised with either mixture had the same food intake, mortality and growth rates. Moreover, when fried in the style popular at the coast, there was no difference in taste between the meats from either batch.

If QPM were to replace regular maize in broiler feed in Kenya, the 5% cost reduction would translate into a gain of US$300,000, either as reduced costs for farmers or profit for feed manufacturers. Although modest in scope, the cost reductions are of interest to the broiler industry in Kenya. The coast is an area of poor, small-scale farmers, and US$32 per farmer per year can make a difference. The alternative procedure, adding synthetic lysine, increases costs by about 5% and hence is rarely used in Kenya.

To exploit the potential benefit of QPM, some problems need to be overcome. First, for maize producers to be interested, yields of QPM crops need to be at least equal to those of regular maize. Fortunately, breeders have made good progress in this area and, in several African countries, QPM varieties have been released that

Table 7. Average weight (g/bird) at the start of the trial and at the end of each week.

Treatment (feed type)	Start of trial	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Overall
Regular maize:								
Mean	47.8	111.7	267.0	514.8	882.4	1,222.8	1,584.1	
Std dev	2.9	15.5	27.7	37.3	69.1	96.4	97.7	
QPM:								
Mean	47.7	113.2	267.1	516.0	884.4	1,213.0	1,584.0	
Std dev	2.9	14.4	26.6	38.1	67.3	105.2	97.4	
F-value [a]	0.017	0.033	2.118	5.408	0.346	0.072	1.028	0.505
p-value	0.196	0.658	0.95	0.849	0.791	0.564	0.706	0.827

[a] Using a general linear model: intercept + farm + treatment.

Table 8. Mean scores of the organoleptic test.

Treatment	Appearance raw	Appearance cooked	Tenderness	Taste	Flavour	Fat content	Mean	N
Normal maize:								
Mean	5.33	5.73	5.84	6.12	5.92	5.24	5.70	49
Std dev	1.88	1.68	1.40	1.49	1.26	1.81	1.18	
QPM:								
Mean	5.39	5.47	5.71	5.63	5.55	5.33	5.51	49
Std dev	1.84	1.62	1.37	1.51	1.19	1.55	0.95	
p-value of difference[a]	0.82	0.26	0.67	0.11	0.12	0.78	0.22	

Notes: Score – on a scale of 1–7, where 1 = dislike very much and 7 = like very much.[a] As calculated from a pairwise t-test for the difference of means. N = number of participants.

outperform the most popular conventional varieties. Second, the resistance of QPM to storage pests, in particular weevils and the larger grain borer, needs to be equal to, or better than, that of regular maize. On average, QPM varieties are more susceptible to storage pests, as documented by the screening of a large number of QPM varieties at CIMMYT-Mexico (Bergvinson, unpublished data). But there is enough variation in the distribution to allow for characterization and screening of QPM varieties for resistance to storage pests before release. Third, the industry would need a way of assessing the quality of the QPM it purchased. Therefore, a local laboratory provided at reasonable cost is needed to analyse maize for its amino acid content. Currently, the feed industry in the country has no way of determining amino acid levels in either the ingredients it uses or in the feeds it produces. An alternative would be for the feed industry to contract farmers to produce and supply QPM maize, while controlling the quality of the seed used. Maize bought from contract farmers might be more expensive than maize from contract traders, the current suppliers, and there could be a cost for maintaining the chain of custody. Fourth, *opaque-2* is a recessive gene and an invisible trait, which makes it harder to maintain during breeding, seed production or while recycling seed under farmers' conditions. Therefore, special attention needs to be paid to training maize breeders, seed producers and farmers in appropriate manipulation of QPM in order to preserve the trait in the seed of future generations.

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