Economics of Quality Protein Maize as a-Feedstuff

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This study evaluates pig and poultry feed cost and composition effects from including quality protein maize (QPM) as an alternative energy and protein source. Cost savings could be as high as 3.4% (about $5/ton) for pig feed, with QPM constituting about 80% of the ration and replacing all regular maize and synthetic lysine and 40% of soybean meal. Savings are slightly lower for poultry feed. However, if a 5% price premium for QPM over regular maize is assumed most of the savings are lost, indicating that QPM should compete at the same price to be economically attractive as a commercial feedstuff. © 1993 John Wiley & Sons. Inc.

Quality protein maize (QPM) has long been considered a nutritionally superior cereal grain and has been promoted mainly for human consumption. However, its nutritional value in the diets of malnourished people in developing countries is still unclear, for nutritionists do not agree on the relative importance of energy vs. protein in such diets.[1–4] Nevertheless, as feed for monogastric animals, especially pigs and chickens, QPM has amply demonstrated its superior performance. Although there is little doubt that QPM performs better than other energy sources for feed such as regular maize and sorghum, few studies have analyzed the potential cost and effects on feed formulation of adding QPM to animal feed rations.[5,6]

Maize and sorghum are the main energy sources in rations for pigs and chickens in many countries, especially those where the pig and poultry industries are well developed. The main source of protein is usually soybean meal. Countries that produce enough maize and soybeans to meet domestic demand are few, and

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thus one or both of these key ingredients have to be imported. Feed ingredients are also limited in some key amino acids, especially lysine, tryptophan, and methionine; and synthetic amino acid supplements are usually added to meet nutritional requirements, especially in pig feed. Synthetic amino acids also need to be imported in many countries and are expensive. Although the price of synthetic lysine has decreased recently, it is still approximately $3.00 US/kg and even more expensive when imported.

Therefore, it is important to determine if QPM, with its higher protein quality, can substitute for regular maize and/or sorghum as a more efficient energy source and, at the same time, for soybean meal and/or synthetic amino acids as an alternative protein source in feed rations. QPM-based feed is converted more effectively into weight gain by both chickens and pigs than feed based upon regular maize.[7-9] If it can be shown that QPM is an economically feasible alternative to regular maize and soybean meal and other protein sources, commercial feed rations could be produced at a lower cost.

This article reports the results of a recent study undertaken to determine whether QPM can substitute for regular maize, sorghum, and/or soybean meal and other protein sources in the composition of pig and chicken feed in an economically efficient manner, reducing total feed costs enough to provide incentives for using QPM in the feed industry. Special attention was paid to the case of Brazil, where extensive interviews were conducted with members of the feed industry, farmers who have produced QPM, and maize research institutions regarding the possible use of QPM for pig and chicken feed.

DEVELOPMENT OF QPM

QPM was developed by plant breeders at the International Maize and Wheat Improvement Center (CIMMYT) through genetic improvement of the Opaque-2 gene discovered in maize at Purdue University in 1963.[10] Although it appears to be physically identical to regular maize. the proportion of two key amino acids in its protein composition, lysine and tryptophan, endows QPM with protein that is of a higher nutritional quality, as it is believed to be used more efficiently by humans and monogastric animals. QPM also differs from regular maize in its leucine and isoleucine contents. The lower leucine to isoleucine ratio in QPM is also believed to promote more efficient use of the total protein. As can be seen in Table I, the total energy and protein contents in QPM are no different from those of regular maize, although some studies show higher levels for QPM.[11,12] The proportions of lysine and tryptophan in QPM are approximately 75 and 83% higher, respectively, than in regular maize.

Early maize varieties and hybrids containing the Opaque-2 gene were low yielding, but current QPM cultivars yield the same as the best regular maize materials.[13-15] Plant breeders in several Latin American countries have succeeded in developing QPM cultivars adapted to local conditions, such as Nutricta in Guatemala, Nutri-Guarani in Paraguay, and BR-451 in Brazil. Other countries with active QPM breeding programs are China, the United States, and South Africc.

The most important remaining problem is the difficulty of physically distinguishing QPM from regular maize. Until recently, complicated chemical tests

Table I. Nutrient Composition of Regular Maize and QPM.

Nutrient	Units	Regular Maize	QPM
Metab. Energy for Pigs	kcal/kg	3430	3430
Metab. Energy for Chickens	kcal/kg	3480	3480
Crude Protein	%	9.70	9.70
Calcium	%	0.02	0.02
Digest. Phosphorus	%	0.09	0.09
Methionine	%	0.15	0.16
Methionine + Cystine	%	0.30	0.34
Threonine	%	0.33	0.37
Arginine	%	0.39	0.56
Valine	%	0.43	0.46
Phenylalanine	%	0.45	0.40
Isoleucine	%	0.30	0.28
Leucine	%	1.14	0.85
Lysine	%	0.24	0.42
Tryptophan	%	0.06	0.11
Leucine:Isoleucine Ratio		3.80	3.04

Source: Unpublished data, Protein Quality Laboratory, CIMMYT, Mexico.

were necessary to identify the levels and proportions of amino acids that set QPM and regular maize apart. This problem has complicated extension efforts to promote a product that appears no different from regular maize. However. some simple techniques have been developed to identify QPM.[16] Another solution to the identification problem may be to introduce a genetic marker in QPM materials such as grain color, which can be easily incorporated by plant breeders. For example, a white QPM variety was developed in Brazil, where virtually all the regular maize produced is yellow.

METHODOLOGY AND DATA SOURCES

To estimate the economic potential of QPM as an ingredient for poultry and pig feed, optimal feed rations with and without QPM were constructed for different chicken and pig growth stages. The rations were formulated so that their nutritional value with and without QPM was equivalent and all energy, protein. and other nutritional requirements of the industry were met. Linear programming (LP) models were developed in which the total ingredient cost of production of the different rations with and without QPM was minimized.‖ The models were developed and run using GAMS[17] and LINDO[18] software for personal computers. The objective function was the minimization of the ingredient cost of producing 1 metric ton of feed subject to the nutritional content of each ingredient in the mix, minimum and maximum nutritional requirements of the animal, and minimum and maximum percentages of the main ingredients. Mathematically, the model can be expressed as

‖The models developed for this study are available from the author upon request.

$$\begin{aligned} &\text{Minimize} && C = \Sigma_i P_i X_i, && i = 1, 2, \ldots, n \text{ ingredients} \\ &\text{Subject to} && B_j \leq \Sigma_j N_{ij} X_i \leq D_j, && j = 1, 2, \ldots, m \text{ nutrients} \\ & && L_i \leq X_i \leq U_i && \\ & && \Sigma_i X_i = 100 && \\ & && X_i \geq 0 && \end{aligned}$$

where C is the total ingredient cost of producing 1 ton of feed for a given growth stage of poultry or pigs ($/ton); X_i is the optimal level of ingredient i in the ration (%); P_i is the price of ingredient i ($/kg); N_{ij} is nutrient j content in ingredient i (kcal/kg for energy and % for others); B_j and D_j are, respectively, the minimum and maximum requirements of nutrient j in the ration; and L_i and U_i are, respectively, the minimum and maximum levels of ingredient i allowed. The data used in the analysis were the nutritional requirements for poultry and pigs at different growth stages, nutritional content of the different ingredients available,[11,19,20] and ingredient prices. The nutritional content of regular maize and QPM used in the base LP model is shown in Table I. Energy and protein content are assumed to be the same for both types of maize in the base model, and the main differences are the levels of lysine, tryptophan, and leucine.

A system of price ratios, using the international price of regular maize as the base, was used to express the prices of the main ingredients (Table II).* For example, the prices of soybean meal and sorghum were set at their long-term averages relative to the price of regular maize. This procedure facilitates interpretation and provides an easy way to test the sensitivity of results to changes in relative prices. It also allows for the model to be applied in any country or region, requiring only the price of one common ingredient, in this case the international price of maize adjusted for transport costs, and an estimate of the relative prices of other ingredients. The price of QPM was initially assumed to be the same as that of regular maize (i.e., a ratio of QPM to regular maize price of 1.0) because no price for commercial QPM is available. Model results with the prices shown in Table II constituted the base case and were compared to the results from the sensitivity analysis, in which one or more of the price ratios were changed. Model output for each growth stage includes the minimum ingredient cost of producing 1 ton of feed, the optimal ration composition, and the range of ingredient prices over which the optimal mix remains unchanged (shadow prices). A detailed description of the models and the GAMS and LINDO programs used are provided elsewhere.[21]

RESULTS: BASE MODEL AND SENSITIVITY ANALYSIS

For the base model with long-term prices, maximum ingredient cost savings from using QPM in pig feed are 3.4% for meat pigs and 3.0% for sows (Table III). Maximum cost savings in poultry feed are more modest but nonetheless substantial, 2.8% for broilers and 2.6% for layers. Lysine and tryptophan are the first and second limiting amino acids, respectively, in maize-based pig feed; for poultry feed, the limiting amino acid is methionine, the content of which is only slightly higher in QPM than in regular maize. Thus, QPM is economically more important as an ingredient in pig feed. In all the LP solutions, QPM substitutes completely for regular maize, another indication of QPM's superiority as a feed ingredient (Table IV). Moreover, the amount of soybean meal required is reduced by as much as 58% in the rations, and the synthetic lysine requirement is eliminated in both poultry and pig feed. These are important results because these ingredients are imported in many countries and the use of QPM could substantially reduce imports needs.

*The price of main cereal grains used in this study are FOB prices in US gulf ports.

Table II. Prices of Main Ingredients used in Base Linear Programming Model.

Ingredient	Price[a] ($/ton)
Regular Maize	120
QPM	120
Sorghum	114
Soybean Meal	240
Synthetic Lysine	3200
Synthetic Methionine	3250

Other available ingredients in the model were: wheat meal. maize gluten. meat and bone meal. calcium carbonate, dicalcium phosphate, tallow, cane molasses, salt, and vitamin and mineral supplements. *Sources:* UNCTAD/CNUCED[24] and *Chemical Marketing Reporter*.[25]

[a]The prices of soybean meal and sorghum are set at their long-term average relative to the price of regular maize (FOB basis. US gulf ports): soybean meal = 2.00: sorghum = 0.95. The relative price of QPM to regular maize is set at 1.00 in the base model.

The price structure of ingredients used in the base model discussed above corresponds to international prices and therefore may not reflect actual relative prices faced by feed producers in specific countries because of local supply and demand conditions (for locally produced ingredients) and/or transportation costs and exchange rate effects (for imported ingredients). For example, in Brazil sorghum is seldom used in feed rations because domestic production is negligible, and vegetable oil is preferred as an energy supplement over molasses or other energy-rich ingredients. Relative prices also favor the use of more soybean meal and less synthetic lysine in Brazilian feed rations. In other countries. the price of synthetic lysine is lower (e.g., the United States, Mexico) or all or most of the soybean meal is imported and thus expensive (El Salvador). Also, in some countries such as El Salvador and Mexico sorghum is an important feed ingredient and the sorghum : maize price ratio has traditionally favored the use of sorghum over maize as the main energy source in commercial feed.†

The robustness of the results of the base model with long-term prices was thus tested by changing the different price ratios of key ingredients and the types of

†In these and other countries in the region and elsewhere, regular maize (usually white) is traditionally consumed as a direct human food. In fact, QPM varieties have been developed in some countries (e.g., Guatemala, Brazil) with an emphasis on improving the nutritional conditions of direct maize consumers.

Table III. Minimum Cost of Feed with and without QPM for Different Growth Stages of Pigs and Chickens, Base Model.

Growth Stage	Feed Cost ($/ton)		Cost Savings	
	QPM	No QPW	$/ton	%
Pig Feed				
Meat Pigs (kg)				
1–15	174.49	178.58	4.09	2.29
15–30	155.40	160.34	4.94	3.08
30–60	139.57	143.43	3.86	2.69
60–100	133.02	137.69	4.67	3.39
Pregnant Sows	128.75	131.99	3.25	2.46
Lactating Sows	142.64	147.11	4.47	3.01
Chicken Feed				
Broilers (weeks)				
1–4	162.74	166.83	4.09	2.45
4–6	153.95	157.94	3.99	2.53
6–8	151.10	155.48	4.39	2.8’
Layers (weeks)				
1–6	153.59	157.27	3.69	2.31
6–12	139.71	143.35	3.65	2.51
12–20	128.95	132.43	3.48	2.63
20–70	139.54	141.72	2.18	1.54

Source: LP model results.

Table IV. Average Optimal Level of Main Ingredients in Pig and Poultry Feed with and without QPM, Base Model.

	Regular Maize	QPM	Soybean Meal	Synthetic Lysine
Pig Feed (kg/ton)				
Meat Pigs (all growth stages)				
Without QPM	785	na	165	0.8
With QPM	0	778	120	0.0
Pregnant and Lactating Sows				
Without QPM	840	na	118	0.1
With QPM	0	835	49	0.0
Chicken Feed (kg/ton)				
Broilers (all growth stages)				
Without QPM	635	na	276	0.2
With QPM	0	604	235	0.0
Layers (all growth stages)				
Without QPM	626	na	173	0.1
With QPM	0	593	118	0.0

Source: LP model results. na, not applicable.

Table V. Sensitivity Analysis of LP Results.

Sensitivity Case	Base Model	Sensitivity Analysis
Ingredient Prices ($/ton)		
1. QPM	120	126
2. QPM	120	132
3. Soybean Meal	240	180
4. Soybean Meal	240	300
5. Sorghum	114	102
6. Sorghum	114	96
7. Synthetic Lysine	3,000	2,000
8. QPM Protein and Energy Content Relative to Regular Maize (ratios)		
Protein	1.0	1.1
Energy	1.0	1.1
9. Ingredient Changes (available? Y or N)		
Sorghum	Y	N
Molasses	Y	N
Tallow	Y	N
Vegetable Oil	N	Y

ingredients available. This sensitivity analysis served to test whether the results of the model would hold at alternative price ratios, or available ingredients, that may prevail in specific countries or regions. The range of ingredient prices over which optimal feed rations remain unchanged in the base model was used to select the relevant price changes used to perform the sensitivity analysis. As well, the models were run under the assumption that the total energy and protein content of QPM is 10% higher than that of regular maize. This sensitivity exercise made it possible to estimate the further potential for QPM as an animal feed based upon the results of studies that claim that QPM indeed has higher levels of protein and/or energy than regular maize.[11,12‡] Finally, the mix of available ingredients in the models was changed to represent a case similar to Brazil, where no sorghum is used and vegetable oil is preferred to molasses and tallow as the energy supplement. Each of the nine changes for the sensitivity analysis was made separately, always with reference to the base case (Table V).

Both the cost savings and optimal QPM content in the different feed types drop substantially when a 5% price premium for QPM over regular maize is assumed (Table VI). Moreover, given a 10% price premium (i.e., a QPM price of $132/ton) QPM ceases to be economically attractive for feed producers and drops out of the optimal solutions. Therefore, any price premium offered by the feed industry to potential QPM producers is not likely to exceed 5%. This result indicates that if QPM is to have potential as a feed ingredient it has to compete with regular maize at about the same price. As expected, percentage feed cost savings from using QPM are positively related to increases in the price of soybean meal (Table VI). Interestingly, even at a low price for soybean meal (a soybean meal to regular maize price ratio of 1.5, a case common in Brazil) cost savings for

*For example, a recent Feedstuffs analysis table shows a 23% advantage in protein content for high lysine maize over regular yellow maize (10.1 vs. 8.2%).[22]

Table VI. Sensitivity Analysis Results: Cost Savings and Average QPM Content in Pig and Poultry Feed.

Sensitivity Case	Price Ratio	Meat Pigs	Pregnant + Lactating Sows	Broiler Chickens	Laying Hens
Ingredient Cost Savings (%)					
Base Case		2.94	2.77	2.56	1.91
Sensitivity Analysis Results					
QPM:Regular Maize	1.05	0.32	0.03	0.32	0.10
QPM:Regular Maize	1.10	0.00	0.00	0.00	0.00
Soybean Meal:Regular Maize	1.50	1.43	0.22	0.99	0.55
Soybean Meal:Regular Maize	2.50	4.49	4.80	4.13	3.25
Sorghum:Regular Maize	0.90	2.87	2.72	1.70	1.04
Sorghum:Regular Maize	0.80	0.02	0.00	0.88	0.44
Optimal QPM Content in Ration (kg/ton)					
Base Case	a	778	835	605	593
Sensitivity Analysis Results					
QPM:Regular Maize	1.05	392	414	605	284
QPM:Regular Maize	1.10	0	0	0	0
Soybean Meal:Regular Maize	1.50	487	456	606	588
Soybean Meal:Regular Maize	2.50	764	826	589	613
Sorghum:Regular Maize	0.90	778	832	373	208
Sorghum:Regular Maize	0.80	77	0	275	170

Source: LP model results.

[a]Regular maize price set at $120/ton; price ratios for QPM, soybean meal. and sorghum. relative to regular maize, set at 1.00, 2.00, and 0.95, respectively. See Table II.

pig feed are still above 1% and QPM comprises about 50% of the ration. For high soybean meal prices (a price ratio of 2.5), cost savings are correspondingly higher, especially for pig feed, although the level of QPM in the different feed types does not change much from the base case as other ingredients, including synthetic lysine and maize gluten, are used to supply protein at a lower total cost.

When the price of sorghum drops to $96/ton (a sorghum : maize price ratio of 0.80), virtually all the savings from using QPM in pig feed disappear (Table VI). Historically, the ratio of sorghum to regular maize price in many countries has been approximately 0.9. Model runs with this ratio produce the same cost savings for pig feed as the base model with a ratio of 0.95, which is close to the prevailing ratio in international markets. Savings in chicken feed costs are more sensitive to slight declines in sorghum prices from the base case, although QPM still comprises about 25% of the chicken ration at the lowest sorghum price assumed.

The results obtained in the base model are not sensitive to reductions in synthetic lysine prices (Table VII), and the optimal QPM content in the rations is still high, averaging 800 kg/ton for pig feed and 600 kg/ton for chicken feed even at the low lysine price of $2/kg. Table VII also shows the effect of including QPM in animal feed assuming that it has a 10% higher energy and protein content than regular maize. In this case, cost savings would be much higher than in the base case, averaging over 9.4% for pig feed. In the specific case of starter pig feed, cost savings with QPM are $19.94/ton (11.2%). This is the only case in which

QPM could command a price premium higher than 10% and still comprise over 50% of the ration at some pig growth stages. The average QPM to regular maize price ratio could be as high as 1.14, and pig feed producers would still use QPM in the proportions shown in Table VII. It should be emphasized, however, that these results correspond to potential situations in which QPM would not only have greater lysine and tryptophan contents but also greater overall protein and energy than regular maize, making it truly superior as a feedstuff, especially for pig feed. This may depend not only upon the advances that can be made in QPM breeding but also upon the specific germplasm used in developing different QPM materials, as content of protein and other nutrients wili vary with different germplasm used.

Finally, when sorghum, molasses, and tallow are dropped from the list of available ingredients and vegetable oil is added as energy supplement the savings from having QPM in pig and chicken feed are increased from the base model results (note that relative prices remain as in the base case). Ingredient cost savings are as high as 4% for starter pigs and 2.8% for growing broilers. This

Table VII. Sensitivity Analysis Results: Cost Savings and Average QPM Content in Pig and Poultry Feed.

	Cost Savings		QPM in Feed
	$/ton	%	(kg/ton)
Base Case[a]			
Meat Pigs	4.38	2.94	778
Pregnant and Lactating Sows	3.86	2.77	835
Broilers	4.14	2.56	605
Layers	2.72	1.91	593
Synthetic Lysine Price at $2/kg			
Meat Pigs	3.59	2.42	798
Pregnant and Lactating Sows	3.67	2.63	838
Broilers	3.65	2.27	578
Layers	2.37	1.67	592
10% Higher Protein and Energy Content for QPM			
Meat Pigs	14.01	9.41	668
Pregnant and Lactating Sows	11.63	8.33	675
Broilers	8.41	5.20	542
Layers	6.25	4.39	512
Changes in Available Ingredients[b]			
Meat Pigs	5.19	3.42	814
Pregnant and Lactating Sows	4.99	3.53	797
Broilers	4.64	2.86	650
Layers	1.82	2.60	635

Source: LP model results.

[a]Synthetic lysine price at $3/kg; total energy and protein content equal for QPM and regular maize; sorghum, molasses. and tallow included and vegetable oil excluded as available ingredients.

[b]Sorghum, molasses, and tallow dropped fmm and vegetable oil added to list of available ingredients.

result indicates that as the number and type of ingredients available for energy and/or protein change the savings from having QPM available will also vary.

IMPLICATIONS FOR THE POTENTIAL OF QPM AS A FEED INGREDIENT

Several general conclusions can be drawn from these results that have implications for both breeding programs and potential QPM producers and users. QPM has the potential to produce modest but important costs savings to both pig and poultry feed producers. The savings potential is greater in the case of pig feed because of the different nutritional requirements of chickens and pigs and QPM's greater content of lysine, which is more important in pig nutrition.[§]

Although this study assumes no phenotypic differences between QPM and regular maize, there is evidence that storage problems are still present. According to Brazilian farmers in the state of Minas Gerais, white QPM (BR-451) left in the field (a form of storage) suffered substantial damage in 1991, mainly caused by a poor husk cover, which invites higher rates of weevil infestation than other maize varieties.[23] This suggests that breeding in new QPM materials should concentrate on improving husk cover and maintaining or improving current grain yields. This could be accomplished with relatively small research programs oriented for testing and adaptation of materials developed at CIMMYT. As for production costs, because average yields of new QPM materials are identical to those of regular maize hybrids, it is not expected that yield differences will create any contrast in production costs for QPM compared to regular maize. Further, QPM varieties and hybrids have no special production requirements, so production costs per ton should be similar and reflect only small differences in seed price.

Interviews with feed producers indicated some interest in QPM for the feed industry in some Latin American countries. Integrated feed producers in Brazil find QPM attractive as a substitute for synthetic lysine and soybean meal, especially in pig feed. In El Salvador, poultry producers, who are mostly integrated into feed production, are concerned about the reliability of their grain sources, especially imported yellow maize. They have shown interest in a yellow QPM to be produced under contract with the poultry feed industry. This would ensure domestic suppliers of yellow quality protein maize and. at the same time, potentially reduce imports of soybean meal and synthetic lysine. Feed producers in both Brazil and El Salvador were willing to pay a small premium for QPM if produced in substantial quantities. As shown above, however, total cost savings to the feed industry are sensitive to the QPM to regular maize price ratio. Even modest price premiums would wipe out any cost advantage and hence reduce interest in QPM as a feed ingredient.

The greatest potential problem for QPM as a commercial feed ingredient is the fact that QPM and regular maize are physically indistinguishable. Most commercial feed producers in developing countries do not have the technology to perform amino acid tests of the ingredients they receive. Thus, the challenge in this regard seems to he that a genetic marker, a chemical test, or a mechanical system should be developed so that a practical method for identification of QPM is available at a low cost. Once it is identified, QPM could be handled as a special grade of maize and stored separately from regular maize in feed mill silos. Contracting maize farmers to produce QPM for the feed industry, or promoting QPM production by pig growers, could be alternatives to dealing with the identification problem. If farmers produce only QPM (and no regular maize) and use it to feed their own pigs, no grain would leave the farm and the identification problem disappears. In this case, care would be necessary only to ensure the availability of good-quality QPM seed every year to preserve the genetic purity of the materials, as the Opaque-2 gene is recessive and can be easily lost by outcrossing or other means of seed contamination. This solution may be feasible in Brazil, where the contracting of pig production by large agribusinesses is common and farmers are used to purchasing improved maize seed every crop season. Overall, practical methods for determining the lysine and tryptophan content of maize would be necessary if the commercial feed industry is to use QPM in significant quantities.

A key production factor determining the economic potential of QPM as an animal feed in a given country or region is the existence of a small but active QPM program capable of developing locally adapted QPM varieties and hybrids. A modest research program for testing QPM materials and adapting them to local conditions should be sufficient in many countries. Breeding priorities should emphasize husk cover improvement, and maintaining or improving yield potential. Once materials are developed, effective promotion is crucial for their timely and rapid diffusion, especially because there may not be any price incentives offered by the commercial feed sector. One way to promote QPM materials is biological trials with pigs and chickens to show its superior performance over regular maize. This may also be beneficial even for subsistence maize farmers because in many countries these farmers also raise pigs and chickens for home consumption using maize as the main (and in some cases the only source of) feed. Another important factor is the need to maintain the purity of QPM seed because of the recessive nature of the Opaque-2 gene. Ideally, seed should be renewed every crop season to reduce contamination, even if open pollinated varieties are used. Therefore, timely and easy access to quality seed by farmers is important. Finally, the models developed in this study can be used to estimate the economic potential for QPM as a feed ingredient in any country or region, with relatively simple modifications to reflect local conditions related to relative prices and availability of special ingredients.

§The other main difference between QPM and regular maize, the leucine to isoleucine ratio, not explored in this study. The lower level of this ratio is claimed to be an important nutritional advantage of QPM over regular maize. However, due to the nature of cost minimization with linear programming QPM was penalized for having a lower leucine content, as ingredients with higher nutrient levels are preferred. If these qualitative characteristics are incorporated in the models, the economic potential of QPM as a feedstuff could be enhanced.

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US Overseas Promotion Programs for Peanuts: An Examination of Trade and Market Development

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This study gives an overview of the US government market promotion programs for peanuts as well as the US trading position in international peanut markets. FAS data on the Cooperator (CMDP), Targeted Export Assistance and Market Promotion Programs (TEA/MPP) were examined to identify how program expenditures have been allocated among regions and activities. Analysis shows that during the 1986–1991 period, three-quarters of CMDP, TEA. and WPP funding for peanuts was directed to the European Community, the largest US peanut export market. Moreover, branded consumer promotion has accounted for a large percentage of program expenditures worldwide.
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The United States is one of the world's largest exporters of peanuts and peanut products. It has accounted for an average one-third of global trade in peanuts during the last decade,' while representing less than 10% of the world's total peanut production. Roughly one-half of the small percentage of global output that

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