COMPARISON OF VITREOUS AND SOFT ENDOSPERM HIGH-LYSINE AND COMMON MAIZE IN DIETS FOR GROWING RATS AND PIGS [1/]

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Summary

Three experiments with growing rats and two with pigs were carried out to evaluate a vitreous endosperm variety of high-lysine maize and to compare its nutritive value with that of a soft endosperm opaque-2 and a common maize. The results indicate that the vitreous endosperm variety has a significantly lower nutritive value than normal soft endosperm opaque-2 maize when fed to growing rats and a slight but nonsignificant inferiority to soft endosperm opaque-2 maize when fed to growing pigs. Chemical analyses and feeding trials indicate that lysine is the first limiting amino acid in the vitreous endosperm variety as compared to the soft endosperm opaque-2 samples.

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Introduction

The nutritive value of opaque-2 maize has been extensively studied in humans (Bressani, 1966; Clark, 1966), pigs (Cromwell, Pickett and Beeson, 1967; Sihombing, Cromwell and Hays, 1969; Gallo, Maner and Corzo, 1969; Maner et al., 1971), chickens (Cromwell et al., 1968; Jarquin, Albertazzi and Bressani, 1970) and rats (Mertz, Bates and Nelson, 1964; Mertz et al., 1965; Bressani, Elias and Gomez-Brenes, 1969; Maner et al., 1971). The superior protein quality of opaque-2 is associated with a better balance of amino acids than is found in common maize and notably to a change in the proportion of protein fractions in the endosperm, leading to a higher content of lysine and tryptophan (Mertz, Bates and Nelson, 1964). The softness of its endosperm makes the opaque-2 kernel more susceptible to weevil attack than the common maize kernel and practical difficulties may be encountered during storage of the grain for normal use in human and animal nutrition. In addition, low consumer acceptance has been identified as one important barrier to the rapid expansion of the consumption of opaque-2 maize, primarily due to its floury texture. Homemakers reported differences between opaque-2 and ordinary flint type maizes in preparation and cooking quality (Andersen, 1971). For these reasons, agronomic programs have taken into consideration the selection of vitreous endosperm maize with the protein quality of the opaque-2 maize.

The Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) in Mexico has obtained a high-lysine variety with a vitreous endosperm which has been further selected by the Maize Program of the Centro Internacional de Agricultura Tropical (CIAT); its genetic designation is (Veracruz 181 x Ant. Gpo. 2) x Ven 1. The purpose of this investigation was to study the

nutritive value of a vitreous endosperm high-lysine variety (VE-21) and to compare its nutritive properties with that of Colombian soft endosperm opaque-2 (H-208) and common maize.

Experimental Procedure

Experiment 1. Thirty-two weanling rats of the Sprague-Dawley strain were randomly alloted within weight and sex to four experimental groups. The experimental diets were randomly assigned to each of these groups. The composition of the diets is shown in table 1. Diets 1 and 2 were calculated isoproteic (8.6% crude protein) based on the nitrogen content of ground whole kernel samples. All the protein and energy of these two diets were supplied by whole kernels of Colombian opaque-2 (H-208) or of vitreous high-lysine variety (VE-21). Diets 3 and 4 were also isoproteic (7.1% crude protein) based exclusively on the endosperm of the opaque-2 (H-208) and the vitreous variety (VE-21), respectively. Weight changes as well as feed consumption were obtained two times each week during the 28-day experimental period. Rats were individually housed in cages with raised screen bottoms. Food and water were given ad-libitum.

Experiment 2. Kernels of the vitreous high-lysine maize (VE-21) were classified according to hardness (vitreous and semi-vitreous). The nutritive value of these two samples were compared with that of soft-endosperm opaque-2 (H-208) and a cross between the vitreous variety and the opaque-2 (VE-21 x H-208). Twenty-five growing rats were randomly alloted within weight and sex to five experimental groups. The composition of the experimental diets is shown in table 2. A methionine supplemented casein-cassava starch control diet was also included in the study. All other experimental procedures were similar to those described in Experiment 1.

Experiment 3. The aim of this experiment was to determine the effect of amino acid supplementation to diets based on vitreous high-lysine kernels (VE-21) and to compare this effect with a diet based on soft-endosperm opaque-2 (H-208) maize. Replacement of a soft endosperm opaque-2 maize (diet 1) by the vitreous variety (diet 2) was made on a weight basis, so that 92.0 per cent of each diet was supplied by ground whole kernels of the opaque-2 or vitreous maize. Tryptophan and/or lysine were added to the basal vitreous high-lysine maize diet in the proportions of 0.05 and 0.1 percent (diets 3-5), respectively. The composition of the experimental diets is shown in table 3. A total of 30 weanling rats were randomly alloted within weight and sex to five experimental groups. The experimental diets were randomly assigned to each of these groups. Experimental procedure was similar to that described in Experiment 1.

Experiment 4. The purpose of this experiment was to compare the nutritive value of vitreous high-lysine kernels with that of opaque-2 (H-208) and common maize in the growing pig (18-50 kg). A positive control common corn-soybean meal diet supplying 16 percent crude protein and a negative control common corn-soybean meal isoproteic with the all maize diets were also included. The composition of the experimental diets is shown in table 4. Forty weaned pigs with an average body weight of approximately 18 kg were randomly distributed by weight and sex (1 castrated male and 3 females) into ten experimental groups, so that each treatment was fed to two replications of four pigs each. Body weight changes and feed consumption were recorded at weekly intervals throughout a 63-day experimental period. Feed and water were given ad libitum. Feed was supplied in automatic feeders.

Experiment 5. This experiment was undertaken in order to compare the nutritive value of the vitreous high-lysine maize to that of the Colombian opaque-2 (H-208) maize in diets for growing pigs at two levels of crude protein. Replacement of opaque-2 maize by vitreous high-lysine maize was made on a weight basis. Diets 1 and 2 contained opaque-2 or vitreous high-lysine maize, respectively, as the only sources of energy and protein; diets 3 and 4 included 9.0 percent soybean meal to supply approximately 12-13 percent total protein in the diet. The composition of the experimental diets is shown in table 5. Twenty-four weaned pigs with an average body weight of approximately 19 kg were randomly distributed by weight and sex into eight groups to provide two replications of three pigs each per treatment. The experimental period was 40 days. The experimental procedure was similar to that described in Experiment 4.

Results and Discussion

The results of Experiment 1 (table 6) clearly demonstrate that whole kernels and endosperms of the opaque-2 (H-208) maize have higher nutritive value for rats than whole kernels and endosperms, respectively, of the vitreous high-lysine maize, as evidenced by the significantly ($P<0.05$) improved body weight gains and protein efficiency ratio (PER). Feed efficiency while not significantly ($P>0.05$) different in the case of whole kernels appears also to be generally better for the opaque-2. These results suggest that the selection of vitreous high-lysine maize has not yet reached the protein-quality of the Colombian soft endosperm opaque-2 (H-208).

Feeding trials with VE-21 maize samples obtained from the visual classification of the kernels into vitreous and semi-vitreous categories

showed that semi-vitreous kernels have a nutritive value similar to soft endosperm opaque-2. Performance of rats fed the vitreous kernels or the VE-2 x H-208 cross was slightly inferior, though not significantly ($P>0.05$) different, to that of rats fed the softer endosperm opaque-2 kernels. Feed efficiency values of rats fed the vitreous high-lysine were significantly ($P<0.05$) lower than those of rats fed the opaque-2 maize. Protein efficiency ratios of rats fed the vitreous high-lysine based diets were slightly ($P>0.05$) lower than those fed the opaque-2 diet.

Since the high nutritive value of soft endosperm opaque-2 kernels is known to be the result of a higher lysine and tryptophan content, these results suggest that the lower performance of rats fed the vitreous high-lysine kernels could be the result of lower than expected concentrations of these two amino acids in the vitreous variety. Lysine supplementation to vitreous maize diets produced significantly ($P<0.05$) better performance than the unsupplemented vitreous maize diet and results similar to that of rats fed the soft endosperm opaque-2 diet (table 8). Tryptophan supplementation alone did not significantly ($P>0.05$) improve the nutritive value of vitreous high-lysine kernels. The combined addition of lysine and tryptophan produced essentially the same results as those of lysine addition alone, suggesting that lysine es the more limiting amino acid in the vitreous variety (VE-21) as compared to the soft-endosperm opaque-2.

Chemical analyses (table 9) confirmed the results obtained in the previous experiment. The tryptophan determination was made following the method of Opienska-Blauth et al. (1963) as modified by Villegas and Mertz (1971). The lysine determination was made according to the procedure described by Villegas and Mertz (1971). Lysine content of soft endosperm

opaque-2 was consistently higher than that of vitreous high-lysine variety; the difference in tryptophan contents was not as pronounced as that of lysine.

The results of experiment 4 (table 10) showed that the growth rate and efficiency of feed conversion of pigs fed a diet based on vitreous high-lysine maize were not significantly ($P>0.05$) different from those fed the diet based on soft endosperm opaque-2. The performance of both groups was significantly ($P<0.01$) better than that of pigs fed common maize, similar ($P>0.05$) to the negative control (9.6 percent crude protein, common maize + soybean meal) and significantly ($P<0.01$) lower than the positive control group (16 percent crude protein). Feed efficiency was similar for the animals fed the negative control, opaque-2 and vitreous high-lysine diets, but lower ($P<0.05$) than that of animals fed the positive control diet. The results of experiment 5 (table 11) confirmed that soft endosperm opaque-2 and vitreous high-lysine maize have similar nutritive value for growing pigs when fed as the only energy and protein source as well as when they are supplemented with soybean meal.

Results of the biological evaluation with rats suggest that vitreous high-lysine kernels (VE-21) have a significantly lower nutritive value than the opaque-2 (H-208) maize. However, feeding trials with pigs showed similar nutritive value for both maizes in diets for growing pigs. Protein and lysine requirements for growing rats and pigs are different (NRC 1968, 1972) and discrepancies of the results obtained with the two species appear to be due, at least partially, to the effect of the experimental diets on the fulfillment of their normal dietary protein and lysine requirements. Chemical analyses and the effect of

lysine supplementation to diets based on vitreous high-lysine kernels suggest that this amino acid is the first limiting factor responsible for the lower nutritional value of the vitreous high-lysine variety as compared to the Colombian opaque-2 (H-208), in the growing rat.

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Table 1. Percentage composition of the diets for rats used in Experiment 1

Ingredient	Experimental diets			
	Whole kernels		Endosperm	
	Opaque-2	Vitreous high-lysine	Opaque-2	Vitreous high-lysine
	1	2	3	4
Maize whole kernels	92.0	84.4	-	-
Maize endosperms	-	-	92.0	82.6
Cassava starch	-	7.6	-	9.4
Vitamins [a/]	2.0	2.0	2.0	2.0
Minerals [b/]	4.0	4.0	4.0	4.0
Corn oil	2.0	2.0	2.0	2.0
Protein content (%) in				
Whole kernels [c/]	9.4	10.2	-	-
Endosperms [c/]	-	-	7.7	8.6
Diets	8.6	8.6	7.1	7.1

a/ Vitamin Diet Fortification mixture; Nutritional Biochemical Corporation, Cleveland, Ohio.

b/ Salt Mixture USP XIV, Nutritional Biochemical Corporation, Cleveland Ohio.

c/ By micro-Kjeldahl determinations (N x 6.25).

Table 2. Percentage composition of the diets for growing rats used in Experiment 2 [a]

Ingredient	Experimental diets				
	Control [b]	Vitreous high-lysine			
		Semi-vitreous	Vitreous	Opaque-2	Vitreous high-lysine x opaque-2
Casein	9.4	-	-	-	-
Maize kernels	-	92.0	86.5	88.7	86.5
Cassava starch	82.6	-	5.5	3.3	5.5
Vitamins [c]	2.0	2.0	2.0	2.0	2.0
Minerals [c]	4.0	4.0	4.0	4.0	4.0
Corn oil	2.0	2.0	2.0	2.0	2.0
Protein [d] content (%) in					
Maize kernels	-	9.3	9.9	9.7	9.9

a/ Diets were calculated isoproteic to contain 8.6 percent of crude protein (N x 6.25).

b/ DL-methionine (0.2%) was added to the control diet.

c/ The vitamin and mineral mixtures were the same as in table 1.

d/ By micro-Kjeldahl determinations (N x 6.25).

Table 3. Percentage composition of the diets for rats used in Experiment 3

Ingredient	Experimental diets	
	1 Opaque-2	2-5 [a] Vitreous high-lysine
Opaque-2	92.0	-
Vitreous high-lysine	-	92.0
Vitamins [b]	2.0	2.0
Minerals [b]	4.0	4.0
Corn oil	2.0	2.0

a/ Tryptophan (Trp) and Lysine (Lys) were added to basal diet as follows: Diet 2: 0% Trp, 0% Lys; diet 3: 0.05% Trp; diet 4: 0.1% Lys; diet 5: 0.05% Trp, 0.1% Lys.

b/ The vitamin and mineral mixtures were the same as in Table 1.

Table 4. Percentage composition of experimental diets for growing pigs used in Experiment 4

Ingredient	Diets				
	1 Control 16% CP	2 Control 9.6% CP	3 Common Corn	4 Opaque-2	5 Vitreous high-lysine
Common corn	80.75	45.45	96.25	-	-
Opaque-2	-	-	-	96.25	-
Vitreous high-lysine	-	-	-	-	96.25
Soybean meal	15.75	10.00	-	-	-
Sucrose	-	40.85	-	-	-
Bone meal	2.00	2.50	2.50	2.50	2.50
Calcium carbonate	0.50	0.20	0.20	0.20	0.20
Vitamin premix[a/]	0.60	0.60	0.60	0.60	0.60
Mineral premix[b/]	0.40	0.40	0.40	0.40	0.40
Calculated nutrients					
Crude protein, %	16.0	9.6	9.6	9.6	9.6
Calcium, %	0.68	0.65	0.63	0.63	0.63
Phosphorus, %	0.42	0.46	0.40	0.40	0.40

a/ The vitamin and antibiotics premix contained, grams per 100 kg of diet: vitamin A and D_3 (A = 750,000 U.I./g, D = 150,000 U.I./g), 0.2; vitamin A (750,000 U.I./g), 0.2; vitamin E (500 U.I./g), 2.0; riboflavin, 0.4; niacin, 3.0; calcium pantothenate, 1.2; choline chloride, 200.0; vitamin B_{12}, 0.002; Aurofac-40 (88 g/kg), 50.0; corn or cassava starch, 43.0.

b/ The mineral mixture contained, grams per 100 kg of diet: manganese sulfate ($MnSO_4.H_2O$ = 32.5% Mn), 12.0; copper sulfate ($CuSO_4.5H_2O$ = 25.5% Cu), 4.0; zinc oxide (ZnO = 80% Zn), 8.0; ferrous sulfate ($FeSO_4.7H_2O$ = 20.1% Fe), 25.0; iodinated salt, 451.0.

Table 5. Percentage composition of the diets for growing pigs used in Experiment 5

Ingredient	Experimental diets			
	1 Opaque-2	2 Vitreous high-lysine	3 Opaque-2 + SBM	4 Vitreous high lisine + SBM
Opaque-2 (10.63%) [a/]	95.7	-	86.7	-
Vitreous high-lysine (9.44%)	-	95.7	-	86.7
Soybean meal, SBM (48.0%)	-	-	9.0	9.0
Vitamin premix [b/]	0.3	0.3	0.3	0.3
Mineral premix [b/]	0.5	0.5	0.5	0.5
Bone meal	3.5	3.5	3.5	3.5
Calculated protein content				
Crude protein, %	10.2	9.0	13.5	12.5

a/ Numbers in parentheses indicate the crude protein content.

b/ The vitamin and mineral mixtures were the same as used in experiment 4.

Table 6. Results of the biological evaluation of vitreous high-lysine and soft endosperm opaque-2 maize in rats. Experiment 1 [a/]

% Crude Protein, diet	Diet	Total gain weight, g	Feed/gain	PER
	Whole kernels			
8.6	Soft opaque-2 (H-208)	94.6[b]	4.38[b]	2.67[b]
8.6	Vitreous high-lysine (VE-21)	64.3[c]	5.21[b]	2.25[c]
	Endosperms			
7.1	Soft opaque-2 (H-208)	39.5[d]	7.86[c]	1.78[d]
7.1	Vitreous high-lysine (VE-21)	25.9[e]	10.39[d]	1.40[e]

a/ Each value is the mean of 8 rats, obtained during a 28-day experimental period. Overall average initial body weight: 48.3 ± 0.71.

b, c, d, e: All means in the same column with a common superscript are not significantly different ($P>0.05$).

Table 7. Results of the biological evaluation of vitreous high-lysine maize classified according to the hardness of endosperm. Experiment 2[a/]

Diet	Total gain weight, g	Feed/gain	PER
Control-casein	118.7[c]	3.31[c]	3.30[c]
Opaque-2 (H-208) [b/]	86.2[d]	4.43[d]	2.53[d]
Vitreous high-lysine (VE-21)			
Vitreous	76.4[d]	5.08[e]	2.34[d]
Semi-vitreous	85.5[d]	4.74[d,e]	2.37[d]
VE-21 x H-208	80.4[d]	4.70[d,e]	2.47[d]

a/ Each value is the mean of 5 rats, unless otherwise indicated, obtained during a 28-day experimental period. Overall average initial body weight: 54.7 ± 0.5 g.

b/ Means of 4 rats.

c,d,e: All means in the same column with a common superscript are not significantly different ($P > 0.05$).

Table 8. Effect of lysine and tryptophan supplementation on the nutritive value of vitreous high-lysine kernels in rats. Experiment 3[a/,b/]

% Protein in diet	Diet	Total gain weight, g	Feed/gain	PER
9.8	Opaque-2 (H-208)	90.5[c]	4.50[c]	2.28[c]
8.7	Vitreous high-lysine (VHL) (VE-21)	69.3[d]	5.17[d]	2.24[c]
8.7	VHL + Tryptophan (Trp)	66.4[d]	5.29[d]	2.18[c]
8.7	VHL + Lysine (Lys)	89.0[c]	4.52[c]	2.56[d]
8.7	VHL + Trp + Lys	91.4[c]	4.49[c]	2.56[d]

a/ Each value represents the mean of 6 rats, obtained during a 28-day experimental period. Overall average initial body weight: 52.4 ± 0.41 g.

b/ Lysine and tryptophan were added as L-forms at levels of 0.1 and 0.05 percent, respectively.

c,d,e: All means in the same column with a common superscript are not significantly different ($P>0.05$).

Table 9. Lysine and tryptophan contents of endosperms of common, opaque-2 (H-208) and vitreous high-lysine (VE-21) maize

Maize endosperm	Protein %	% Tryptophan in		% Lysine in	
		Sample	Protein	Sample	Protein
Common	9.69	0.06	0.63	0.21	2.17
Vitreous high-lysine	8.19	0.09	1.04	0.30	3.67
Opaque-2	7.75	0.10	1.29	0.34	4.39

Table 10. Comparative nutritive value of common, opaque-2 and vitreous high-lysine maize in growing pigs. Experiment 4 [a]

Parameter	Control 16% CP	Control 9.6% CP	Common maize	Opaque-2	Vitreous high-lysine
Number of pigs/group	7 [b]	7 [b]	7 [b]	8	8
Initial body weight, kg	18.9	18.6	18.4	18.7	18.7
Total body wt. gain, kg	39.0[c]	32.4[d]	10.4[e]	30.3[d]	27.3[d]
Feed efficiency	2.67[c]	3.55[d]	5.81[e]	3.52[d]	3.51[d]

a/ Experimental period: 63 days. Overall initial average body weight: 18.7 ± 0.4 kg.

b/ One animal from each group was eliminated during the first week of the experimental period due to feet and leg problems not related to treatment.

c, d, e: All means in the same row with a common superscript are not significantly different ($P > 0.05$).

Table 11. Performance of growing pigs fed Colombian opaque-2 (H-208) and vitreous high-lysine maize, at two protein levels. Experiment 5 [a]

Parameter	Experimental diets			
	Opaque-2	Vitreous high-lysine	Opaque-2 + SBM [b]	Vitreous high-lysine + SBM [b]
Protein content in diet, % [c]	10.2	9.0	13.5	12.5
Number pigs/group	6	5	6	6
Avg initial body wt., kg	19.6	19.7	19.5	19.8
Avg final body wt., kg	37.0	35.5	43.6	45.0
Avg daily gain, kg	0.435[e]	0.395[e]	0.603[d]	0.630[d]
Feed efficiency	3.54[e]	3.98[e]	2.69[d]	2.81[d]

a/ Experimental period: 40 days.

b/ SBM: soybean meal

c/ Protein contents of opaque-2 and vitreous high-lysine were 10.63 and 9.44 percent, respectively, as determined by micro-Kjeldahl.

d, e: All mean in the same row with a common superscript are not significantly different ($P>0.05$).