APPENDIX V-p

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Nutritional Value of Maize for Young Children

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Endosperm and whole kernel maize meals from three different 3-way hybrids were made available by Dr. David Glover of Purdue University. A Sugary 2 - Opaque 2 variety was developed to overcome some of the acceptability problems of Opaque 2 but studies by Dr. Helen Clark suggested inferior digestibility of its carbohydrates by adults. The digestibility and utilization of these two high-lysine, high-tryptophan variaties was compared with that of normal maize, both as the commonly consumed whole kernel meal and as endosperm meal, in recovered malnourished children 12 to 25 months of age. It is currently fashionable to accept the claim that if children eat enough of their staple food to satisfy most of their energy needs, not an easy task, they will automatically meet their protein requirements. The large amounts of maize that were fed in these studies allowed us to examine this hypothesis.

The three endosperm meals were fed consecutively to six subjects in six different sequences, preceded and followed by casein-based diets. The same protocol was followed for whole kernel meals. Four children participated in both studies. All diet periods were of nine days, with 3 for adaptation and 6 for metabolic collections. All diets were isocaloric and isonitrogenous for each child. Intakes were 100 to 125 Kcal/kg/day and had previously been demonstrated to support steady weight gain. Protein represented 6.4% and fat 10% of energy in all diets. Minerals and vitamins were supplied to meet or exceed recommended allowances.

Table 1 lists protein content of the six meals, the amounts for 100 Kcal of diet so that protein represented 6.4% of calories, and the resulting percentages of calories from the maize meals. Soy and cottonseed oils (80:20) were added to complete 10% fat calories, cane sugar to complete the desired total calories. The lower protein content of the endosperms left little room for sugar. In the casein diets the same vegetable oils provided 10% of calories and a mixture of corn starch, dextrimaltose and sugar 83.6% of calories. The last column lists fecal energy as a percentage of intake from the six maize diets and their respective casein control diets. Energy losses, particularly from endosperm diets, were much higher than from the control diets and seemed related in part to the amounts of maize meal that had to be fed.

Table 2 summarizes results from the endosperm studies. Fecal wet and dry weights and energy were slightly higher from Sugary 2 - Opaque 2 but the small "n" prevented statistical significance. All were significantly higher than during the control periods, as was fecal fat. Apparent absorption of

nitrogen was notably lower than the control, as was apparent retention, particularly from normal maize, when it was only 40% of control values. Even if these children had consumed 100% of energy needs from maize and the same percent retentions had held, they still would have been far short of meeting their protein needs, represented quite closely by the retentions from casein.

Table 3 summarizes results from whole kernel meals. Differences between varieties in fecal wet and dry weights, fat and energy, were not significant, though slightly favoring normal maize. Apparent absorption of nitrogen was similar from all three, but the apparent retention from normal maize, as expected, was lower, but not as strikingly as from endosperm meal. If these children had consumed 90+% of diet energy as Opaque 2 or 85+% as Sugary 2 - Opaque 2, and the same percent nitrogen retentions had held, they could have conceivably satisfied their protein needs. With normal maize it would have been impossible, requiring over 108%.

Table 4 compares results of all endosperm with all whole kernel meals. It demonstrates the clear superiority of the latter, particularly in protein and energy digestibility and in protein quality. The endosperm diets contained considerably more maize, which may explain part of the difference in energy digestibility of the diets. We have no explanation for the superior digestibility of whole kernel protein, other than the possible poor digestibility of zein, which represents a much greater percentage of protein in endosperm meals.

Table 5 relates presumably absorbed lysine to nitrogen retention from the six meals. The higher lysine content of the whole kernel meals and the lower lysine content of normal maize are evident and determine the intakes. To arrive at figures for absorbed lysine, the digestibility of each protein by each child was arbitrarily applied. For all the individual values from each study, endosperm or whole kernel, there was a highly significant correlation between presumably absorbed lysine and apparent nitrogen retention. There was a further superiority to the whole kernel meals that might be due to the smaller losses of energy in the feces. The figures for lysine from casein are approximations and are not included in the regressions as lysine does not limit casein utilization. For maize, of course, tryptophan may be as limiting as lysine, or even more so.

For those concerned with the nutrition and health of the millions of children who may have to, or already, depend on maize as their sole source of protein, the superiority of whole kernel over endosperm meals and the obvious advantages of the opaque and sugary genes must not be lost sight of, as unfortunately seems to be happening.

Table 1

Protein content of six maize meals and the amounts and calories from each meal that had to be fed for each 100 Kcal of a diet with 6.4% of energy as protein, all from maize. Last column represents fecal energy losses from the six diets and from the preceding and following casein control diets.

MAIZE MEAL		% Protein	100 Kcal Diet (6.4% Protein) Grams	Kcal	Fecal Energy % Intake
Endosperm	Normal	7.1	22.7	83.2	16.5 ± 4.0
	O_2-O_2	6.5	24.8	91.2	16.1 ± 2.9
	S_2-O_2	7.1	22.6	82.1	18.4 ± 1.3
(Casein Diet)					(5.4 ± 1.4)
Whole Kernel	Normal	8.3	19.4	73.2	11.7 ± 0.9
	O_2-O_2	8.6	18.6	68.6	13.1 ± 1.4
	S_2-O_2	9.0	17.7	67.2	13.5 ± 1.4
(Casein Diet)					(4.7 ± 0.6)

Fecal Energy: Endosperm>Whole Kernel, $P<0.001$.

Table 2

Fecal wet and dry weights, fecal fat (as % of dry weight and as % of intake), and fecal energy (as % of intake) of six children consuming three different maize endosperm meals or a casein control diet. Apparent absorptions and retentions of nitrogen, as a percentage of intake, are also listed.

ENDOSPERM MEAL	Fecal					N Balance % of Intake	
	Wet Wt g/day	Dry Wt g/day	Fat % d.w.	Fat % Int.	Kcal % Int.	Abs.	Ret.
Normal	154 ±73	36 ±11	5.8 ±0.8	20.3 ±3.5	16.5 ±4.0	64.1 ±11.4	15.1 ± 8.9
O_2-O_2	159 ±82	37 ±11	5.3 ±1.3	18.3 ±4.4	16.1 ±2.9	69.6 ± 6.3	22.8 ± 5.5
S_2-O_2	180 ±57	41 ± 8	6.2 ±2.7	21.5 ±9.2	18.4 ±1.3	66.7 ± 5.1	24.8 ± 8.0
(Casein)	104* ±49	13* ± 3	9.4 ±5.0	11.6* ±7.3	5.4* ±1.4	81.8* ± 5.2	37.0* ±14.2

* Significantly different from all endosperm meals, $P<0.05$

Table 3

Fecal wet and dry weights, fecal fat (as % of dry weight and as % of intake) and fecal energy (as % of intake) of six children consuming three different maize whole kernel meals or a casein control diet. Apparent absorptions and retentions of nitrogen, as a percentage of intake, are also listed.

WHOLE KERNEL MEAL	Fecal					N Balance % of Intake	
	Wet Wt g/day	Dry Wt g/day	Fat % d.w.	Fat % Int.	Kcal % Int.	Abs.	Ret.
Normal	133 ±27	29 ±5	4.8 ±1.4	12.6 ± 3.6	11.7 ±0.9	73.1 ±1.9	26.8 ±4.6
O_2-O_2	158 ±23	31 ±4	6.5 ±0.8	18.8 ± 3.8	13.1 ±1.4	70.6 ±4.3	30.1 ±8.3
S_2-O_2	154 ±34	33 ±3	5.4 ±3.5	16.3 ±10.6	13.5 ±1.4	74.0 ±4.0	31.6 ±9.7
(Casein)	102* ±26	13* ±2	7.1 ±2.9	7.8* ± 2.9	4.7* ±0.6	83.5* ±2.5	39.6* ±9.1

* Significantly different from all whole kernel meals, $P<0.05$

Table 4

Comparison of results obtained with all endosperm meals combined with those obtained with all whole kernel meals, also combined.

MAIZE MEALS	Fecal					N Balance % of Intake	
	Wet Wt g/day	Dry Wt g/day	Fat % d.w.	Fat % Int.	Kcal % Int.	Abs.	Ret.
Endosperm	164 ±71	38 ±10	5.8 ±1.6	20.0 ±5.7	17.0 ±2.7	66.8 ±7.6	20.9 ±7.5
Whole Kernel	148* ±28	31* ± 4	5.6 ±1.9	15.9 ±6.0	12.8† ±1.2	72.6† ±3.4	29.5** ±7.5

* $P<0.05$ ** $P<0.01$ † $P<0.001$

Table 5

Amount of lysine ingested and presumably absorbed by infants consuming maize meals, related to apparent nitrogen retentions. Values for casein control diets are approximations and are not included in the regressions.

MAIZE MEALS		Lysine % of Prot.	Lysine mg/kg/day Intake	Lysine mg/kg/day Abs'n	N mg/kg/day Ret'n
Endo-sperm	Normal	2.2	41 ± 5	26 ± 6	35 ± 47
	O_2-O_2	3.4	63 ± 7	43 ± 3	68 ± 23
	S_2-O_2	4.0	74 ± 9	49 ± 6	75 ± 31
(Casein Diet)				(100+)	(112 ± 52)
Whole Kernel	Normal	2.9	54 ± 5	39 ± 4	81 ± 15
	O_2-O_2	4.0	77 ± 7	54 ± 8	93 ± 31
	S_2-O_2	4.3	81 ± 7	60 ± 8	97 ± 35
(Casein Diet)				(100+)	(121 ± 33)

Linear regressions of N retention on absorbed lysine:

Endosperm "r" = 0.74, $P<0.001$; Wh. Kernel "r" = 0.64, $P<0.01$