APPENDIX V-c

PN AAS-570

Nutritional Value of Normal, Opaque-2, and Sugary-2
Opaque-2 Maize Hybrids for Infants and Children.
1. Digestibility and Utilization

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ABSTRACT

The opaque-2 gene increases the lysine and tryptophan contents of maize and its protein quality; the sugary-2 gene improves vitreousness and density but decreases lysine; the double-mutant sugary-2 opaque-2 (Su_2-O_2) has the improved kernel characteristics and an even higher protein quality than opaque-2 opaque-2 (O_2-O_2). Digestibility of energy and protein, and protein quality of Normal, O_2-O_2 and Su_2-O_2, both as endosperm (E) and whole kernel (WK) meals, were studied in eight convalescent malnourished children, 10 to 25 months of age. Diets provided 100-125 Kcal/kg/day, 10% fat, with all of 6.4% protein calories from one of six maize meals or casein. E meals provided 83.2, 91.2 and 82.1% of energy, WK meals 73.2, 68.6 and 67.2% of energy in respective diets. Fecal wet and dry weight and fecal energy were higher when E meals were consumed, probably because of larger amounts of maize in diets. Nitrogen absorption was higher from WK meals (72.6±3.4% of intake) than from E meals (66.8± 7.6%), possibly because of lower zein content. Apparent N retention from E meals (15.1, 22.8 and 24.8% of intake from Normal, O_2-O_2 and Su_2-O_2) was lower than from WK meals (26.8, 30.1 and 31.6% of intake), both lower than from casein (37.0 and 39.6%). For each type of meal (E and WK) there was strong correlation between lysine "absorbed" and N retention, but this was higher from WK at equal lysine intakes. For 50% of children to match N retention from casein, presumably equal to requirement, they would have to consume 203.9, 148 or 122.5% of energy requirement as Normal, O_2-O_2 or Su_2-O_2 E meals, obviously impossible. For WK meals, they would have to consume 108.2, 90.3 or 84.2% of energy as Normal, O_2-O_2 or Su_2-O_2. Despite lower yields,

production of Su_2-O_2 or O_2-O_2 maize specifically for feeding of small children in maize-dependent societies would make a major contribution to their nutrition.

More than 15 years have elapsed since Mertz and his associates reported that the opaque-2 gene produced a change in the distribution of endosperm proteins in maize, and that this resulted in a marked increase in the contents of lysine and tryptophan, the essential amino acids severely limiting in ordinary maize (1). This, along with a decrease in the excessive leucine content and a consequent improvement in the balance between leucine and isoleucine, opened up the possibility of markedly enhancing, through genetic improvement of the locally grown maize, the nutritional status of the many peoples throughout the world who depend heavily on this grain and who suffer from a high incidence of protein malnutrition, pellagra, or both.

The original material was shown to have a markedly increased protein efficiency ratio (PER) in experimental animals (2, 3) and a clearly superior utilization of its protein by human adults (4) and children (5). Subsequently, reports from many parts of the world demonstrated that the incorporation of the opaque-2 gene into local varieties of maize significantly increased the utilization of their proteins by experimental animals, farm animals, and humans. Because most local varieties have proteins of a lower nutritional value than those of the hybrids grown in this country, the contrast with opaque-2 has often been greater (6). In animals (7) and in human adults (8) it has been shown that lysine is still the first-limiting amino acid in opaque-2 maize.

Extensive studies with opaque-2 containing varieties have revealed some undesirable kernel characteristics and relatively low yields, approximately 90% of those from commercial hybrids (9). Although the problem of yield remains a relatively stubborn one, it has been

shown that the kernel characteristics can be altered favorably by the incorporation of other genes. The sugary-2 gene improves kernel vitreousness and density, which should improve acceptability, resistance to ear rot and storage insects, and the dry milling of the grain. Although sugary-2 varieties have a lower lysine content and protein quality than that of opaque-2 (PER's of 1.57 and 2.35 vs. 2.80 for casein), the double-mutant sugary-2 opaque-2 not only has the improved kernel characteristics of sugary-2, but also has a slightly higher protein quality (PER 2.57) than the opaque-2 (9).

Clarke et al compared the nitrogen retention of young men who consumed isonitrogenous amounts of normal, opaque-2 and sugary-2 opaque-2 maize as whole kernel meals at two different levels of nitrogen intake: 5.5 and 4.4 g/day (10). Although both varieties of improved maize were superior at 5.5 g, only the opaque-2 was superior at 4.4 g, and none of the differences were significant. This lesser difference, when compared to the animal results, was attributed to the proportionately higher lysine and tryptophan requirements for growth than for maintenance, and to differences in amino acid composition between the "normal" maize varieties used in the two types of studies. In the studies with young men it was also noted that stool weights, which were high in all the maize studies when compared to rice and wheat studies, were particularly so when the young men consumed the sugary-2 opaque-2 maize[2].

The studies being reported here were carried out for a dual purpose: first, to investigate the energy and protein digestibilities and the protein utilization by infants and children of normal,

opaque-2 containing, and sugary-2 opaque-2 containing hybrids, and second, to determine how well the three varieties could satisfy the protein needs of the same subjects when they provided most of the energy and all of the protein in energy-adequate diets. This last was prompted by the repeated assertions made in recent years that even normal maize can satisfy the protein needs of children when it provides most of the energy in their diets (11). Because maize is consumed as the endosperm meal (dry-milled) in some parts of the world and as the whole kernel meal (wet-milled) in others, all three varieties were studied as both types of meal.

MATERIALS AND METHODS

The maize used in these studies was of the same origins as those used in the studies by Clark et al (10). These were 3-way hybrids of isogenic lines of Normal, opaque-2 opaque-2 (O_2-O_2), and sugary-2 opaque-2 (Su_2-O_2) maize and were each used as whole kernel (WK) and degerminated endosperm (E) meals. Table 1 lists the protein, fat and fiber contents of the six meals in g/100 g meal, and their typical lysine, tryptophan, and leucine contents in g/100 g protein. The endosperm meals were lower in protein, fat and fiber contents than the corresponding whole kernel meals. The proteins of the endosperm meals were lower in lysine and leucine than the corresponding WK meals, but only the Su_2O_2 E meal had a seemingly lower tryptophan content than its WK meal. The Normal meals were both appreciably lower in lysine and tryptophan, and higher in leucine than the counterpart O_2-O_2 and Su_2-O_2 meals. The Su_2-O_2 meals had similar leucine contents but higher lysine and tryptophan contents than the

corresponding O_2-O_2 meals.

Eight convalescent malnourished male children, 10 to 25 months of age, participated in these studies. They were well along in their recovery, had no evidence of infection or malabsorption, had reached weights which were at least 80% of those appropriate for their heights, and had serum albumin levels of at least 3.7 g/dl. Table 2 lists their status at the beginning of these studies. Informed consent was secured from their parents and the protocols were approved by the Joint Committee on Clinical Investigation of the Johns Hopkins University and the corresponding committee of the Instituto de Investigacion Nutricional.

Our assessments of relative nutritive value depend on isonitrogenous comparisons between proteins fed at a critical level in diets which are isoenergetic at a level which supports steady weight gain. All the maize meals were fed as the only source of the 6.4% protein calories, as was casein[3] in the control diets. The three endosperm meals were fed consecutively to six children in six different sequences, preceded and followed by casein-based diets. The same protocol was followed for the whole kernel meals. Four children participated in both studies, two in the E studies only and two in the WK studies only.

All diet periods were of nine days, with three for adaptation and six for metabolic collections. All diets were isonitrogenous and isocaloric for each study. Intakes were 100 to 125 Kcal/kg body weight/day and had been demonstrated to support steady weight gain during a preceding period of adaptation of no less than 10 days.

Fat provided 10% of energy in all diets, with a blend of soy and cottonseed oils (80:20) completing the fat not provided by the maize meal. Cane sugar was added to complete the desired total calories. The low protein content of the E meals left little room for sugar. In the control diets the vegetable oil blend supplied 10% of calories, and cane sugar, dextri-maltose, and cornstarch provided the carbohydrate calories. Minerals and vitamins were supplied to meet or exceed recommended allowances. Sodium and potassium intakes were equalized at 2.0 and 3.0 mEq/kg/day respectively for all diets.

Table 3 lists the components of 100 Kcal of each diet and the contribution of each maize meal to the total energy intake. This ranged from 67.2% of total calories for Su_2-O_2 WK meal to 91.2% for the O_2-O_2 E meal, that with the lowest protein content. The compositions of the mineral and vitamin supplements are included. In order to assure precise measurement of consumption of the diets and prevent spillage, these were prepared in a liquid suspension and fed from a bottle.

Feces and urine were collected separately during the last six days of each nine-day diet period. Nitrogen contents were determined by micro-Kjeldahl, fecal fat by the Van de Kamer technique (12), fecal energy by bomb calorimetry, and serum albumin by acetate gel electrophoresis. Apparent nitrogen absorption is diet N-fecal N as a percentage of diet N. Apparent N retention is diet N-fecal N-urine N as a percentage of diet N.

RESULTS

The diets were generally well tolerated, although ingestion of the maize meal diets was time-consuming and some of the children obviously became bored with the bulkiness and monotony. No untoward reactions were noted, particularly vomiting, diarrhea, or evidence of blood- or protein-losing enteropathy.

Because weight gain or loss over short periods of time is an unreliable measure, no attempt to analyze the results during individual dietary periods was made. Weight changes during the entire duration (27 days) of the three consecutive periods on either E or WK meals were compared with those of the preceding and following casein periods combined. For the E meals, mean weight gain was 12.8±17.5 (S.D.) g/day, and for the corresponding casein periods it was 23.7±16.7 g/day, the difference not being statistically significant. For the WK meals, mean weight gain was 15.1±11.6 g/day, and for the corresponding casein periods 26.6±11.6 g/day. This difference was also not significant, although more nearly so. During the E meal periods, serum albumin fell a mean of 0.18±0.20 g/dl, from 3.87±0.21 to 3.69±0.15. Because of the small "n", this difference just missed statistical significance. During the WK periods, serum albumin fell a mean of 0.07±0.26 g/dl, from 3.96±0.36 to 3.89±0.52, without being significant.

Table 4 summarizes results from the endosperm meal studies. Fecal wet and dry weights and energy were slightly higher from Su_2-O_2, but the small "n" prevented statistical significance. All were significantly higher than during the casein control periods, as was fecal fat, both in absolute amounts and as a percentage of intake.

Apparent absorption of nitrogen was not different between maize meals, but notably lower than the control. Apparent retention of N from the normal E meal was considerably lower than from the O_2-O_2 and Su_2-O_2 meals but the small "n" made the differences just miss being statistically significant. All were significantly poorer than from the casein diets, being approximately 41, 62 and 67% respectively of the control retentions.

Table 5 summarizes the results from the whole kernel meal studies. Differences between varieties in fecal wet and dry weights, fat and energy, though slightly favoring the normal maize, were not significant. As in the case of the endosperm meals, all were significantly higher than from the casein control diets. Apparent absorptions of N from the three WK maize meals were not different, but all, though higher than from the corresponding E meals, were still significantly lower than from the casein diets. Apparent retention of N from the normal WK meal was lower than from the O_2-O_2 and Su_2-O_2 meals, but not significantly so, and was more nearly equal than in the case of the E meals. All were significantly lower than the retentions from casein, being approximately 68, 76 and 80% of those values.

Table 6 compares the results of all endosperm meals combined, with those of all whole kernel meals, also combined. It demonstrates the clear superiority of the latter, particularly in protein and energy digestibilities and in protein quality. The endosperm meal diets contained considerably higher percentages of total calories as maize (Table 3), which may explain all or part of the apparent differences in energy digestibilities.

Table 7 relates apparent nitrogen retentions from the six maize meals to the amounts of lysine presumably absorbed from each. To calculate "absorbed" lysine for each child in each study the percentage of nitrogen apparently absorbed was arbitrarily applied to the amount of lysine calculated to have been ingested, based on the lysine content of the maize meals and the amounts of meal ingested. The absorption of lysine, of course, may not be the same as for total nitrogen. For the endosperm meals there was an obvious progressive increase in nitrogen retention as "absorbed" lysine increased, and when all the individual pairs of values were used, there was a highly significant linear correlation between the two. For the whole kernel meals there was a similar apparent increase in nitrogen retention as "absorbed" lysine increased, with again a highly significant correlation for individual pairs of values. It is apparent, however, that nitrogen retentions from the WK meals were higher than those from E meals at presumably equal levels of "absorbed" lysine. This was not significant by linear analysis of covariance for the two regressions.

DISCUSSION

These findings confirm the superiority of opaque-2 hybrid maize protein over that of isogenic normal maize protein, as demonstrated by Clark *et al* in adults (10). Additionally, they confirm the further superiority of an isogenic sugary 2-opaque 2 hybrid which was apparent in rats (9), but not in adult humans (10). This is most likely due to the lower essential amino acid requirements of adults: it is probable that these were satisfied by the amounts of O_2-O_2 and Su_2-O_2 consumed in the 5.5 g N studies, as demonstrated by the apparently positive

mean balances. That this was not the case for the children in this study is demonstrated by the fact that all of them retained less nitrogen from all six maize meals than they did from casein at equal levels of intake. Part of the inferiority to casein may be due to greater fecal energy losses (Tables 4 and 5) and consequently lesser "effective" energy intakes.

The lesser rates of weight gain during the maize meal periods than during the casein control periods is explained in part by fecal losses of energy and in part by the lesser retentions of nitrogen. When the nitrogen content of the weight gain during the casein periods is estimated, it is very near the theoretical norm of 3% for this age group. For the WK periods it is also very near 3% but for the E periods it is closer to 2%, suggesting a higher proportion of fat in the weight gain, or actual deterioration of lean body mass composition, or both. The fall in serum albumin levels is indicative of some deterioration of lean body mass composition (13).

Although fecal wet weight, dry weight and energy were higher when consuming the Su_2-O_2 E meal than when consuming the Normal and O_2-O_2 E meals, the differences were not statistically significant and if they did exist, were probably not of biological significance, particularly the slight differences in absorbed energy: there was no apparent effect of this on nitrogen retention, which was still higher from the Su_2-O_2 E meal. With the WK meals, these parameters of energy digestibility were not different between O_2-O_2 and Su_2-O_2 meals.

The greater fecal losses of energy from the E meal diets than from the WK meal diets were most probably due to the considerably greater contribution of the E maize meals to the diets, the result of

the larger amounts needed to achieve equal nitrogen intakes (Table 3). There was no difference in fat absorption between the two types of maize meal diets. Although fecal fat seemed high when expressed as a percentage of intake, and was higher than that from the control diet, this may in part be due to the low fat intake: 10% of total energy. As a percentage of fecal dry weight, fecal fat was actually very low in the maize studies. The increased losses of fat might then be attributed to the higher amounts of fecal dry matter.

The significantly higher apparent absorption of nitrogen from the WK than from the E meals was not expected. Young et al found no such difference in similar studies with adults (14). It may be that this is the result of the much greater zein content of the endosperm meals. Although the diets were isonitrogenous, some of the losses of nitrogen from the E meal diets may have been due to the slightly increased fecal water and dry matter, as in the case of lactose malabsorption, which does cause some increase in fecal N from otherwise well-absorbed milk proteins (15). An 11% increase in fecal water does not seem enough, however, to explain any significant part of a 21% increase in fecal nitrogen.

The strong correlations between apparently "absorbed" lysine and nitrogen retention, though suggestive, do not establish cause and effect. Nitrogen retention might be equally dependent on available tryptophan. Bressani et al showed that significant improvement in nitrogen retention from ordinary maize was not consistently attained in children unless lysine and tryptophan were both supplemented (16). Plasma amino acids of the same children in the current studies, to be

reported separately, suggest that often enough tryptophan seemed to be first-limiting[4]. The higher retentions of nitrogen from the WK meals, at equal lysine "absorptions", could be due to the higher "effective" energy intakes, the result of lesser fecal energy losses, or to a better overall balance of absorbed amino acids. They might also be due to better absorptions of lysine than the simplistic calculations assume.

The present results, because of the large amounts of maize meal consumed by the children, allow an approach to the question of whether this major staple can satisfy their protein needs when it provides most of the energy in the diet (11). All of the children were consuming total energy intakes which were at least the equal of the 1973 FAO/WHO recommendations for their ages (17). To accomplish this, however, took a great deal of time and patience on the part of an experienced staff with this as its major responsibility. It is not reasonable to assume that a harried poor mother with many other responsibilities and no modern facilities could easily match this, least of all exceed it. It is questionable, also, whether the achievement of a required protein intake through the consumption of an excessive calorie intake would be without ill effects. That the energy intakes of the children in this study were adequate was documented in each case by the prior establishment of a satisfactory rate of weight gain.

Although casein is not the ideal protein, we have found that at 6.4% protein calories in this age group, it supports rates of growth and nitrogen retention equal to those from modified cow milk formulas fed at isoenergetic, isonitrogenous levels. Thus, the nitrogen

retentions from casein by these children can be assumed to be maximal for the protein and energy intakes and rates of growth. If it is assumed that the rates of nitrogen and energy absorption and of nitrogen retention from the maize meals would hold at even higher levels of consumption, then the amounts that would have to be consumed to match the nitrogen retentions from casein can be calculated.

For the normal endosperm meal, consumption would have to be increased from 83.2 to 203.9% of the normal energy intake for 50% of the children in this study to retain as much nitrogen as they did from casein ($83.2 \times \frac{37.0}{15.1}$). O_2-O_2 endosperm meal consumption would have to be increased from 91.2 to 148%, and Su_2-O_2 endosperm meal from 82.1 to 122.5% of the normal energy intake for half the children to achieve the same nitrogen retention. Obviously, none of these is within the range of the physiologically possible.

The outlook for the whole kernel meals is considerably better. For the normal WK meal, its consumption would have to increase from 73.2 to 108.2% of the normal energy intakes for 50% of the children to retain as much nitrogen as from casein. For the O_2-O_2 WK meal the consumption would have to increase from 68.6 to 90.3%, and for the Su_2-O_2 WK meal the consumption would have to increase from 67.2 to 84.2% of total energy intake. Only the Su_2-O_2 WK meal, and possibly the O_2-O_2 WK meal, have the protein content and quality needed to achieve satisfactory nitrogen retentions from amounts within the realm of reason. Even so, individual variation in requirements, digestibility and efficiency of utilization would make these high and monotonous intakes marginal for 50% of the children in this study. For older

children, with lesser relative requirements and possibly better capacities to ingest and digest, it would be considerably easier to satisfy protein needs from these two genetically superior varieties when consumed as the whole kernel meal, the usual way in developing countries.

In view of these results with maize and the similar ones reported for normal and genetically improved rice (18, 19), it does not seem reasonable for increased consumption of these two major staples in their ordinary varieties to be touted as a way of meeting the needs of small children in the developing world for nitrogen and amino acids, the building blocks of growth. To have the same done for inferior staples, such as sorghum, cassava, and the sweet potato, seems beyond reason. Nevertheless, such proposals, untested even under the favorable conditions of a metabolic unit, are beginning to appear in programs of the international agencies and of specific developing countries.

To put aside the enormous possibilities of maize improved by the incorporation of opaque-2 and other genes, strictly on the basis of the economic consideration of a 10% lesser yield, seems to be a large step backward in the effort to improve the lot of millions of children. If these improved varieties of maize were to be grown only to make a one-component food for children, with the price differential, if necessary, covered by a subsidy, the gains in meeting their protein needs would certainly be cost-effective. If the varieties prove to be less acceptable to adults, this might well be a plus, helping to assure that they are consumed only by those who would benefit from

them, the small children who are not likely to receive the legumes and other sources of supplementary and complementary proteins.

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FOOTNOTES

1. Supported by Research Contract AID/ta-C-1286 with the Agency for International Development, U.S. Department of State, and by Research Grant HD-10111 from the National Institutes of Health, U.S.P.H.S.

2. Clark, Helen C.: personal communication.

3. Calcium caseinate (Casec), supplied by Mead Johnson and Company, Evansville, Indiana.

4. Graham, G.G., Placko, R.P. & MacLean, W.C. Jr. Nutritional value of normal, opaque-2, and sugary-2 opaque-2 maize hybrids for infants and children. II. Plasma free amino acids. Submitted to J. Nutr.

Table 1

Protein, fat (ether extract), lysine, tryptophan and leucine contents of the three endosperm (E) and three whole kernel (WK) meals used in these studies

Maize Meal	g/100 g meal			g/100 g protein		
	Protein	Fat	Fiber	Lys	Trp	Leu
Normal E	7.1	1.1	1.4	2.2	0.50	12.9
O_2-O_2 E	6.5	0.8	1.5	3.4	0.67	9.9
Su_2-O_2 E	7.1	1.5	1.8	4.0	0.69	9.6
Normal WK	8.3	3.8	1.8	2.9	0.51	14.4
O_2-O_2 WK	8.6	4.4	2.1	4.0	0.70	11.2
Su_2-O_2 WK	9.0	5.2	2.3	4.3	0.91	11.1

Table 2

Age, height, height age, weight, weight age, and serum albumin levels, at the beginning of these studies, of the 8 children who participated

Subject Number	Age in Months	Height in cm	Height age, Months	Weight in kg	Weight age, Months	Serum Albumin g/dl
549	22	78.0	14.5	9.62	10.5	4.25
553	10	63.8	4.5	5.35	2.3	3.78
560	12	68.5	7.3	7.00	5.2	4.16
561	18	69.6	8.0	7.37	5.7	3.85
565	18	76.2	13.0	9.56	10.5	3.89
567	12	70.3	8.3	6.78	4.9	3.81
568	25	75.1	12.3	8.52	7.8	3.74
569	15	70.0	8.0	8.83	8.5	3.96

Table 3

Major ingredients in 100 Kcal of each of the 6 study diets and the control diet, all providing 1.6 g protein and 10 Kcal fat*

	Endosperm Diets			Whole Kernel Diets			Control Diets
	Normal	O_2-O_2	Su_2-O_2	Normal	O_2-O_2	Su_2-O_2	
Maize Meal - g	22.66	24.77	22.60	19.35	18.58	17.74	--
(Kcal)	(83.2)	(91.2)	(82.1)	(73.2)	(68.6)	(67.2)	--
Ca Caseinate - g	--	--	--	--	--	--	1.82
Sucrose - g	2.29	0.11	2.74	5.85	7.19	7.78	5.78
Dextrimaltose - g	--	--	--	--	--	--	8.00
Cornstarch - g	--	--	--	--	--	--	8.00
Veg. Oil - ml	0.97	1.06	0.88	0.43	0.34	0.22	1.28

* Each child received 0.68 g/kg/day of a mineral mixture with the following composition (W/W): NaCl, 17.3%; $MgSO_4$, 12.85%; $CaHPO_4$, 23.45%; $KHCO_3$, 41.0%; KCl, 2.65%; Ferric citrate, 2.0%; $CuSO_4 \cdot 4H_2O$, 0.352%; Zn $SO_4 \cdot 7H_2O$, 0.20%; Mn $SO_4 \cdot H_2O$, 0.156%; KI, 0.014%; NaF, 0.028%. Vitamins to meet U.S. RDA's were given separately as Poly-Vi-Sol (Mead Johnson): retinyl palmitate 1500 I.U., ergocalciferol 400 I.U., vitamin E 5 I.U., ascorbic acid 35 mg; thiamin 0.5 mg, riboflavin 0.6 mg, niacin 8 mg, vitamin B_6 0.4 mg, and vitamin B_{12} 2 μg.

Table 4

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 preceding and following 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, % of dry wt	Fat, % of Intake	Kcal % Intake	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
Su_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, $P<0.05$. The casein values are the means of the preceding and following control periods.

Table 5

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 preceding and following 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, % of dry wt	Fat, % of Intake	Kcal % Intake	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
Su_2-O_2	154 ±34	33 ±3	5.4 ±3.5	16.3 ±10.6	13.5 ±1.4	70.4 ±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, $P<0.05$. Casein values are the means of preceding and following control periods.

Table 6

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

Maize Meals	FECAL Wet Wt g/day	FECAL Dry Wt g/day	FECAL Fat, % of dry wt	FECAL Fat, % of Intake	FECAL Kcal % Intake	N Balance % of Intake Abs.	N Balance % of Intake 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 7

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

Maize Meals		Lysine mg/kg/day Intake	Lysine mg/kg/day Absorbed	N mg/kg/day Retention
Endosperm	Normal	41 ± 5	26 ± 6	35 ± 47
	O_2-O_2	63 ± 7	43 ± 3	68 ± 23
	Su_2-O_2	74 ± 9	49 ± 6	75 ± 31
(Casein Diet)			(100+)	(112 ± 52)
Whole Kernel	Normal	54 ± 5	39 ± 4	81 ± 15
	O_2-O_2	77 ± 7	54 ± 8	93 ± 31
	Su_2-O_2	81 ± 7	60 ± 8	97 ± 35
(Casein Diet)			(100+)	(121 ± 33)

* Linear regressions of N retention on "absorbed" lysine:

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

The regression lines are not significantly different from each other by linear analysis of covariance.