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NUTRITIONAL IMPLICATIONS OF LOW INTESTIONAL LACTOSE ACTIVITY IN CHILDREN

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SUBJECT:

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Nutritional Implications of Low Intestinal Lactase Activity in Children

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Centuries of experience have taught us to rely on cow's milk as a most valuable source of nutrients in the diet of infants and children. Congenital inability to split lactose, the sugar of milk, is fortunately quite rare. Acute intolerance to lactose has long been known to complicate recovery from severe diarrheal disease but, once identified, can usually be managed successfully. Relative lactase deficiency is now recognized as an important, usually correctible, manifestation of malnutrition in infants and children (Bowie, Brinkman and Hansen, 1963). It is only in the last few years that we have become aware of the fact that a notable decrease in intestinal lactase activity developing after the age of weaning is a common occurrence in man, being the rule in most non-white populations studied (Cook and Kajubi, 1966). Confirmatory observations from other parts of the world are now appearing regularly in the medical literature. Most of the world's children are not white, are malnourished to varying degrees, and suffer from frequent episodes of diarrhea, thus making it difficult in the mind of most workers in the health field to determine which factor, if not all three simultaneously, is involved in a particular individual or population. It is of particular importance to health authorities to know if a high incidence of low lactase activity means that milk drinking by such a population is potentially harmful, or that it will not result in the nutritional benefits traditionally expected. Reddy and Pershad (1972)

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"Nutritional Implications of Low Intestinal Lactose Activity in Children"

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Nutritional and metabolic consequences of lactose ingestion by children with presumed low intestinal lactose activity have been investigated. Consumption of moderate amounts of lactose results initially in a notable increase in stool weight, water, dry weight, and electrolyte content. These manifestations can easily result in rejection of lactose-containing foods by susceptible populations, without waiting for the adaptation which probably occurs and which was already evident by the end of the 9-day period of study. The initial increase in stool nitrogen which was observed was probably not of major consequence but a persistent increase in urine nitrogen and phosphate was suggestive of decreased protein synthesis, possibly the result of calorie inadequacy. Stool fat and calcium were little affected but there was an unexplained increase in urine calcium and a decrease in serum alkaline phosphatase. The nature of the "adaptation" or "acquired tolerance" to unabsorbed lactose requires further investigation.

(*Children, Nutrition), *Nutrition, *Milk

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have already suggested that it is of relatively minor importance. They, as well as many others, are well aware of the fact that many adults and children drink moderate amounts of milk with apparent impunity, despite the fact that in standard lactose tolerance testing they have insignificant blood sugar elevations and develop symptoms, being classified as "lactose intolerant" and presumed to have low intestinal lactase activity.

The studies we are now reporting are an attempt to define the consequences of significant and continued lactose ingestion by children who on the basis of the standard lactose tolerance test were classified as lactose intolerant and were presumed to have low lactase activity. We did not measure the enzyme directly but used the criteria of Bayless et al (1968) to make this assumption. The amount of lactose consumed by our subjects at each feeding was equivalent to that present in one to two 8 oz. glasses of whole cow's milk, depending on the child's weight. We did not use milk for the studies because we wished to be certain that the only variable was the carbohydrate in the diet.

METHODS

Balance studies were carried out in six Peruvian mestizo children between 23 and 82 months of age (Table I). The four oldest were considered lactose intolerant: after receiving 2 g of lactose per kg body weight the maximum

increase in their blood sugar over the fasting level was 4 mg/100 ml or less. All developed one or more of the symptoms associated with lactose intolerance. These four children have been followed by us for a number of years: two of them have never been clinically malnourished; one of them had been admitted twice to our unit, once with marasmic kwashiorkor and once with kwashiorkor, the last time over three years ago; the remaining child had been admitted with marasmic kwashiorkor over two years ago. All had been in apparent good health for many months prior to these studies. According to their mothers, two of the four usually drink one glass of milk daily, one drinks a glass occasionally and the other does not drink milk. These histories are of very questionable value: on the basis of our experience with these families it is more likely that none of the four drinks milk. They are hereafter referred to as "intolerant".

The two youngest children had increases in their blood sugar of 36 and 34 mg/100 ml over the fasting level when given a lactose load: they had no symptoms. The youngest, #288, had been admitted with marasmic kwashiorkor over six months earlier and was clinically very well at the time of these studies: his weight was appropriate to his height. The remaining child had been admitted with marasmus three years earlier and readmitted, this time with kwashiorkor, only 24 days before these studies: he was making an uneventful recovery. According to his mother he

was drinking one to two glasses of milk daily but this is grossly inconsistent with the admitting diagnosis. These two children are identified as "tolerant".

The diet during these studies (Table II) consisted exclusively of a formula providing daily per kg body weight: 75 kcal, with 2.0g protein as casein, 7.8g carbohydrate as sucrose or lactose, and 3.9g fat as cottonseed oil. A complete mineral mixture provided the four listed in the table as well as all other known requirements. A vitamin mixture was also given daily. Total water intake was 1000-1200 ml/day.

The studies were carried out on metabolic beds in an air-conditioned environment. After an adjustment period of 6 days on the casein-sucrose-oil diet, collections were carried out for 21 days, the first 6 on the same diet. During the following 9 days the carbohydrate was changed to lactose and during the last 6 days back to sucrose. Consumption of the diets was complete on nearly all days; there was no vomiting. Stools and urine were analyzed for each 3-day period, except during the first three days on lactose, when each day's collection was analysed separately. Stool and urine calcium were determined by atomic absorption spectrometry, all other determinations by standard techniques.

RESULTS

Figure 1 illustrates the mean stool weights, dry weight and fat for the two groups. Whereas daily stool weight for

the intolerant children averaged 50g during the first 6 days on sucrose and less than 40g during the final 6 days, it averaged 310g during the first three days on lactose. This decreased appreciably but was still 85g daily during the last three days of this diet. In one child stool weight exceeded 800g/day on the 2nd, 3rd and 4th days of lactose feeding. This represented 4 to 5% of body weight. In another, the highest value, on the 2nd day, was 520g, about 3% of his body weight. In the other two the increases were more modest. Increases in dry weight of the stool paralleled those in total weight but on a more modest scale. Stool fat was not significantly affected.

In the two tolerant children lactose had no effect on stool weight, dry weight, or fat.

Figure 2 depicts the changes in stool water, nitrogen, potassium, and sodium. Stool water was a close reflection of stool weight in all the periods. In the intolerant, stool nitrogen almost tripled during the first three lactose days and improved thereafter, but was still double the baseline values on the last three days. Stool K and Na more than tripled on the first three days of lactose but improved more rapidly. Reciprocal decreases in urine K and Na occurred but are not shown. In the tolerant children there was again no effect of lactose feeding.

Figure 3 summarizes the nitrogen balance studies in the tolerant child recovering from kwashiorkor. The steady

decrease in stool nitrogen, as in other stool values, is probably the result of continued recovery of intestinal function. His fairly impressive nitrogen retentions, shown by the clear areas above the baseline, are again most probably a function of recovery. Dietary nitrogen is plotted from the baseline up, stool and urine nitrogens are plotted from the intake down in this figure and the next. No effect of switching from sucrose to lactose is apparent.

Figure 4 summarizes the nitrogen balances in one of the intolerant children who initially was just in balance. The increase in stool nitrogen during the lactose periods is apparent, but perhaps more impressive is the increase in urine nitrogen, which far from compensating for the stool losses, aggravates them and results in clearly negative balance. We interpret this as probably due to a marked decrease in absorbed energy, the result of lactose malabsorption. In this child there was a notable improvement during the last sucrose period. That this was not always the case is demonstrated in Table III, where the nitrogen balances of the four intolerant children have been averaged. Although the decrease in stool nitrogen, beginning already during the lactose feeding, is evident, no such decrease in urine nitrogen occurs. This is conceivably a "carry-over" effect of inadequate calorie retention. As a result, nitrogen retention during this last period was still below that of the initial sucrose period.

Table IV presents in some detail the results of stool and urine calcium and phosphorus values. Because of their more advanced age and greater body weight, the intolerant children had larger intakes, resulting in greater excretions. The one intolerant child with the greatest increase in stool weight, #166, had a marked increase in stool Ca and P during the same days: otherwise the stool values were quite variable and unpredictable. In these limited studies it is not possible to identify a consistent effect of lactose malabsorption on the apparent absorptions of Ca and P.

Both the urine Ca and urine P values of the intolerant children reveal suggestive trends. In all three there was an approximate doubling of urine Ca during the lactose periods, with recovery during the final sucrose period. The increase in urine P was even more impressive but recovery was less complete, suggesting a "carry-over" effect as in the case of nitrogen. Both might conceivably be due to decreased protein synthesis, the result of calorie inadequacy. The increases in urine Ca, if not a chance occurrence, are most difficult to explain. Unfortunately, we did not measure blood or urine pH: systemic acidosis, or a markedly acid urine might explain this finding.

Serum calcium and inorganic phosphate levels (Figure 5) were not affected. Serum alkaline phosphatase, however, fell significantly in all the intolerant children at the

end of the lactose feeding and had not recovered at the end of the final sucrose period. If not a chance occurrence, this might represent stool losses of intestinal alkaline phosphatase: (Kaplan, 1972).

DISCUSSION

These studies suggest that consumption of moderate amounts of lactose by children with low intestinal lactase activity can have important nutritional and metabolic consequences. Of particular importance is the apparent adaptation which was evident, even during the short periods of study.

The relatively large losses of water and electrolytes in the stool of some of the children are of more than passing concern. Assuming that the consumption of equivalent amounts of lactose in milk produces the same initial response, and our experience in the hospital and the field indicates that it does, we have a plausible explanation for the rejection of milk by people who are not habitual consumers and have low lactase activities. If the stool losses result in significant morbidity, the mistrust of milk which we so frequently encounter is quite understandable. Certainly, when milk is being introduced to such populations, it must be done gradually, with attention to the possibility that some children may never tolerate its sugar.

Losses of nitrogen in the stool, though significant, decreased with time and probably would never deprive the consumer of the advantages of the high content and quality

of the protein in cow's milk. Losses of fat and of calcium were noted only when stool volume was very large; otherwise they were not significant.

The only evidence from these studies which suggests that there was an important wastage of energy from lactose malabsorption is in the increased nitrogen and phophorus of the urine. Studies of considerably longer duration are necessary to document effects on body weight and growth.

As indicated above, there was considerable evidence of adaptation to lactose consumption by the intolerant children. We can only speculate as to whether this represented "tolerance" to the products of bacterial degradation of lactose by the large intestine, without any nutritional benefit, or an actual adaptation to bacterial degradation, with absorption and utilization of the resultant short-chain organic acids. That these are at least absorbed has been demonstrated in the premature infant (Lifshitz, et al, 1971).

SUMMARY

Nutritional and metabolic consequences of lactose ingestion by children with presumed low intestinal lactase activity have been investigated. Consumption of moderate amounts of lactose results initially in a notable increase in stool weight, water, dry weight, and electrolyte content. These manifestations can easily result in rejection of lactose-containing foods by susceptible populations,

without waiting for the adaptation which probably occurs and which was already evident by the end of the 9-day period of study. The initial increase in stool nitrogen which was observed was probably not of major consequence but a persistent increase in urine nitrogen and phosphate was suggestive of decreased protein synthesis, possibly the result of calorie inadequacy. Stool fat and calcium were little affected but there was an unexplained increase in urine calcium and a decrease in serum alkaline phosphatase. The nature of the "adaptation" or "acquired tolerance" to unabsorbed lactose requires further investigation.

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TABLE I

History and physical characteristics of six boys who were subjects of this study.

Case No.	*Past Nutrit. History	Age in Mos.	Ht. in cm	Wt. in kg	State of Health	History of milk use: glasses/day	Max. Bl. Sugar Rise on L.T.T. mg/100 ml
140	N	68	102	17.0	Good	1	2.0
166	MK,K	70	107	18.0	Good	0-1	4.0
257	MK	55	94	15.8	Good	0	0
310	N	82	106	20.8	Good	1	2.0
288	MK	23	76	10.3	Good	0	36.0
242	M,K	41	83	12.0	Fair	1-2	34.0

* N = normal; M = marasmus; K = kwashiorkor; MK = marasmic kwashiorkor

TABLE II

Composition of study diets

	Amounts/kg body weight daily	one meal
Protein as casein	2.0 g	0.33 g
nitrogen	320 mg	53 mg
Carbohydrate as sucrose or lactose	7.8 g	1.3 g
Fat as cottonseed oil	3.9 g	0.65 g
Calcium	83.3 mg	13.9 mg
Phosphorus	54.5 mg	9.1 mg
Sodium	2.1 mEq	0.35 mEq
Potassium	3.0 mEq	0.5 mEq

TABLE III

Nitrogen balances in "lactose intolerant" boys
(Mean of four studies.)

	Sucrose	Lactose			Sucrose
	6 days	3 d	3 d	3 d	6 days
Intake - mg/kg/day	320	320	313	320	320
Stool - mg/kg/day	22	58	46	42	25
Urine - mg/kg/day	249	268	267	257	270
Absorption - % of intake	93	82	85	87	92
Retention - % of intake	15	-2	0	7	8

TABLE IV

Calcium and phosphorus in stool and urine (mg/day) of three "lactose intolerant" and two "lactose tolerant" boys receiving sucrose (S) or lactose (L) as the carbohydrate in the diet.

Case No.		Stool			Urine		
		S	L	S	S	L	S
257	Calcium	391	442	615	23	43	36
	Phosphorus	176	218	279	9	103	88
166	Calcium	572	813	347	32	69	23
	Phosphorus	244	375	139	86	200	179
140	Calcium	635	423	571	48	~~113~~ 128	89
	Phosphorus	402	267	397	41	121	22
Intolerant (means)	Calcium	533	559	511	34	~~75~~ 80	49
	Phosphorus	274	287	272	45	141	96
288	Calcium	241	150	196	38	40	9
	Phosphorus	133	111	143	12	25	6
242	Calcium	395	601	321	22	26	40
	Phosphorus	172	317	231	63	29	63
Tolerant (means)	Calcium	318	375	258	30	33	25
	Phosphorus	153	214	187	37	27	35

LEGENDS FOR FIGURES

Figure 1. Stool weight, stool dry weight, and stool fat of lactose-intolerant and lactose-tolerant children consuming sucrose (S) or lactose (L) as the only carbohydrate in the diet.

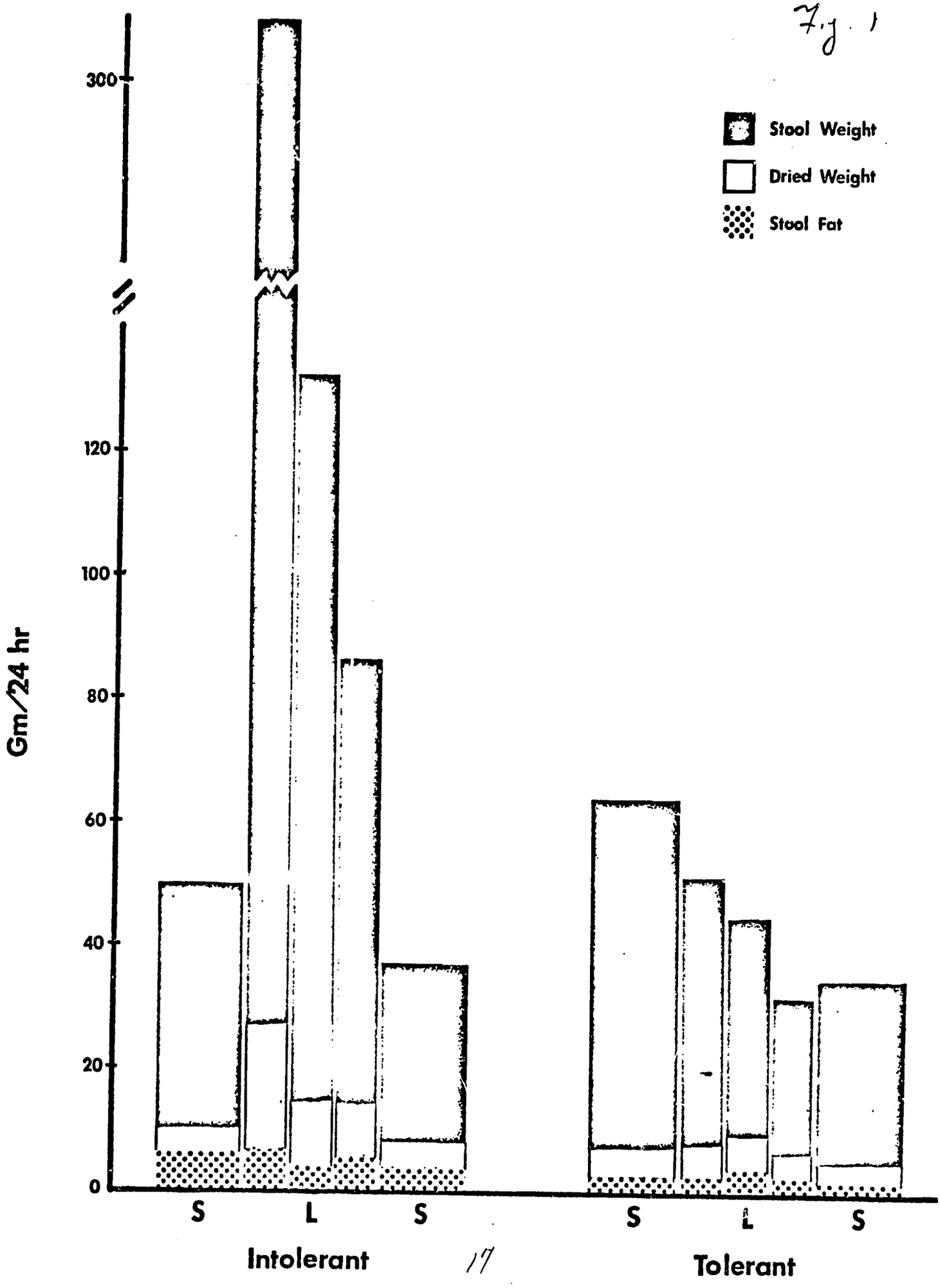
Figure 2. Stool water, nitrogen, potassium and sodium of lactose-intolerant and lactose-tolerant children consuming sucrose (S) or lactose (L).

Figure 3. Nitrogen balances of a lactose-tolerant child consuming sucrose (S) or lactose (L). Each bar represents three days. Intake is plotted up from the baseline, stool and urine down from intake; clear areas represents apparent retentions of nitrogen.

Figure 4. Nitrogen balances of a lactose-intolerant child consuming sucrose (S) or lactose (L). Intake is plotted up from baseline, stool and urine down from intake; clear areas represent apparent retentions, shaded areas below baseline apparent losses.

Figure 5. Serum alkaline phosphatase (Bodansky units), inorganic phosphorus, and calcium at end of sucrose (S) and lactose (L) periods in children who were intolerant or tolerant of lactose.

Fig. 1


Stool Weight
Dried Weight
Stool Fat
Gm./24 hr
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120
100
80
60
40
20
0
S
L
S
S
L
S
Intolerant
Tolerant

Fig. 2

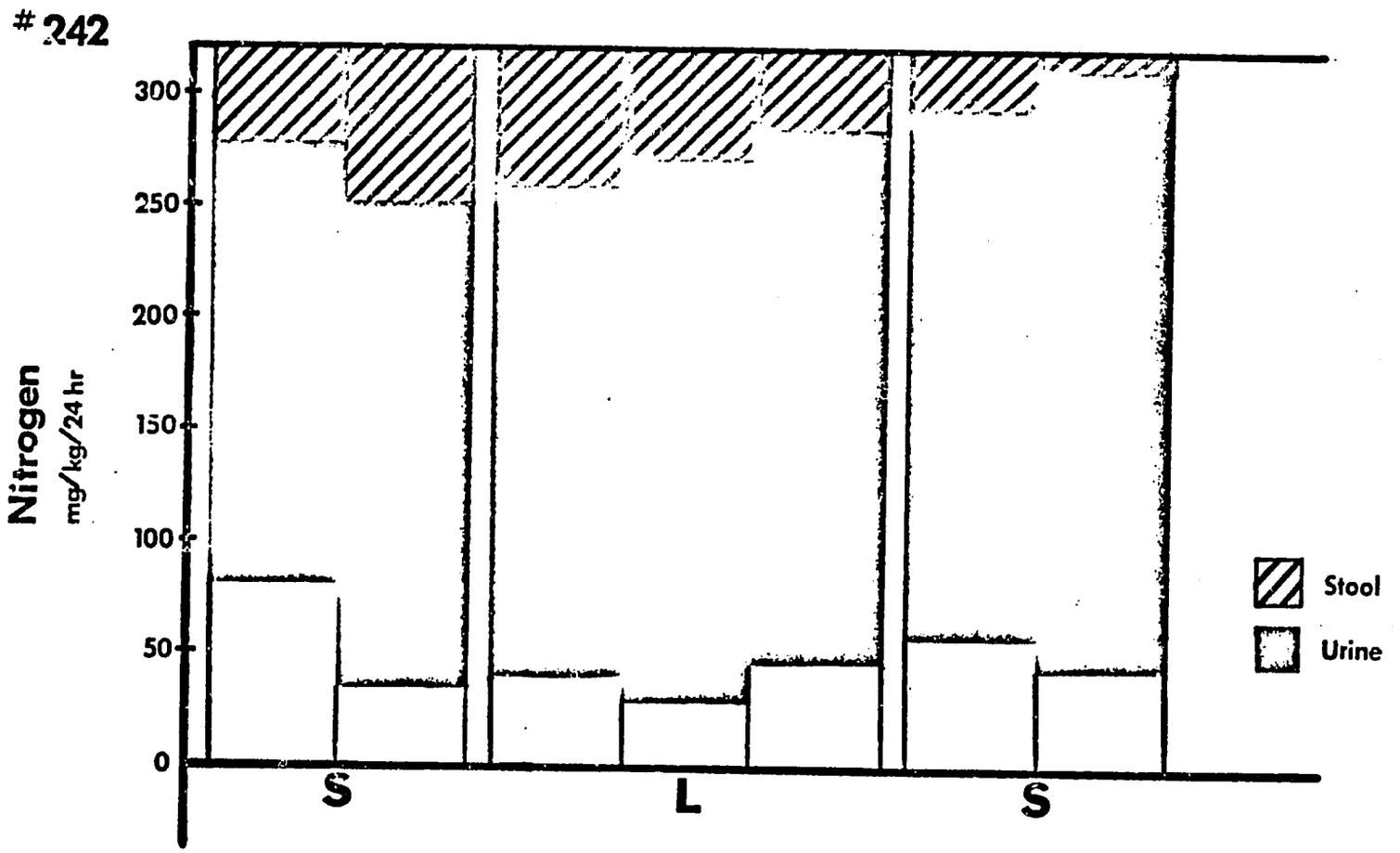

242
Nitrogen
mg/kg/24 hr
300
250
200
150
100
50
0
S
L
S
Stool
Urine

Fig 3

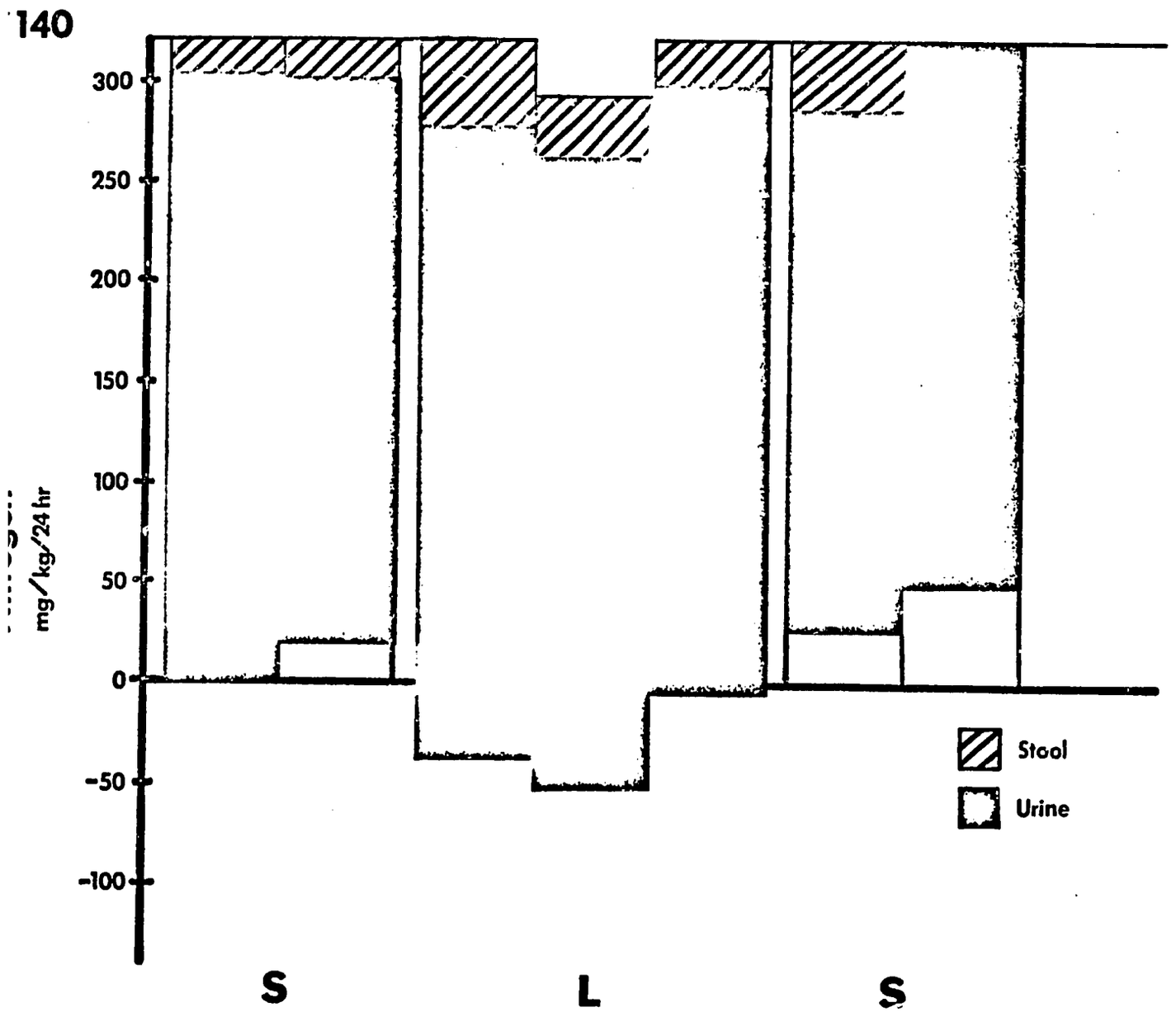


Fig. 4

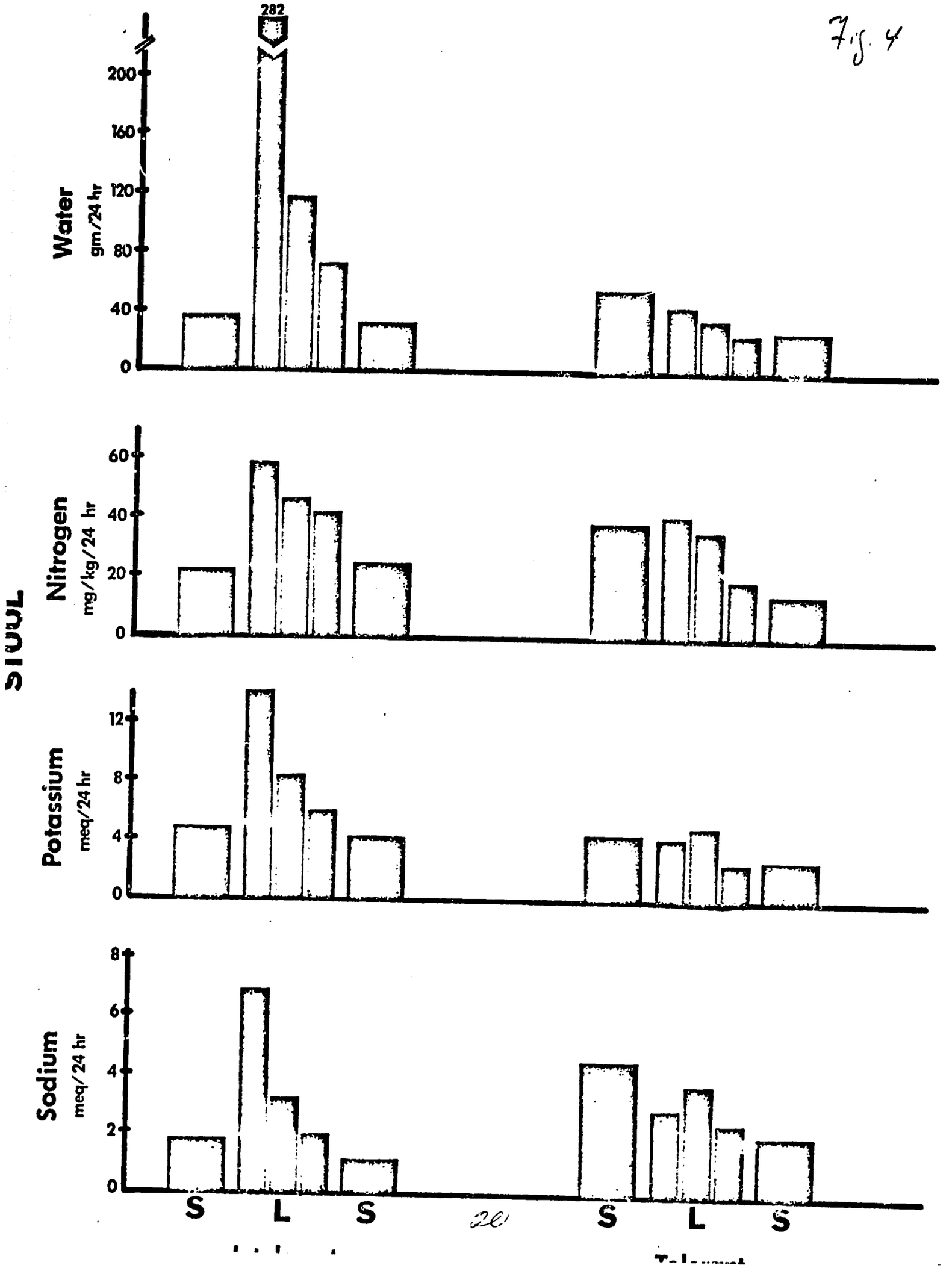
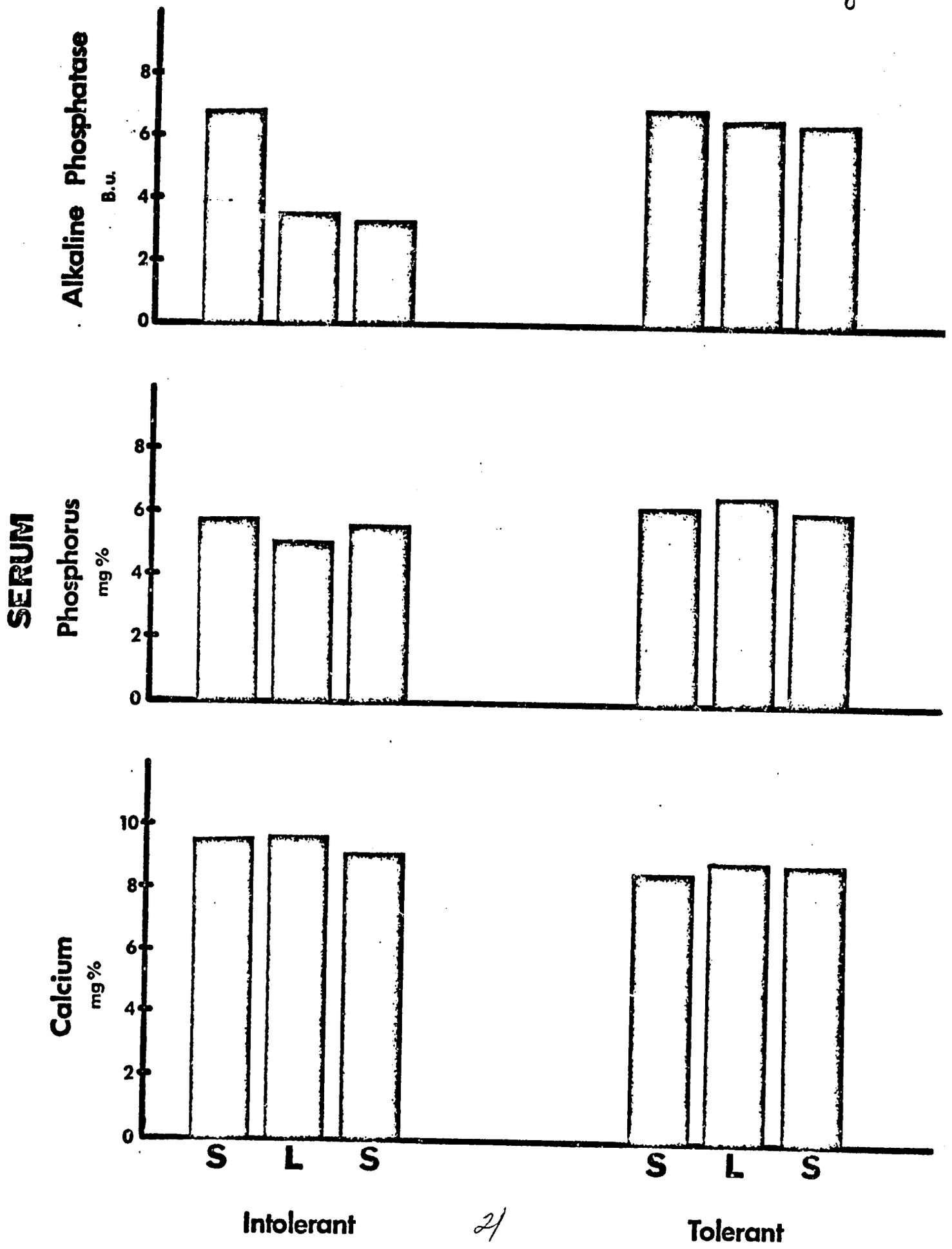

282
Water
gm/24 hr
200
160
120
80
40
0
Nitrogen
mg/kg/24 hr
60
40
20
0
Potassium
meq/24 hr
12
8
4
0
Sodium
meq/24 hr
8
6
4
2
0
S
L
S
S
L
S

Fig. 5


SERUM
Alkaline Phosphatase
B.u.
0
2
4
6
8
Phosphorus
mg %
0
2
4
6
8
Calcium
mg %
0
2
4
6
8
10
S
L
S
S
L
S
Intolerant
Tolerant