Endogenous Oxalate Synthesis and Glycine, Serine, Deoxypyridoxidine Interrelationships in Vitamin B₆-deficient Rats*

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Attempts to study the etiology of diseases associated with oxaluria or oxalate deposition or both, have been handicapped by the misconception that very little urinary oxalate is endogenous in origin. However, Gershoff et al. (1) have demonstrated oxalate nephrocalcinosis and oxaluria in vitamin B₆-deficient cats. In vitamin B₆-deficient rats consuming diets free from oxalate, renal calculi of calcium oxalate monohydrate have been observed (2). Such renal calculi and the obstructive sequelae they produce, closely resemble the conditions found in human cases of kidney disease accompanied by oxalate stones. The possibility that these findings relating oxalate production and vitamin B₆ may be pertinent in human nutrition is indicated by the finding (3) that vitamin B₆ supplements decreased oxalate excretion in human subjects receiving diets thought to be more than adequate in vitamin B₆.

In the present paper, the effect of glycine, deoxypyridoxine, and isonicotinic acid hydrazide supplements on oxaluria in vitamin B₆-deficient rats is reported. The effect of L-serine and glycine on deoxypyridoxine toxicity has also been studied.

EXPERIMENTAL AND RESULTS

Male weanling rats of the Charles River CD strain were used. The diets fed contained 15 or 40 per cent casein, 4 per cent salts IV (4), 4 per cent corn oil, 1 per cent cod liver oil, and 0.3 per cent choline. In a number of instances different levels of glycine or L-serine were added to the diets. Sucrose was used to bring each diet to 100 per cent. All diets were supplemented with 4 mg. of thiamine, 8 mg. of riboflavin, 40 mg. of niacin, 20 mg. of Ca pantothenate, 1 mg. of folic acid, 1 mg. of menadione, 0.2 mg. of biotin, and 0.1 mg. of vitamin B₁₂ per kilogram of diet. When used, 4 mg. of pyridoxine HCl, 500 mg. of deoxypyridoxine, and 2 gm. of isonicotinic acid hydrazide were added per kilogram of diet.

In the first experiment 12 groups of 9 rats were used. The diets fed contained 15 or 40 per cent casein with or without 3 per cent added glycine. Some of the vitamin B₆-deficient diets contained deoxypyridoxine. At the end of each week during the 30-day experimental period, subgroups of 3 rats from each group were placed in metabolism cages and 48-hour urine collections made. The oxalic acid content of the urine was determined by the method of Powers and Levatin (5). The results of this experiment (Table I) clearly show that in vitamin B₆-deficient rats there is a marked increase in urinary oxalate excretion. The addition of 3 per cent glycine to the 15 per cent casein diets and of deoxypyridoxine to both 15 per cent and 40 per cent casein diets, resulted in a further increase in oxalate excretion. Oxaluria was most pronounced when 40 per cent casein diets containing both added glycine and deoxypyridoxine were fed. Although the addition of deoxypyridoxine inhibited growth, as expected when added to the basal diet, the further addition of glycine provided considerable protection against the growth-inhibiting and lethal effects of the deoxypyridoxine. Three per cent glycine had no significant effect on the growth of animals receiving vitamin B₆, but it caused some growth inhibition in deficient rats not receiving deoxypyridoxine.

Isonicotinic acid hydrazide, commonly used in the treatment of tuberculosis, is known to increase vitamin B₆ requirements (6). Its effect on oxalate production in rats fed 15 per cent casein diets without added glycine has been studied in groups of 9 rats. At the end of the first and second experimental weeks, urines were collected (over a 48-hour period) for oxalate analysis. The mean results of this study shown in Table II, demonstrate again the protective effect of glycine and that isonicotinic acid hydrazide is effective in increasing urinary oxalate excretion by rats particularly when they are vitamin B₆ deficient.

The protective effect of glycine on deoxypyridoxine toxicity and the fact that glycine is rapidly converted to serine in animal tissues, led to the third study in which the effect of L-serine and glycine in sparing vitamin B₆-deficient rats from the toxic effects of deoxypyridoxine was studied. The results of this experiment, Table III, demonstrate again the protective effect of glycine and that L-serine is more effective than glycine when fed on an equal molecular basis.

DISCUSSION

The quantity of endogenous oxalate produced in these experiments must be related to the amount of oxalate precursors ingested and the degree of vitamin B₆ deficiency produced. It appears from this study and that of Calhoun et al. (7) in vitamin B₆-deficient rats and the work of Archer et al. (8) and Scowen

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Glycine-containing diets when the deficiency became intensified. Progressed, may have been due to lessened consumption of the et.

Increased oxalate formation. The slightly decreased oxalate excretion of some of the deficient groups as the first experiment could result in an accumulation of glyoxylic acid with derived in great part from glycine. Oxalate has been shown to be formed from glycine via glyoxylic acid (10, 11) and inhibition amount of urinary oxalate may be of endogenous origin and parentheses represent survivors.

<table>
<thead>
<tr>
<th>Diet</th>
<th>Average weight change per 28 days</th>
<th>Mg. urinary oxalic acid per 100 gm. body weight on days*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>8 + 9</td>
</tr>
<tr>
<td>15% Casein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+B6</td>
<td>105</td>
<td>1.0</td>
</tr>
<tr>
<td>+B6 + 3% glycine</td>
<td>102</td>
<td>1.3</td>
</tr>
<tr>
<td>-B6</td>
<td>31</td>
<td>1.9</td>
</tr>
<tr>
<td>-B6 + deoxypyridoxine</td>
<td>2.8</td>
<td>2.3 (8)</td>
</tr>
<tr>
<td>-B6 + 3% glycine</td>
<td>15</td>
<td>3.1</td>
</tr>
<tr>
<td>-B6 + 3% glycine + deoxypyridoxine</td>
<td>26</td>
<td>4.5</td>
</tr>
<tr>
<td>40% Casein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+B6</td>
<td>161</td>
<td>0.8</td>
</tr>
<tr>
<td>+B6 + 3% glycine</td>
<td>166</td>
<td>1.1</td>
</tr>
<tr>
<td>-B6</td>
<td>30</td>
<td>2.0</td>
</tr>
<tr>
<td>-B6 + deoxypyridoxine</td>
<td>4.2</td>
<td>3.1 (4)</td>
</tr>
<tr>
<td>-B6 + 3% glycine</td>
<td>20</td>
<td>2.3</td>
</tr>
<tr>
<td>B6 + 3% glycine</td>
<td>5.2</td>
<td>5.2</td>
</tr>
</tbody>
</table>

* Except for groups in which rats died, each value represents the mean of six determinations plus standard error of the mean.

† INH, isonicotinic acid hydrazide.

Table I: Effect of glycine and deoxypyridoxine on oxaluria and weight changes in vitamin B6-deficient rats

Table II: Effect of isonicotinic acid hydrazide on oxaluria in rats

Two vitamin B6 antagonists, deoxypyridoxine and isonicotinic acid hydrazide, have been used to accelerate the production of the deficiency state. The feeding of either of these compounds, particularly to animals not receiving dietary vitamin B6, was accompanied by an increase in oxaluria. This is presumably due to an acceleration in the rate of development or severity of the deficiency. Some practical significance may be attached to this action of isonicotinic acid hydrazide, since it is widely used in the treatment of tuberculosis. It has not yet been determined whether the administration of isonicotinic acid hydrazide to patients results in increased oxalate production. It seems probable that this would occur unless adequate pyridoxine supplementation was provided.

Although serine and glycine are "nonessential" amino acids, they are necessary for the synthesis of body proteins and a number of essential metabolites. The use of deoxypyridoxine in these studies apparently resulted in a deficiency of glycine and serine since dietary supplementation with these amino acids reversed the growth inhibition caused by the antivitamin. Deoxypyridoxine may inhibit the formation of serine and glycine or enhance their degradation.

Excessive amounts of glycine are toxic (13) particularly when the diet is vitamin B6 deficient (14). Thus, it would appear that whether glycine supplementation accentuates or ameliorates vitamin B6 deficiency depends on the different degrees to which the vitamin B6-dependent systems are depressed.

SUMMARY

Urinary excretion of endogenous oxalate by rats is markedly increased in vitamin B6 deficiency. This effect can be enhanced by dietary supplementation with glycine, deoxypyridoxine, or isonicotinic acid hydrazide.

Deoxypyridoxine toxicity can be overcome by serine or glycine supplementation suggesting that deoxypyridoxine interferes with the availability of these amino acids.

REFERENCES

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