

# Identification of the Forms of Vitamin B<sub>6</sub> Present in the Culture Media of "Vitamin B<sub>6</sub> Control" Mutants

WALTER B. DEMPSEY AND LARRY J. ARCEMENT

*Microbiology, Genetics and Biochemistry Unit, Veterans Administration Hospital, and Department of Biochemistry, The University of Texas Southwestern Medical School, Dallas, Texas 75216*

Received for publication 19 April 1971

An *Escherichia coli* mutant resistant to isoniazid (WG497) contained 0.6  $\mu$ mole of extracellular pyridoxamine and pyridoxamine phosphate in the early stationary phase. A suppressed lysine mutant (AT1024) contained 1.4  $\mu$ moles of pyridoxal phosphate under the same conditions. The internal concentration of vitamin B<sub>6</sub> was one-half of normal for AT1024 and increased fivefold for WG497.

Two mutants of *Escherichia coli* which appear to have mutations in the regulation of vitamin B<sub>6</sub> levels have been recently reported. One strain (WG497) derived from *E. coli* B is resistant to high levels of isoniazid (L. J. Arcement, W. Korytnyk, and W. B. Dempsey, *Bacteriol. Proc.*, p. 121, 1968). The other strain, AT1024, derived from *E. coli* K-12, is a genotypic *lys* mutant which is phenotypically *Lys*<sup>+</sup> owing, it is thought, to the overproduction of vitamin B<sub>6</sub> (3). The purpose of this report is to identify the nature of the forms of vitamin B<sub>6</sub> found in the culture media after growth of these mutants.

Wild-type *E. coli* B (WG1) and WG497 were grown in glucose minimal medium (5). AT1024 (*thr-4, leu-8, proA2, thi-1, strA20 lys9, F*<sup>-</sup>) and its parent strain AB712 (*thr-4, leu-8, proA2, thi-1, strA20, F*<sup>-</sup>) were grown in glucose minimal medium containing L-proline (160 mg/liter), L-threonine (40 mg/liter), L-leucine (40 mg/liter), and thiamine (0.2  $\mu$ g/liter). WG8004 (a phage-resistant derivative of the wild-type K-12 strain ATCC 14948) was grown in glucose minimal medium (5).

For growth experiments reported here, a 50- to 100-ml portion of medium was inoculated with the appropriate strain and incubated overnight at 37 C with vigorous shaking. In the morning, the cells were centrifuged, washed once with 20 ml of 0.9% NaCl, and then used to inoculate 1 liter of medium. The organisms were grown in their respective media until the cells appeared to just stop doubling at an exponential rate. For identification of vitamin B<sub>6</sub> compounds, portions of the cultures were then centrifuged for 10 minutes at 5,000  $\times$  g at room temperature, and the su-

pernatant fluid was passed through a 0.45- $\mu$ m nitrocellulose filter. A 10-ml amount of this filtrate was diluted to 25 ml with water, and a portion was applied to the sequential cation-anion exchange columns described by Bain and Williams (2). Elution was as described by those authors (2), and identification and quantitation of vitamin B<sub>6</sub> were by yeast bioassay (1) by using the modifications previously described (4). The various forms of vitamin B<sub>6</sub> were identified by comparison of their elution pattern with that of known compounds (Fig. 1).

The distribution of vitamin B<sub>6</sub> in several culture samples is shown in Table 1. These measurements were made by the methods previously described (4) on separate cultures similarly grown and harvested. We found during these studies that AT1024 and AB712 stopped exponential growth at a cell density of 0.3 to 0.4 mg/ml, in other words before reaching maximum cell density for the amount of glucose supplied. In this state, AT1024 continued to synthesize vitamin B<sub>6</sub> for several hours after growth had stopped. The other strains grew to a cell density of 1 mg/ml before ceasing growth and net vitamin B<sub>6</sub> synthesis.

The results of these analyses show that the two presumed control mutants are different from their respective wild-type *E. coli* strains both in the amounts of vitamin B<sub>6</sub> found in the medium and in the amounts found in the cells. The results also show that the two mutants are different from each other in the amounts of vitamin B<sub>6</sub> in the cells and in the kinds of vitamin B<sub>6</sub> found in the medium. A very significant difference between the two mutants can be clearly seen if the

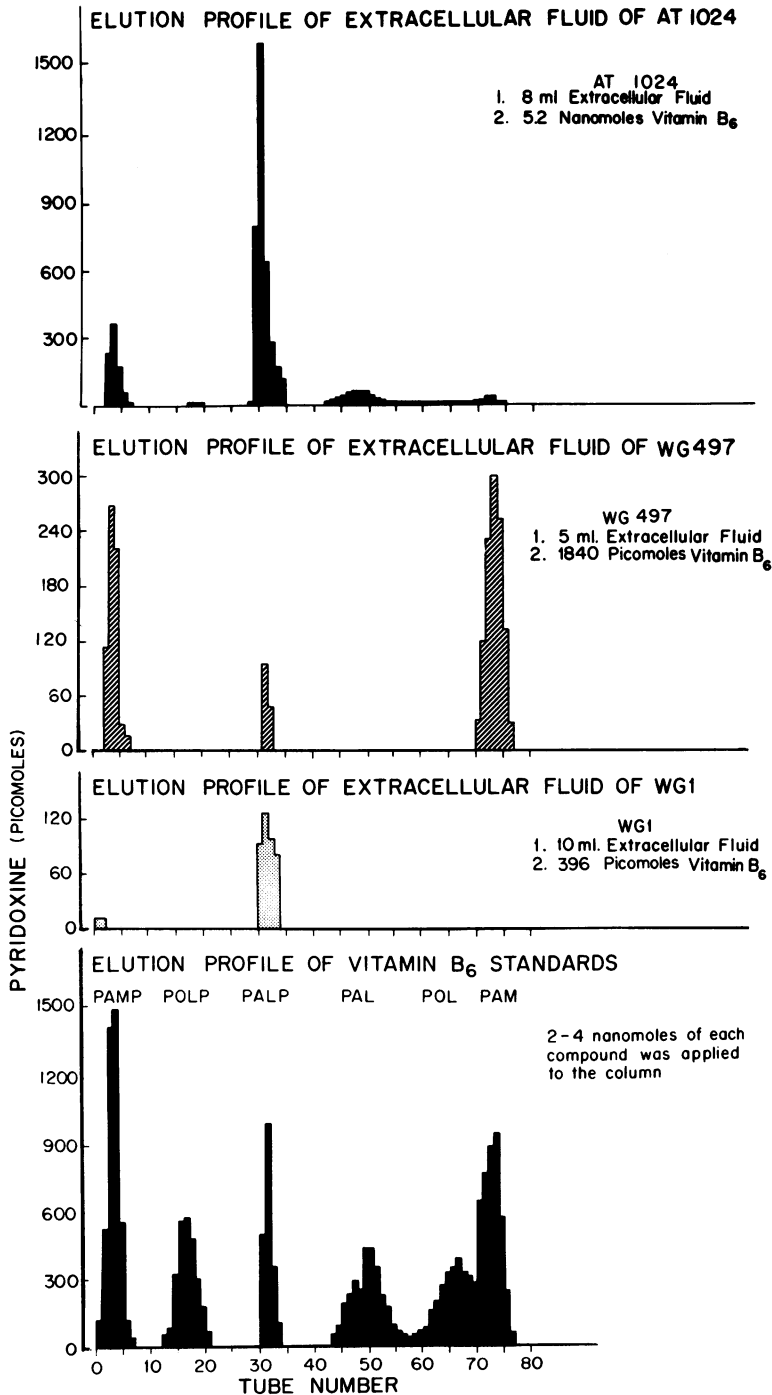


FIG. 1. Patterns of elution of vitamin B<sub>6</sub> compounds. In each of the three experiments shown, the number 1 refers to the net amount of cell-free culture medium applied to the columns and the number 2 refers to the total amount of vitamin B<sub>6</sub> applied. The abbreviations used for the known compounds are: PAMP, pyridoxamine-5'-phosphate; POLP, pyridoxol-5'-phosphate; PALP, pyridoxal-5'-phosphate; PAM, pyridoxamine; POL, pyridoxol; PAL, pyridoxal.

TABLE 1. Total nanomoles of vitamin B<sub>6</sub> per milliliter of culture containing 1 mg (dry weight) of cells per milliliter during the early stationary phase

Sample analyzed	<i>E. coli</i> B		<i>E. coli</i> K-12		
	WG497	WG1	WG8004	AB712	AT1024
Culture .....	1.5 ± 0.2 <sup>a</sup>	0.53 ± 0.10	0.57 ± 0.04	0.50 ± 0.08	1.9 ± 0.3
Cell-free culture medium .....	0.73 ± 0.1	0.16 ± 0.04	0.25 ± 0.03	0.22 ± 0.06	1.5 ± 0.2
Cells .....	0.74 ± 0.08	0.37 ± 0.05	0.32 ± 0.03	0.29 ± 0.06	0.44 ± 0.05
Toluene extract of cells .....	0.27 ± 0.04	0.05 ± 0.008	0.12 ± 0.04	0.11 ± 0.01	0.066 ± 0.04

<sup>a</sup> Standard deviations are shown.

TABLE 2. Extracellular and toluene-extractable pool concentrations of vitamin B<sub>6</sub> in cells and in the medium

Strain no.	Strain	Cell (μM)	Medium (μM)	Cell/ medium
WG497	B	90 ± 10	0.73 ± 0.1	123
WG1	B	17 ± 3	0.16 ± 0.04	106
WG8004	K-12	40 ± 3	0.25 ± 0.03	160
AB712	K-12	37 ± 3	0.22 ± 0.06	168
AT1024	K-12	22 ± 3	1.5 ± 0.2	14.6

data of Table 1 are used to calculate the molar concentrations of vitamin B<sub>6</sub> both in the cells and in the medium. In this calculation, we assume (i) that all forms of vitamin B<sub>6</sub> are equally diffusible, (ii) that 3 ml of cell water is associated with 1 g of dry cell mass, and (iii) that toluene-extractable vitamin B<sub>6</sub> is identical with the free or unbound vitamin B<sub>6</sub> of the cell. The results of these calculations point out clearly that the ratio of the toluene-extractable pool to external vitamin B<sub>6</sub> is nearly the same for WG497 and wild-type *E. coli* B, whereas in AT1024 the ratio is greatly reduced (Table 2). One interpretation of these findings is that WG497 is a true "control" mutant in which the increase in extracellular vitamin B<sub>6</sub> is merely a reflection of an increased intracellular vitamin B<sub>6</sub> arising perhaps from a mutation in an enzyme needed for regulating the vitamin B<sub>6</sub> level of the cell. By this type of reasoning, AT1024 is less likely to be a

"control" mutant because the increase in extracellular vitamin B<sub>6</sub> does not reflect any increase in cellular vitamin B<sub>6</sub>. Instead the cellular vitamin B<sub>6</sub> is one-half that found in both prototrophic and genetically related K-12 strains. There would be a likely explanation for this if AT1024 had altered the permeability of its membrane.

This work was supported by Public Health Service grants AM14157 and A104369 from the National Institute of Arthritis and Metabolic Diseases and the National Institute of Allergy and Infectious Diseases, respectively.

We especially want to thank A. L. Taylor for generously providing strains AB712 and AT1024 and some of his data before publication.

#### LITERATURE CITED

- Atkin, L., A. A. Schultz, W. L. Williams, and C. N. Frey. 1943. Yeast microbiological methods for determination of vitamins. *Pyridoxine*. *Ind. Eng. Chem., Anal. Ed.* **15**:141-144.
- Bain, J. A., and H. L. Williams. 1960. Concentrations of B<sub>6</sub> vitamers in tissues and tissue fluids, p. 275-293. *In* E. Roberts, C. F. Baxter, A. VanHarreveld, C. A. G. Wiersma, W. R. Adey, and K. F. Killiam (ed.), *Inhibition in the nervous system and gamma-aminobutyric acid*. Pergamon Press, New York.
- Bukhari, A. I., and A. L. Taylor. 1971. Mutants of *Escherichia coli* with a growth requirement for either lysine or pyridoxine. *J. Bacteriol.* **105**:988-998.
- Dempsey, W. B. 1965. Control of pyridoxine biosynthesis in *Escherichia coli*. *J. Bacteriol.* **90**:431-437.
- Dempsey, W. B. 1969. Characterization of pyridoxine auxotrophs of *Escherichia coli*: chromosomal position of linkage group I. *J. Bacteriol.* **100**:295-300.