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# Fruits and vegetables: there is no substitute[1,2]

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The current recommended dietary allowance for vitamin C (ascorbate) is 60 mg/d, based on prevention of the deficiency disease scurvy, with a margin of safety (1). However, the basis of this and other recommended dietary allowances has been questioned (2–4). In light of new information, the Food and Nutrition Board of the National Academy of Sciences is considering how the recommendations should be revised (5). I believe strongly that new recommendations should account for the following (3, 4):

1) Vitamin biochemical and molecular function in relation to vitamin concentration.
2) Availability of the vitamin in the diet.
3) Steady state vitamin concentration in plasma as a function of dose.
4) Steady state vitamin concentration in tissues as a function of dose.
5) Vitamin bioavailability.
6) Vitamin excretion.
7) Vitamin safety and adverse effects.
8) Beneficial effects in relation to dose: direct effects and epidemiologic observations.

As above, one inclusive factor for recommendations is availability of the vitamin for consumption. Vitamin C can be consumed in three ways. First, vitamin C is widely distributed in fruits and vegetables, and as such is present in foods endogenously. Second, vitamin C is consumed by a significant minority of the US population as vitamin supplements (6). Third, vitamin C is added exogenously to foods as an additive, usually to prevent oxidation. As an additive, vitamin C itself is often used. However, in some foods the additive is erythorbic acid, or isoascorbic acid, the stereoisomer of vitamin C at the fifth carbon position. Erythorbic acid (erythorbate) is used widely in cured meats (luncheon meats) and in some beverages.

Could erythorbate ingestion affect recommendations for vitamin C ingestion? The answer depends on whether erythorbate can replace vitamin C. Does erythorbate act like vitamin C biologically and physiologically? Does it compete with vitamin C for absorption but not substitute for it biologically, or is erythorbate entirely independent of vitamin C?

Erythorbate probably cannot prevent scurvy in humans (7). Although results from animal studies have been available for many years, it is unknown whether animals and humans are comparable with respect to erythorbate metabolism. Part of the problem in many studies was that it was difficult to distinguish measurements of ascorbate from those of erythorbate.

With HPLC, it became possible to measure both compounds distinctly (8). Using this assay, Sauberlich et al (9) provide several new answers about erythorbate in humans in this issue of the Journal. Both erythorbate and ascorbate are absorbed. Although erythorbate does not interfere with ascorbate absorption, ascorbate interferes with erythorbate absorption. This may be because ascorbate has a higher affinity for its transporter than does erythorbate.

Functional tests of ascorbate action are very difficult to perform in human subjects. Thus, there is no in vivo functional test available to investigate whether erythorbate can spare ascorbate. Nevertheless, Sauberlich et al found that erythorbate did not displace ascorbate nor change ascorbate absorption. Erythorbate did not cause ascorbate concentrations to change, particularly to increase, so that there was no apparent sparing of ascorbate by erythorbate. Sauberlich et al also report that erythorbate was accumulated by monocytes but not by polocytes. Although the ascorbate transporter has not yet been isolated, these data suggest that the transporter may have more than one subtype (10–12).

Even though erythorbate does not replace ascorbate, it is possible that ascorbate plasma measurements can be confounded by erythorbate, because many assays cannot distinguish between the two. In particular, ascorbate might be overestimated if erythorbate were also present. The solution to this problem is based on data that erythorbate is very rapidly cleared. In volunteers given 200–300 mg erythorbate in three meals, no erythorbate was detected the following morning (13). If fasting morning ascorbate samples are obtained, the confounding effect of erythorbate is probably eliminated (9, 13).

Is erythorbic acid safe? Erythorbate had no antagonistic action with vitamin C, so in this regard erythorbate is safe. No adverse effects were reported by Sauberlich et al. It is unknown whether erythorbate has adverse effects on oxalate or urate excretion. Ascorbate does not affect oxalate or urate excretion at doses $\leq$ 500 mg (3), and this amount of erythorbate would be difficult to ingest in foods. If ascorbate and erythorbate behave similarly in the urinary system, then erythorbate should not have adverse consequences on kidney stone formation.

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The diet of US citizens varies widely. Although the average diet probably does not contain 200 mg erythorbate, it is possible to consume 200–300 mg/d by food choice (13). The data in this article indicate that erythorbate does not influence vitamin C. The two act independently, erythorbate cannot replace vitamin C, and erythorbate had no effect on vitamin C utilization. Stated another way, for many reasons, ham and bacon cannot replace fruits and vegetables.

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