

# Calcium absorption from kale<sup>1-3</sup>

Robert P Heaney and Connie M Weaver

**ABSTRACT** Absorption of calcium from intrinsically labeled kale was measured in 11 normal women and compared in these same subjects with absorption of calcium from labeled milk. The average test load was 300 mg. Fractional calcium absorption from kale averaged  $0.409 \pm 0.101$  ( $\bar{x} \pm SD$ ) and from milk,  $0.321 \pm 0.089$  ( $P < 0.025$ ). In contrast with the poor absorption previously reported for spinach calcium, kale, a low-oxalate vegetable, exhibits excellent absorbability for its calcium. *Am J Clin Nutr* 1990;51:656-7.

**KEY WORDS** Calcium absorption, kale, bioavailability

## Introduction

We and others (1-4) have reported that the calcium of spinach is very poorly absorbed in both humans and animals. Presumably the oxalate content of spinach is partly responsible. It seemed important, therefore, to test calcium absorbability from low-oxalate vegetables. For this purpose we chose kale.

## Subjects and methods

### Subjects

Subjects were 11 healthy premenopausal women, aged 20-45 y, screened to exclude not only concurrent illnesses but both excessive leanness and adiposity. Where it was possible to make the determination, women were tested in the follicular phase of the menstrual cycle and only after a negative pregnancy test (performed on the same morning as the absorption measurement). The study protocol was approved by the Institutional Review Board of Creighton University and each subject gave informed consent.

### Protocol

Eleven subjects were studied twice, 8 wk apart; milk was the calcium source at the first meal and kale at the second. (Because of problems with isotope availability, we did not consider it practical to randomize the sequence of test substances.) The kale was first cooked, then pureed, then stored frozen in individually weighed serving containers and was warmed in a microwave oven just before serving. The serving size was 150 g, found on analysis to contain 288 mg calcium. The milk test load was calculated to produce a comparable load and was found on analysis to contain 312 mg calcium. Test meals were consumed under supervision of a project nurse. Both the milk and the kale containers were rinsed with distilled water after

the contents were consumed, and the rinsings were consumed as well.

### Labeling

Milk was labeled by adding <sup>47</sup>Ca as high-specific-activity <sup>47</sup>CaCl<sub>2</sub>. After the milk was mixed, quantities of labeled milk calculated to contain ~300 mg of calcium were weighed on a top-loading analytical balance (precision, 10 mg) into tared serving containers, and the labeled milk was allowed to equilibrate in the refrigerator for 16 h before being served.

Kale was labeled by growing the plants hydroponically by techniques described elsewhere (2, 5) in a defined synthetic medium to which high-specific-activity <sup>45</sup>CaCl<sub>2</sub> was added. Thus, uniform distribution of the tracer throughout the kale tissue was assured. Labeled kale was grown and harvested at Purdue University and was blanched, frozen, and shipped frozen to Creighton for dose preparation and tracer analysis. Tracer doses were ~0.11 MBq for both the milk and kale calcium. The kale was found by analysis to contain 1.92 mg Ca/g. This value is quite close to values for calcium content of kale as found in standard diet tables.

### Analytical methods

Absorption was measured from the concentration of the orally administered isotope in a blood sample taken at precisely 5 h after the ingestion of the test load, with fractional absorption calculated according to methods described elsewhere (6, 7). As also described elsewhere (8), the calcium test load was ingested in the middle of a neutral meal consisting of two pieces of white-bread toast with butter or margarine and coffee, tea, or diet cola (without sugar).

Serum calcium was measured by atomic-absorption spectrophotometry (model 2380, Perkin-Elmer, Norwalk, CT), <sup>45</sup>Ca was measured by liquid scintillation counting (LS-3150T counter, Beckman Instruments, Inc, Irvine, CA), and <sup>47</sup>Ca was measured by  $\gamma$  emission (Gamma 300 System, Beckman) with the window adjusted to eliminate <sup>47</sup>Sc radiation.

<sup>1</sup> From Creighton University, Omaha, NE, and the Department of Foods and Nutrition, Purdue University, West Lafayette, IN.

<sup>2</sup> Supported by NIH grant AR39221 (Specialized Center of Research in Osteoporosis).

<sup>3</sup> Address reprint requests to RP Heaney, Creighton University, Omaha, NE 68178.

Received January 23, 1989.

Accepted for publication May 3, 1989.

### Statistical methods

The investigational design called for a pair-wise comparison within subject. Accordingly the standard paired *t* test was used for analysis (9).

### Results


Fractional absorption of milk calcium was  $0.321 \pm 0.089$  ( $\bar{x} \pm$  SD) and fractional absorption of calcium from kale was  $0.409 \pm 0.101$ . Absorption of kale calcium was excellent in all 11 subjects, with no value being  $< 30\%$ . In 9 of the 11 subjects kale calcium absorbability was higher than milk calcium. The mean within-subject difference was  $0.088 \pm 0.033$  ( $\bar{x} \pm$  SEM;  $P < 0.025$ ).

### Discussion

Many dark-green leafy vegetables are known to have relatively high calcium nutrient densities and, spinach excepted (1), have been presumed to be good sources of calcium. Animal studies have generally supported this assumption as have a few balance studies in humans. But balance studies in humans are prey to large errors, and hence the question of absorbability of calcium from these sources has remained open. This report is the first to our knowledge that describes in humans the absorbability of calcium for kale by use of modern isotope methods and an intrinsically labeled food source.

We selected kale specifically because it was a low-oxalate vegetable that nevertheless contains some of the pectins and other plant fibers that might be typical of other greens. For example, the total fiber content of kale (2.6 g/100 g) is similar to that of spinach (2.3 g/100 g) (10). Kale also has approximately the same uronic acid content as spinach (11). Further, kale seemed a suitable choice because it is one of the varieties of *Brassica oleracea*, several of the members of which are known to be rich in calcium and are commonly recommended to the general public as good calcium sources (eg, broccoli). Further, turnip, collard, and mustard, the greens of which are also rich in calcium, are also members of this same *Brassica* genus. Hence

kale seemed a good surrogate for a large class of low-oxalate, high-calcium vegetable greens.

We interpret our findings as evidence of good bioavailability for kale calcium and probably for the class of low-oxalate vegetable greens as well. The somewhat higher absorbability found for kale relative to milk is probably of little practical nutritional importance. The mean value we found for kale had a confidence interval that extensively overlaps the range we commonly find for milk. Hence the actual degree of superiority is likely to be small. When tested in rats, absorption from intrinsically labeled kale was found to be similar to absorption from a  $^{45}\text{Ca}$ -labeled casein test meal (2). It does, however, seem clear that greens such as kale can be considered to be at least as good as milk in terms of their calcium absorbability. 

We gratefully acknowledge the professional assistance of Annette LeRoy, Rita Ryan, Sharilyn Hinders, and Janet Barger-Lux in the conduct of this project.

### References

1. Heaney RP, Weaver CM, Recker RR. Calcium absorbability from spinach. *Am J Clin Nutr* 1988;47:707-9.
2. Weaver CM, Martin BR, Ebner JS, Krueger CA. Oxalic acid decreases calcium absorption in rats. *J Nutr* 1987;117:1903-6.
3. Wien EM, Schwartz R. Comparison of in vitro and in vivo measurements of dietary calcium exchangeability and bioavailability. *J Nutr* 1983;113:388-93.
4. Ponerros-Schneier AG, Erdman JW Jr. Bioavailability of calcium from sesame seeds, almond powder, whole wheat bread, spinach and nonfat dry milk in rats. *J Food Sci* 1989;54:150-3.
5. Weaver CM. Intrinsic mineral labeling of edible plant: methods and uses. *CRC Crit Rev Food Sci Nutr* 1985;23:75-101.
6. Heaney RP, Recker RR. Estimation of true calcium absorption. *Ann Intern Med* 1985;103:516-21.
7. Heaney RB, Recker RR. Estimating true fractional calcium absorption. *Ann Intern Med* 1988;108:905-6 (letter).
8. Heaney RP, Smith KT, Recker RR, Hinders SM. Meal effects on calcium absorption. *Am J Clin Nutr* 1989;49:372-6.
9. Snedecor GW, Cochran WG. *Statistical methods*. 6th ed. Ames, IA: Iowa State University Press, 1973.
10. Lanza E, Butrum RR. A critical review of food fiber analysis and data. *J Am Diet Assoc* 1986;86:732-40.
11. James WPT, Branch WJ, Southgate DAT. Calcium binding by dietary fiber. *Lancet* 1978;1:638-9.

