Calcium absorbability from milk products, an imitation milk, and calcium carbonate[1-3]

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ABSTRACT Whole milk, chocolate milk, yogurt, imitation milk (prepared from dairy and nondairy products), cheese, and calcium carbonate were labeled with ^{45}Ca and administered as a series of test meals to 10 healthy postmenopausal women. Carrier Ca content of the test meals was held constant at 250 mg and subjects fasted before each meal. The absorbability of Ca from the six sources was compared by measuring fractional absorption by the double isotope method. The mean absorption values for all six sources were tightly clustered between 21 and 26% and none was significantly different from the others using one-way analysis of variance. We conclude that none of the sources was significantly superior or inferior to the others. *Am J Clin Nutr* 1988;47:93–5.

KEY WORDS Calcium, calcium absorption, milk, dairy products, calcium carbonate

Introduction

Inadequate calcium intake is widely held to be an important factor in postmenopausal bone loss (1), and it was shown that increasing the intake of Ca in postmenopausal women mitigates this loss (2). Not all studies have shown the same beneficial effect, particularly in the immediate postmenopause (3, 4). However, there remains widespread interest in assuring adequate Ca intake at critical stages in a woman's life. Dairy products constitute the principal food source of Ca, ~72% of total Ca content of the typical US diet (5). Although the Ca content of many dairy products is known, the effectiveness of Ca intake is determined not only by Ca content but also by the intrinsic absorbability of that Ca present in various food sources (6), individual differences in absorption efficiency (7), and miscellaneous influences that include drugs, disease states, and other nutrients (8).

Popular nutrition literature suggests that absorption of Ca from chocolate milk may be impaired by the oxalate present in chocolate and that Ca may be more readily absorbed from products subjected to partial digestion by bacteria during manufacture. This study compares the relative absorbability of several different Ca sources—whole milk, chocolate milk, yogurt, imitation milk, cheese, and calcium carbonate—by measuring fractional absorption following the ingestion or radiolabeled test meals by healthy middle-aged women.

Subjects and methods

Design

Absorbability of Ca from four different dairy products, an imitation milk, and calcium carbonate was compared in healthy female subjects. A total of 60 fractional absorption studies were performed, with each of 10 subjects receiving six different ^{45}Ca-labeled test meals on separate occasions separated by 7 or 14 d. The six test meals were administered in the same order to each subject as a concession to convenience in radiolabeling. Subjects fasted overnight before each test meal and continued to fast for 2 h following its ingestion.

Subjects

Ten ostensibly healthy women were recruited to participate in the study. Nine of the subjects were age 51–70 y (mean 61.1 y) and one was 40 y. All were white and all were postmenopausal. The subjects were screened for the presence of illness or treatments known to influence Ca absorption or metabolism. Significant abnormalities were also judged to be absent from serum multichannel biochemical screening examinations and spine radiographs. The protocol for the study was approved by the University Institutional Review Board and informed consent procedures were followed with each subject.

Test meals

Absorption studies involved radiolabeled portions of whole milk, chocolate milk, yogurt, imitation milk, cheese, and $CaCO_3$. The imitation milk was Meadow Fresh Imitation Low Fat Dry Milk (Meadow Fresh Farms, Inc, Salt Lake City, UT), which is manufactured from dairy and nondairy ingredients including

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Received December 22, 1986.

Accepted for publication March 3, 1987.

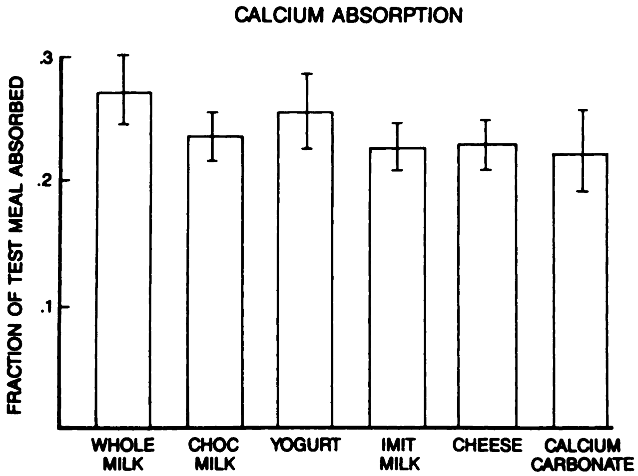

FIG 1. Mean values for the fractional absorption of six ^{45}Ca-labeled test meals. The error bars represent 1 SEM.

sweet dairy whey, corn syrup solids, coconut oil, sodium caseinate, and nonfat milk.

Aliquots of whole milk, chocolate milk, and reconstituted imitation milk were labeled by placing carefully measured quantities of ^{45}Ca in the solutions and equilibrating under refrigeration overnight. The yogurt was made from scalded 2% milk and yogurt culture (Dannon Yogurt Co, White Plains, NY); ^{45}Ca was added immediately before incubation of the mixture in a yogurt maker designed for home use. The cheese was made by precipitating the casein in whole milk with rennet according to the method of Kosikowski (9) as modified for the preparation of small quantities of cheese in a laboratory setting. ^{45}Ca was added to the milk at the beginning of the procedure. The product resembled cream cheese in consistency and taste and was judged to be quite palatable. The $CaCO_3$ was labeled by adding ^{45}Ca to a solution of calcium chloride and then precipitating the carbonate salt with sodium carbonate. The $CaCO_3$ powder was harvested and placed in single-dose capsules.

To eliminate variation in carrier Ca content, all of the test meals contained 6.25 mmol of elemental Ca, as determined using atomic absorption spectrophotometry (Model 2380, Perkin-Elmer Corp, Norwalk, CT) (10). The first test meal (whole milk) contained 5 μCi of ^{45}Ca, and the radiolabel was increased by 1 μCi for each subsequent test meal to compensate for retention of ^{45}Ca from previous tests in the series.

Analytical methods

Fractional absorption of Ca was determined by an adaptation of the double isotope method introduced by Bronner (11) and modified by DeGrazia et al (12). Both the test material and the pool into which is was absorbed were labeled with ^{45}Ca. Fourteen days before the first test meal, 2.5 μCi of ^{45}Ca was injected intravenously. The specific activity of ^{45}Ca was determined on a serum specimen collected 22 h later. This value was used as the 100% absorption value in subsequent calculations of fractional Ca absorption for the entire series of Ca-absorption studies in each subject.

Immediately before each test meal, a serum specimen was collected to measure ^{45}Ca retained from previous tests in the series. Serum and urine specimens were collected immediately before ingestion of each test meal and again exactly 24 h later. The urine specimens were collected to preserve a source of back-up data for calculating fractional absorption. All of the data in this report were generated from determinations on serum specimens. Fractional calcium absorption was expressed as a ratio of the specific activity of ^{45}Ca 24 h after an oral dose (test meal) divided by the specific activity of ^{45}Ca 22 h after the intravenous dose. As reported earlier, fractional absorption measured by this method measures absolute Ca absorption, is not affected by differences in rates of Ca absorption, and produces values identical to absorption measured by the full metabolic balance method (7).

Statistical method

Repeated-measures one-way analysis of variance (13) was used to test for differences in Ca absorbability among the six different sources.

Results

Results of the series of absorption studies are in **Figure 1** and in greater detail in **Table 1**. Mean values for fractional absorption for the six test meals varied from 0.220 to 0.267. Repeated-measures one-way analysis of variance failed to demonstrate significant differences in Ca ab-

TABLE 1
Fractional absorption of ^{45}Ca-labeled test meals containing 250 mg elemental Ca. No significant differences were found in the absorbability of Ca from the six different test meals

Subjects	Whole milk	Chocolate milk	Yogurt	Imitation milk	Cheese	$CaCO_3$
1	0.329	0.276	0.288	0.207	0.270	0.218
2	0.406	0.257	0.365	0.309	0.290	0.313
3	0.279	0.199	0.180	0.193	0.195	0.098
4	0.254	0.202	0.237	0.248	0.190	0.123
5	0.195	0.259	0.251	0.191	0.291	0.366
6	0.134	0.200	0.151	0.209	0.165	0.212
7	0.262	0.204	0.202	0.268	0.271	0.087
8	0.251	0.220	0.328	0.257	0.236	0.273
9	0.211	0.151	0.130	0.101	0.135	0.240
10	0.344	0.351	0.408	0.258	0.244	0.276
Mean	0.267	0.232	0.254	0.224	0.229	0.220
SD	0.079	0.056	0.093	0.057	0.055	0.093

TABLE 2
Aggregate values for multiple studies of fractional absorption in ten healthy middle-aged female subjects

Subject	Mean	SD
1	0.265	0.046
2	0.323	0.054
3	0.191	0.058
4	0.209	0.049
5	0.259	0.065
6	0.179	0.033
7	0.216	0.071
8	0.261	0.038
9	0.161	0.033
10	0.314	0.064

sorbability in the six different test meals ($F = 1.170$, df $= 5, 45$; NS). The Ca in whole milk, chocolate milk, yogurt, imitation milk, cheese, and $CaCO_3$ was absorbed equally well by the group of subjects. As **Table 2** shows, mean values for fractional absorption among the subjects ranged from 0.161 to 0.323, all within the range of values previously reported for healthy postmenopausal women (7).

Discussion

This study shows that Ca from various dairy products is absorbed equally well. A reduction in the absorbability of Ca from chocolate milk was not demonstrated, suggesting that the postulated oxalate effect in chocolate milk can safely be ignored.

No difference was shown between the absorbability of Ca from the imitation milk and the various dairy products. Thus no advantage in terms of fractional absorption of Ca can be claimed for imitation products of this type. It should also be noted that this imitation milk, when reconstituted according to the instructions of the manufacturer, contained substantially less Ca per unit volume than whole milk, 2% low-fat milk, or skim milk.

Higher values for the absorbability of Ca from the processed dairy products, yogurt and cheese, were not demonstrated. Thus, no advantage in terms of fractional absorption of Ca can be claimed for products of this type on the basis of this study. This does not, of course, mean that other bacterial culture methods or other fermented milk products would not have exhibited greater fractional absorption than we found. Nevertheless, a recent paper by Smith et al (14) compared Ca absorption from commercial yogurt and whole milk, both in normal persons and in alactasic subjects, and found no difference between the whole milk and yogurt.

Ca from the dairy products was absorbed at least as well as Ca from $CaCO_3$. The mean absorption value for $CaCO_3$ was the lowest of the six sources and its variance was the highest of the six. Two subjects absorbed < 10% of the carbonate load although they averaged 21 and 24% for the other five sources. There were no other absorption values < 10% for any of the other sources. It is possible therefore that some persons who absorb Ca adequately from food sources are less able to utilize the Ca from $CaCO_3$ than are others.

We wish to thank Prafulla Ravel and Rita Ryan for their assistance in the conduct of this work.

References

1. Office of Medical Applications of Research, National Institutes of Health. Consensus development conference on osteoporosis. JAMA 1984;252:799–802.
2. Recker RR, Saville PD, Heaney RP. The effect of estrogens and calcium carbonate on bone loss in postmenopausal women. Ann Intern Med 1977;87:649–55.
3. Heaney RP. Calcium, bone health, and osteoporosis. In: Peck WA, ed. Bone and mineral research. Annual 4. Amsterdam: Elsevier, 1986:255–301.
4. Riis B, Thomsen K, Christiansen C. Does calcium supplementation prevent postmenopausal bone loss? N Engl J Med 1987;316:173–7.
5. Marston RM, Welsh SO. Nutrient content of the US food supply, 1982. Natl Food Rev 1984;25:7–13.
6. Heaney RP. Calcium bioavailability. Contemp Nut 1986;11(8): 1–2.
7. Heaney RP, Recker RR. Distribution of calcium absorption in middle-aged women. Am J Clin Nutr 1986;43:299–305.
8. Heaney RP, Gallagher JC, Johnston CC, Neer R, Parfitt AM, Whedon GD. Calcium nutrition and bone health in the elderly. Am J Clin Nutr 1982;36:986–1013.
9. Kosikowski F. Cheddar cheese and related types. In: Cheese and fermented milk foods. 2nd ed. Ann Arbor, MI: Edwards Brothers, Inc, 1977:228–58.
10. Trudeau DL, Freier EF. Determination of calcium in urine and serum by atomic absorption spectrophotometry (AAS). Clin Chem 1967;13:101–14.
11. Bronner F. Experimental studies of calcium absorption in man. Bibl Nutr Dieta 1962;3:22–31.
12. DeGrazia JA, Ivanovich P, Fellows H, Rich C. A double isotope method for measurement of intestinal absorption in calcium in man. J Lab Clin Med 1965;66:822–9.
13. Winer JB. Statistical principles in experimental design. 2nd ed. New York: McGraw-Hill Book Company, 1971.
14. Smith TM, Kohlars JC, Savaiano DA, Levitt MD. Absorption of calcium from milk and yogurt. Am J Clin Nutr 1985;42:1197–200.