J. Dairy Sci. 88:2295–2301

Bioavailability of Vitamin D from Fortified Process Cheese and Effects on Vitamin D Status in the Elderly*

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ABSTRACT

We conducted 2 studies to determine the effect of vitamin D-fortified cheese on vitamin D status and the bioavailability of vitamin D in cheese. The first study was designed to determine the effect of 2 mo of daily consumption of vitamin D_3-fortified (600 IU/d) process cheese on serum 25-hydroxyvitamin D (25-OHD), parathyroid hormone (PTH), and osteocalcin (OC) concentrations among 100 older (≥60 yr) men and women. Participants were randomized to receive vitamin D-fortified cheese, nonfortified cheese, or no cheese. Serum levels of 25-OHD, PTH, and OC were measured at the beginning and end of the study. There were no differences in 25-OHD, PTH, or OC after 2 mo of fortified cheese intake. The vitamin D-fortified cheese group had a greater decrease in 25-OHD than other groups, due to higher baseline 25-OHD. A second study was conducted to determine whether the bioavailability of vitamin D_2 in cheese (delivering 5880 IU of vitamin D_2/56.7-g serving) and water (delivering 32,750 IU/250 mL) is similar and whether absorption differs between younger and older adults. The second study was a crossover trial involving 2 groups of 4 participants each (younger and older group) that received single acute feedings of either vitamin D_2-fortified cheese or water. Serial blood measurements were taken over 24 h following the acute feeding. Peak serum vitamin D and area under the curve were similar between younger (23 to 50 yr) and older (72 to 84 yr) adults, and vitamin D_2 was absorbed more efficiently from cheese than from water. These studies demonstrated that vitamin D in fortified process cheese is bioavailable, and that young and older adults have similar absorption. Among older individuals, consuming 600 IU of vitamin D_3 daily from cheese for 2 mo was insufficient to increase serum 25-OHD during limited sunlight exposure.
(**Key words:** process cheese, vitamin D, elderly, bioavailability)

Abbreviation key: AI = adequate intake, **25-OHD** = 25-hydroxyvitamin D, **OC** = osteocalcin, **PTH** = parathyroid hormone.

INTRODUCTION

Vitamin D is essential in maintaining blood calcium concentrations within a narrow physiological range. Although vitamin D is typically classified as a fat-soluble vitamin, it actually functions as a hormone in the body (Dabek, 1990). Vitamin D is not technically classified as an essential nutrient because it can be manufactured by the body through exposure of the skin to the ultraviolet rays of the sun. Exposure to ultraviolet radiation converts 7-dehydrocholesterol to previtamin D_3, which is then converted to vitamin D_3 through thermal isomerization. Vitamin D_3 is transported to the liver where it is hydroxylated to 25-hydroxyvitamin D (**25-OHD**). Serum concentrations of 25-OHD are often used as an indicator of vitamin D status.

There are limited dietary sources of vitamin D, including cod liver oil, fatty fish such as salmon, as well as small amounts found in egg yolks (Holmes and Kumerow, 1983). Fortified dietary sources of vitamin D include milk and, more recently, some juice products. Regular exposure to sunlight is the usual way for meeting vitamin D requirements. If one's exposure to sunlight is limited, vitamin D deficiency may develop, and the need for supplementation, either as an oral supplement or through innovations in food fortification is compelling.

It is widely accepted that adequate amounts of vitamin D are crucial for healthy bone development, maintenance of bone density and bone strength, and prevention of osteoporosis. A deficiency of vitamin D may re-

Received March 17, 2005.
Accepted April 15, 2005.
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*Published with the approval of director of the South Dakota Agricultural Experiment Station as Publication Number 3409 of the Journal Series. This research was sponsored, in part, by the National Dairy Council, Rosemont, IL.

sult in osteomalacia and rickets. Osteomalacia refers to the softening of the bones in adults, and rickets is the syndrome that affects deficient children, causing bowed legs, joint deformities, and poor growth and development (Bronner, 1976). The needed amount of vitamin D is expressed as an adequate intake (**AI**), rather than a required daily amount, because it is difficult to quantify the amount of vitamin D that is produced by the body with exposure to sunlight. The AI for individuals under age 50 is 200 IU/d, for 51 to 70 yr olds is 400 IU/d, and for those over 70 yr of age is 600 IU/d (Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, 1997).

The elderly population is at increased risk of developing vitamin D deficiency and associated bone disease due to decreased sun exposure and a reduced ability to adequately synthesize vitamin D endogenously (Gloth et al., 1995). In addition, their dietary intakes may be lower because of declining milk consumption (Kevin, 1997). However, it is not merely the elderly population who should consider supplementation. Vitamin D supplementation is a feasible option for those individuals living in northern cities, particularly during the winter months, when their exposure to sunlight is significantly reduced.

Due to the concern for adequate intakes of vitamin D and the change in food consumption trends, it is apparent that there is a need for a larger range of food products that can provide the necessary amounts of vitamin D in the diet. A previous study was conducted to develop techniques for manufacturing pasteurized process cheese fortified with vitamin D (Upreti et al., 2002). The objectives of this research were to determine the effect of consumption of vitamin D-fortified process cheese on serum 25-hydroxyvitamin D (25-OHD), parathyroid hormone (**PTH**), and osteocalcin (**OC**) concentrations among the elderly, and the bioavailability of vitamin D from fortified process cheese and water.

MATERIALS AND METHODS

Study 1

One hundred ten older individuals (≥60 yr) were enrolled in a partially double-blind, randomized clinical trial designed to determine the effect of 2 mo of daily vitamin D-fortified process cheese consumption, delivering 600 IU of vitamin D per day, on changes in serum 25-OHD, PTH, and OC concentrations. The intervention groups consisted of one group that received 85 g of process cheese fortified with vitamin D_3 (delivering 600 IU/d), one group that received process cheese without vitamin D_3, and a control group that received no process cheese. If couples were enrolled in the study, randomization was for the pair to avoid confusion that might occur if each participant were randomized to a different cheese group. The placebo group (process cheese without addition of vitamin D) was included to allow for the determination of the specific effect of vitamin D fortification. The control group (no cheese) was included to allow for the determination of the overall effect of the process cheese, with its high protein, calcium, and phosphorus content, on the outcome measurements. Compliance was measured by having participants save all remaining process cheese they were unable to eat, which was then picked up by study personnel when the new cheese was delivered every 2 wk. The leftover cheese was returned to the South Dakota State University dairy plant to be weighed and recorded on each participant's chart.

Subjects were recruited from local community organizations. Inclusion criteria included no routine use of vitamin or mineral supplements, a total serum cholesterol at baseline of less than 240 mg/dL, ability to consume and digest cheese without gastrointestinal difficulty, and willingness and ability to remain in the Great Plains region of the country during the study period. The study was conducted during the winter months to minimize sunlight exposure.

Fasting blood samples were collected from all study participants at the time of enrollment and after the 2-mo intervention. A 10-mL serum sample was drawn, separated, aliquoted, and frozen at –70°C for the duration of the study, at which point the samples were analyzed in one batch for total 25-OHD ($25\text{-}OHD_2$ + $25\text{-}OHD_3$; Hollis et al., 1993) and PTH concentrations, using the DiaSorin kit (normal range for PTH of 13 to 54 pg/mL), by the laboratory of Bruce Hollis (Medical University of South Carolina). Osteocalcin concentrations were measured by Clinical Laboratories of the Midwest in Sioux Falls, SD. A blood lipid panel was obtained to determine the effect of cheese consumption on blood lipids.

Three-day diet records were completed by each of the participants at baseline, including each individual's use of vitamins or supplements. The records were sent to each subject with instructions and a list of size estimates to provide approximate food intake amounts. Subjects were asked to record their diets during 2 weekdays and 1 weekend day and return the record to study personnel. The diet records were reviewed and analyzed using Nutritionist Pro software (1998 edition; First Data Bank, San Bruno, CA). Mean total vitamin D intakes were calculated as the sum of dietary vitamin D from the 3-d record at baseline and the average amount obtained from cheese. Participants were weighed (SECA digital scale, model #770; SECA, Hanover, MD) to the nearest 0.1 kg, and changes were compared among groups to determine if there was a significant