1. SOURCES OF VITAMIN K

Vitamin K is a fat-soluble vitamin that may have a protective role against age-related bone loss. Vitamin K refers to a family of compounds with a common chemical structure, 2-methyl-1,4-napthoquinone (Fig. 1). Phylloquinone, or vitamin K<sub>1</sub>, is present in foods of plant origin. Green, leafy vegetables contain the highest content of phylloquinone, and contribute up to 60% of total phylloquinone intake (1,2). Certain plant oils, margarine, spreads, and salad dressings, derived from plant oils, are also important dietary sources of phylloquinone, whereas animal fat sources, such as butter, are not (3,4). Recently, phylloquinone has been added in varying amounts to some dietary supplements. During the process of hydrogenation of certain phylloquinone-rich vegetable oils, phylloquinone is converted to 2',3'-dihydrophylloquinone, which differs from the parent form by saturation of the 2',3' double bond of the phytyl side chain (5) (Fig. 1). Dihydrophylloquinone is found exclusively in hydrogenated phylloquinone-rich vegetable oils, which are widely used by industry in food preparation because of their physical characteristics and oxidative stability.

Bacterial and other forms of vitamin K, referred to as the menaquinones or vitamin K<sub>2</sub>, differ in structure from phylloquinone in their 3-substituted lipophilic side chain. The major menaquinones contain 4–10 repeating isoprenoid units, indicated by MK-4 to MK-10; forms of up to 13 isoprenoid groups have been identified (Fig. 1). Of the limited data available, MK-6 to MK-9 are found in significant amounts in cow livers, some animal meats, and in foods whose preparation involves bacterial fermentation, such as cheese and fermented soybean products (6–8). Very little is known about the contribution of dietary menaquinones to overall vitamin K nutrition, and although it is a generally held belief that approx 50% of the daily requirement for vitamin K is supplied by the gut flora, there is insufficient experimental evidence to support this conviction (9). Menaquinone-4 (MK-4) is not a major constituent of bacterial production; instead it is alkylated
from menadione present in animal feeds or is the product of tissue-specific conversion directly from dietary phylloquinone (10). Poultry products are the primary dietary sources of MK-4 in the US food supply (unpublished data); MK-4 is also available in therapeutic doses for treatment of osteoporosis in Japan.

Different forms of vitamin K have a tissue-specific distribution. The liver, which is the major storage site for vitamin K, contains long-chain menaquinones (MK-7 through MK-13), with limited capacity for storing phylloquinone (11). In plasma, serum, and bone, the major forms of vitamin K are phylloquinone, followed by short-chain menaquinones, such as MK-4 through MK-8 (12). Vitamin K may be delivered to osteoblasts by triglyceride-rich lipoproteins, although the precise mechanisms are still not well understood (13).

Based on representative dietary intake data, the Adequate Intake (AI) for vitamin K was set at 120 and 90 μg/d for men and women, respectively (14). Recent surveys of dietary phylloquinone intakes in North America, Europe, and Asia indicate that dietary intakes of phylloquinone are lower than previously assumed (15). In the United States and the Netherlands, older adults report higher average phylloquinone intakes (80–210 μg/d) compared to younger adults. However, reported mean phylloquinone intakes in a study among a national sample of British elderly men and women were below the current AI (70 and 61 μg/d, respectively) (1).