Vitamin K_1 (Phylloquinone) Content of Edible Oils: Effects of Heating and Light Exposure†

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The vitamin K_1 content of 10 commercially available vegetable oils was determined by reversed-phase high-performance liquid chromatography (HPLC). Prior to HPLC, crude lipid extracts were purified by solid-phase extraction on silica. Rapeseed and soybean oils were found to contain the greatest amounts of vitamin K_1 (140–200 μg/100 g) followed by olive oil (55 μg/100 g). Almond, sunflower, safflower, walnut, and sesame oils contained between 6 and 15 μg/100 g, while peanut and corn oils provided less than 3 μg/100 g. Vitamin K_1 was stable to processing mode, decreased slightly but significantly with heat, and was rapidly destroyed by both daylight and fluorescent light. Amber glass containers protected the oils from the destructive effects of light. Soybean and rapeseed oils are excellent sources of vitamin K_1 and can provide greater than 100% of the required dietary allowance for vitamin K when present in the diet at greater than 15% of the caloric content.

INTRODUCTION

Vitamin K is required as a cofactor for the posttranslational synthesis of γ-carboxyglutamic acid from specific glutamic acid residues in vitamin K-dependent proteins. Prior to the discovery of γ-carboxyglutamic acid in 1974, only four proteins involved in blood coagulation were recognized as vitamin K-dependent proteins (Suttie, 1985). Since that time, five other vitamin K-dependent proteins have been discovered and characterized. Two of these proteins, bone gla protein (BGP or osteocalcin) and matrix gla protein (MGP), were discovered in bone and are not structurally related to the clotting proteins (Hauschka et al., 1989; Price, 1988). MGP has recently been shown to be synthesized by a variety of tissues (Fraser and Price, 1988). Although the functions of BGP and MGP are not yet understood, their existence implies an expanded physiological role for vitamin K. These discoveries have generated a renewed interest in vitamin K and forced investigators to study vitamin K nutritional status from a new perspective.

The current recommended dietary allowance (RDA) for vitamin K has been established at 1 μg/kg of body weight (National Research Council, 1989). The adequacy of the American diet to furnish the RDA for vitamin K has not been determined and needs to be evaluated. Unfortunately, such an analysis cannot be performed at the present time due to the lack of an accurate and reliable database for the vitamin K composition of commonly consumed foods and beverages. The major dietary source of vitamin K has been identified as green and leafy vegetables, in which the vitamin occurs as vitamin K_1 (phylloquinone).

Data from the 1985 Continuing Survey of Food Intake by Individuals (CSFII) indicate that the average percentage of calories from fat for adults ages 19–50 was 36–37% (National Research Council, 1988). Recent trends in dietary consumption indicate a decreased consumption of animal fats and an increased consumption of vegetable oils. It is currently estimated that 60% of calories derived from fat are of animal origin (meat, dairy products, eggs) and the remainder from vegetable oil sources (margarine, salad dressings, cooking oils). Approximately 15% of total calories are therefore derived from vegetable oils. Since vegetable oils supply an important part of the total calories in the American diet, their relative contribution to meeting the recommended dietary requirements for vitamin K may be significant.

For many years the lack of reliable and sensitive analytical procedures for the determination of vitamin K has made quantitation of this nutrient in food both difficult and time-consuming. However, recent developments in methods for the analysis of vitamin K have increased the sensitivity and decreased the difficulty previously associated with the accurate and reliable quantitation of this vitamin in various food matrices (Haroon et al., 1986). To assess the role of vegetable fats in meeting dietary requirements for vitamin K, we determined the vitamin K_1 content of 10 commercially edible oils. Since vitamin K_1 is known to be sensitive to light and vegetable oils are used for cooking, we also chose to investigate the stability of the vitamin in these oils during storage, heating, and exposure to light.

EXPERIMENTAL PROCEDURES

Sampling Procedures. Peanut, corn, almond, sunflower, safflower, walnut, sesame, olive, rapeseed, and soybean oils were analyzed for vitamin K_1 content. All oils were purchased randomly from local supermarkets.

The stability of vitamin K_1 in oils was examined according to processing conditions, heating, light exposure, and storage conditions. The effect of oil processing was investigated by comparing the vitamin K_1 content of six different brands of olive oil. Brands were divided into two categories: cold pressed and normal pressed, with cold pressing assumed when the container label indicated "cold pressed". The thermal stability of the vitamin in the oils was determined by heating peanut, corn, safflower, sunflower, olive, rapeseed, and soybean oils to tem-

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peratures of 185–190 °C for 40 min. Aliquots of each oil were taken before heating and 20 and 40 min after the target temperature was reached. The stability of vitamin K_1 was further examined in safflower and rapeseed oils exposed to light. The effect of daylight was examined by exposing the oils to sunshine coming through a window in the laboratory. Fluorescent light exposure and its effects were determined by placing the oils in a windowless room illuminated with fluorescent lamps. A Model IL700 radiometer (International Light Research, Newburyport, MA) was used to measure the energy emitted by these lamps and reaching the bench surface. No detectable UVB (band range 285 ± 5 nm) was observed, while the UVA (band range 360 ± 25 nm) observed was 1.30 W/cm^2. During light exposure the oils were kept in clear glass containers and exposed to the light sources for a total of 22 days. Oil samples were collected every 2 days, and the vitamin K_1 content was determined. The stability of vitamin K_1 in rapeseed oil contained in clear and amber glass containers exposed to daylight and fluorescent light was determined. Exposure was for 36 h, and an aliquot was collected every 3 h for the determination of vitamin K_1. Finally, the interstore variation of the vitamin K_1 content of two different brands of rapeseed oil was determined by obtaining bottles from different grocery stores and analyzing their vitamin K_1 content.

Analytical Procedures. The concentration of vitamin K_1 in the oils was quantitatively determined in oil extracts by reversed-phase high-performance liquid chromatography (HPLC) using postcolumn chemical reduction of the vitamin to its fluorescent hydroquinone as described previously (Haroon et al., 1986). Prior to HPLC, the oils were extracted with hexane and the extracts partially purified by solid-phase extraction on silica. Briefly, 0.25–1.0 g of oil was weighed directly into a borosilicate glass screw-cap culture tube to which an appropriate amount of internal standard, dihydrovitamin K_1, was added. Lipids and lipophilic compounds were extracted with hexane by shaking vigorously for 3 min. An aliquot of the hexane extract was applied to a 3.0-mL silica column (J. T. Baker Inc., Phillipsburg, NJ) that had been preconditioned by a wash of 8.0 mL of hexane. The silica column was washed with an additional 8.0 mL of hexane to remove the hydrocarbons and the vitamin K_1 containing fraction was eluted with 8.0 mL of hexane–diethyl ether (97:3 v/v). The eluant was collected and evaporated to dryness under reduced pressure in a centrifugal evaporator (Savant Instrument Inc., Farmingdale, NY). The final residue was dissolved first in 0.045 mL of methylene chloride with swirling to help dissolve the lipids before addition of 0.255 mL of methanol containing 10 mM zinc chloride, 5 mM acetic acid, and 5 mM sodium acetate. One hundred and fifty microliters of sample was analyzed by HPLC, and the vitamin K_1 and internal standard were detected by fluorescence with a Spectroflow 980 fluorescence detector (Applied Biosystems, Ramsey, NJ). The recovery of added internal standard ranged from 65 to 80% for all of the oils analyzed but was reproducible for each brand and sample analyzed.

Oils were analyzed in triplicate unless otherwise indicated. The data were examined for statistical significance using two-factor analysis of variance (SAS general linear procedure, Statistical Analysis System Institute, 1985). Differences between groups were determined using paired t test.

RESULTS AND DISCUSSION

Ten different types of commercially available vegetable oils were analyzed for their vitamin K_1 content by HPLC, and the results are presented in Table I (micrograms of vitamin K_1/100 g of oil). Rapeseed and soybean oils were found to contain the greatest amounts of vitamin K_1 (140–200 μg/100 g) followed by olive oil (55 μg/100 g). Almond, sunflower, safflower, walnut, and sesame oils contained 6–15 μg/100 g, while peanut and corn oils provided less than 3 μg/100 g. Although the vitamin K_1 contents for soybean and corn oil have been previously reported (Matschiner and Doisy, 1966a,b; Schneider et al., 1974; Zonta and Stancher, 1985), no data have been previously published for the other oils. Using HPLC, Zonta and Stancher (1985) reported a vitamin K_1 content of 121–333 μg/100 g for soybean oil. Although this estimate varies over a wide range according to brand analyzed, it approaches that reported in Table I (200 μg/100 g) and is considerably lower than the earlier values obtained by Schneider et al. (1974) of 450–630 μg/100 g. The discrepancies between current and earlier soybean oil values are probably due to different analytical methodologies since in the same paper corn oil was reported to contain 20-fold more vitamin K_1 (50–70 μg/100 g) than what is reported in this study (3 μg/100 g). Such variations in vitamin K_1 content are unlikely to be explained by differences intrinsic to the oil samples alone.

To evaluate whether food processing affects the vitamin K_1 content of oils, vitamin K_1 was determined in six different brands of olive oil. Three of the six brands analyzed were labeled cold pressed, while the other three were not. As shown in Table II, the processing mode did not significantly affect the vitamin K_1 content of olive oil ($p > 0.05$).

The thermal stability of vitamin K_1 in oils was investigated by exposing peanut, corn, safflower, sunflower, olive, rapeseed, and soybean oils to temperatures of 185–190 °C for 40 min. Oils were divided into two categories:

Table I. Vitamin K_1 (Micrograms per 100 g) Content in Various Oils[a]

type and brand analyzed	vitamin K_1, μg/100 g	combined av, μg/100 g
peanut (A)	0.30 ± 0.07	
peanut (B)	1.19 ± 0.13	
peanut (C)	0.47 ± 0.03	0.65 ± 0.27 (3)
corn (A)	4.18 ± 0.42	
corn (B)	1.63 ± 0.26	2.91 ± 1.28 (2)
almond (A)	6.70 ± 0.24	6.70 (1)
sunflower (A)	9.19 ± 0.79	
sunflower (B)	8.86 ± 0.71	9.03 ± 0.17 (2)
safflower (A)	6.49 ± 0.19	
safflower (B)	11.77 ± 0.24	9.13 ± 2.64 (2)
walnut (A)	15.0 ± 2.0	15.0 (1)
sesame (A)	18.7 ± 1.6	
sesame (B)	12.1 ± 1.4	15.5 ± 3.3 (2)
olive (A)	46.6 ± 7.1	
olive (B)	82.1 ± 3.6	
olive (C)	59.8 ± 2.2	
olive (D)	58.5 ± 6.3	
olive (E)	48.6 ± 0.9	
olive (F)	37.2 ± 1.5	55.5 ± 6.3 (6)
rapeseed (A)	114 ± 14.0	
rapeseed (B)	188 ± 2.5	
rapeseed (C)	146 ± 11.0	
rapeseed (D)	117 ± 1.0	141 ± 17.0 (4)
soybean (A)	152 ± 5.0	
soybean (B)	290 ± 5.0	
soybean (C)	139 ± 4.0	
soybean (D)	165 ± 11.0	
soybean (E)	218 ± 12.0	193 ± 28 (5)

[a] Each brand reported represents the average value obtained by triplicate analysis (mean ± SD). The average value reported corresponds to the mean value obtained (mean ± SEM).

Table II. Effect of Oil Processing on Vitamin K_1 (Micrograms per 100 g of Oil) Content of Olive Oil[a]

cold pressed (3)	normal processing (3)
55.64 ± 2.59	54.95 ± 8.06

[a] Cold pressing was assumed when container label indicated cold pressed. Vitamin K_1 content is not statistically significant when compared using Student's t test. Numbers in parentheses correspond to brands of oils tested (mean ± SEM, n = 6 per category).

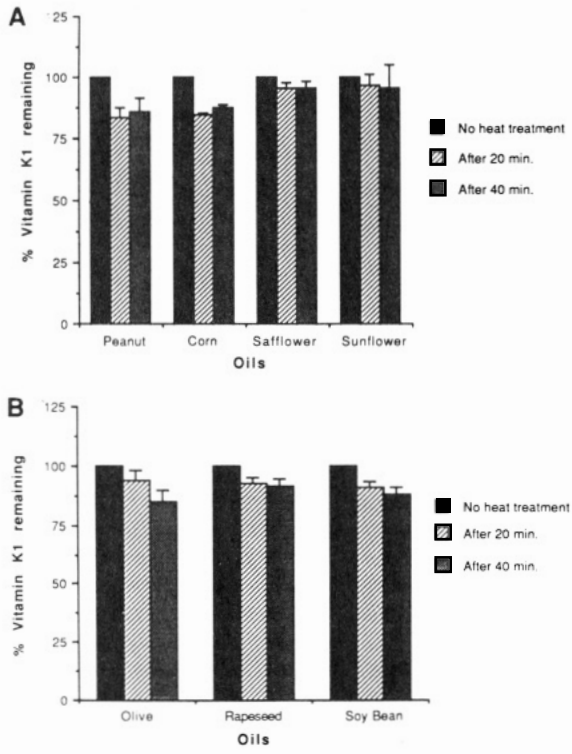

Figure 1. Percent vitamin K_1 remaining in peanut, corn, safflower, sunflower (A) and olive, rapeseed, and soybean (B) oils after 0, 20, and 40 min of exposure to temperatures of 185–190 °C. Analysis of variance indicated a significant decrease ($p = 0.0076$) in vitamin K_1 over time. Values were derived from two to six different brands/oil (mean ± SEM, $n = 4$–12).

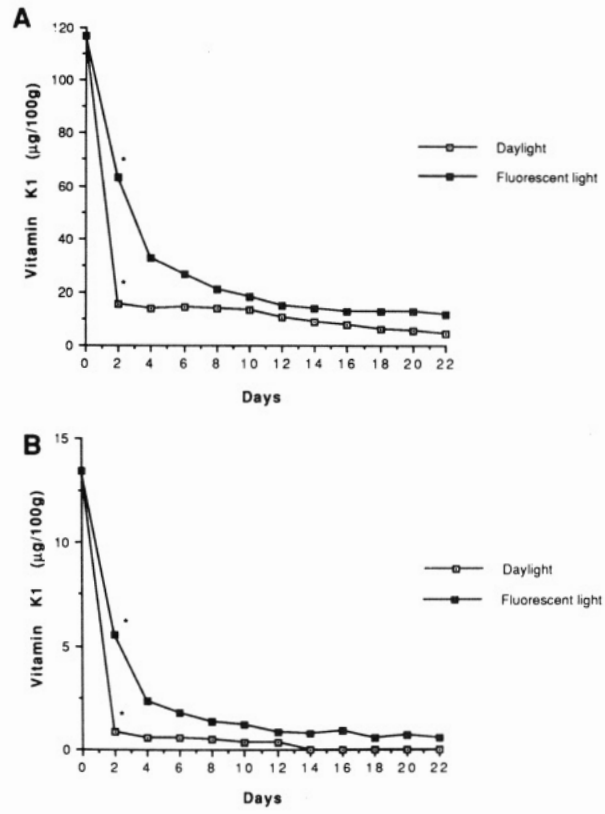

Figure 2. Effect of daylight and fluorescent light on vitamin K_1 content of rapeseed (A) and safflower (B) oils. Values were derived from one brand of oil (mean ± SEM, $n = 3$). *$p < 0.01$ when compared to values at day 0.

low (Figure 1A) and moderate to high (Figure 1B) vitamin K_1 containing oils. Using single factor of variance analysis, there was a small but statistically significant loss of vitamin K_1 over time when the oils were heated ($p = 0.0076$). The statistical analysis was carried out in the log scale because a certain percentage rather than a fixed amount of vitamin K_1 was expected to be lost due to heating. Seven percent of the original vitamin K_1 was lost during 20 min of heating; 11% of the original vitamin K_1 was lost during 40 min of heating. When examined individually, heat had the greatest effect on peanut, corn, and olive oils, with the vitamin K_1 content of these oils decreasing by 15%. Neither initial vitamin K_1 content nor fatty acid composition of the oils was correlated to the response to heat treatment. The heat-related changes observed here contradict what was reported for the pure compound, where vitamin K_1 was found to be stable to heat (Suttie, 1985). However, changes observed for vitamin K_1 are not as marked as those observed for other fat-soluble vitamins (Bunnell et al., 1965; Chow and Draper, 1974; Simpson, 1983). When heated to 175 °C for 30 min, the tocopherol contents of peanut and sesame oils were shown to decrease by 32 and 40%, respectively (Bauernfeind, 1980).

To further evaluate the stability of vitamin K_1, oils were exposed for 22 days to either fluorescent light or sunlight. The experiments were performed using a high (rapeseed; Figure 2A) and a low (safflower; Figure 2B) vitamin K_1 containing oil. As can be seen in Figure 2, vitamin K_1 is extremely sensitive to both sources of light. After only 2 days of exposure, fluorescent light decreased the vitamin K_1 contents of rapeseed and safflower oils by 46 and 59%, respectively, and daylight by 87 and 94%, respectively ($p < 0.01$). Although fluorescent light and daylight induced comparable losses of the vitamin after 22 days of exposure (91 and 96% for rapeseed oil; 96 and 100% for safflower oil), the disappearance of vitamin K_1 from both oils occurred more rapidly in daylight. The vitamin K_1 content of oils exposed to fluorescent light decreased for 10 days before reaching a plateau, whereas the vitamin K_1 content of oils exposed to daylight varied little after 2 days of exposure to daylight. Though statistically insignificant ($p > 0.05$), vitamin K_1 losses due to light exposure appeared to be more pronounced for safflower than for rapeseed oil.

The effects of the storage container on the stability of vitamin K_1 in oils exposed to light were determined on samples of rapeseed oil stored in either transparent or amber glass containers exposed to fluorescent light or daylight. As shown in Figure 3, the type of container had a significant protective effect on vitamin K_1 stability in rapeseed oil. After 36 h of exposure, daylight and fluorescent light decreased the vitamin K_1 content of rapeseed oil stored in clear bottles by 93 and 44%, respectively, but had no significant effect on the vitamin K_1 content in rapeseed oil stored in amber bottles (<1% loss). The destructive effects of daylight and fluorescent light observed in the samples stored in clear bottles were comparable to that observed in Figure 2.

In summary, the vitamin K_1 content of various edible vegetable oils was analyzed by high-performance liquid chromatography and found to vary according to plant source with olive, rapeseed, and soybean oils being the richest sources of vitamin K_1. Stability studies on the vitamin K_1 content of vegetable oils demonstrated that the vitamin was stable to processing mode but was significantly affected by heat (temperatures of 185–190 °C), fluorescent light, and daylight. Furthermore, amber glass bottles were shown to be very effective in protecting the vitamin K_1 in oils from the destructive effects of light. From a practical point of view, these observations suggest that, even when used in cooking (e.g., deep frying), oils can remain good sources of dietary vitamin K_1. However,

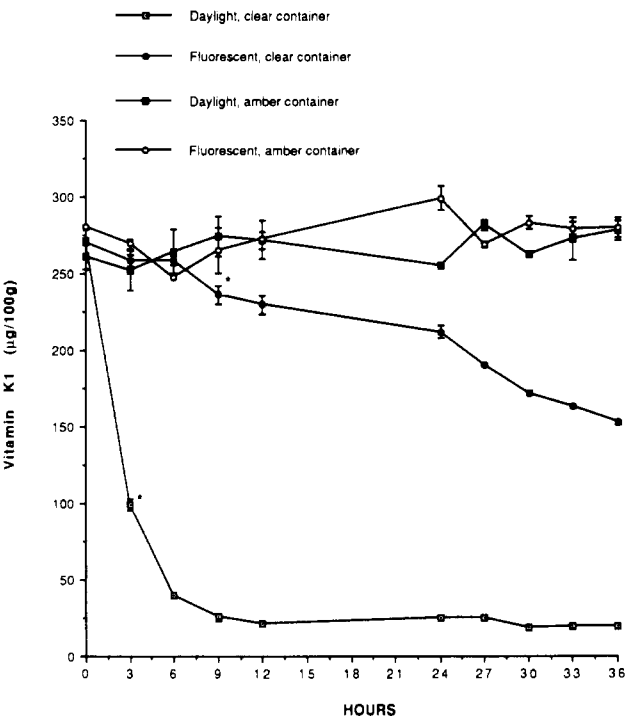

Figure 3. Effect of oil container on vitamin K content of rapeseed oil exposed to daylight and fluorescent light. Oil samples were stored in either transparent or amber glass bottles. One brand of rapeseed oil was analyzed (mean ± SEM, $n = 3$). *$p < 0.01$ when compared to values at hour 0.

Table III. Vitamin K_1 (Micrograms per 100 g of Oil) Determinations of Two Brands of Rapeseed Oil from Containers Purchased from Different Stores[a]

brand 1		brand 2	
container 1	container 2	container 1	container 2
116.8 ± 1.1	145.9 ± 5.4	115.4 ± 5.4	187.80 ± 1.9

[a] For both oils, differences observed between containers are statistically significant ($p < 0.05$) using Student's t test (mean ± SEM, n = 2–4 per brand).

the vitamin K_1 content of oils will be adversely affected by exposure to light. These results further imply that even in a laboratory environment it becomes imperative to work in subdued light when foods are being analyzed for their vitamin K_1 content. From a consumer's perspective, oils sold in dark containers (amber glass or metal) are more likely to retain their vitamin K_1 content than oils sold in transparent containers. Storage conditions and length of storage on the shelf in supermarkets should influence the vitamin K_1 content of various oils. Oils obtained from stores with slow merchandise turnover or improper storage conditions would be expected to have lower vitamin K_1 contents since these oils would have had more time to be exposed to fluorescent light and natural sunlight. To illustrate this point, the vitamin K_1 content of rapeseed oil was determined from bottles purchased at different stores. As shown in Table III, the vitamin K_1 content of a given brand of oil was found to vary significantly ($p < 0.05$) from store to store (20% for brand 1 and 40% for brand 2).

The relative contribution that vegetable oils can make to meet the suggested daily recommended dietary allowance for vitamin K (1.0 µg/kg of body weight) in the American diet is difficult to determine because of the diversity of oils consumed and the various effects of storage on their vitamin K_1 content. However, assuming that vegetable oils can constitute approximately 15% of the total calories consumed on a daily basis and that they

Table IV. Contribution of Vitamin K_1 from Edible Oils in Meeting the Recommended Daily Allowance for Vitamin K

category	age, years	wt, kg	energy requirement, kcal/day	vitamin K requirement, µg/day	vitamin K_1 from oils, µg/day
males	19–24	72	2900	72	82 (114%)
	25–50	79	2900	79	82 (104%)
	51+	77	2300	77	65 (84%)
females	19–24	58	2200	58	62 (107%)
	25–50	63	2200	63	62 (98%)
	51+	65	1900	65	54 (83%)

provide 9 kcal/g of oil in energy, the contribution of vitamin K_1 from edible vegetable oils can be calculated for known energy requirements. The National Research Council (1989) has recommended energy allowances for reference adults engaged in light to moderate activity for three age categories. These categories were used to construct Table IV to determine the amount of vitamin K_1 that would be provided by consuming a diet providing 15% of the calories from an equal mixture of soybean and rapeseed oils. It is certainly clear from Table IV that moderate consumption of edible vegetable oils high in vitamin K_1 content can provide significant quantities of the vitamin and can provide from 83 to 114% of the daily dietary requirement if the diet contains equal amounts of soybean and rapeseed oils.

Vitamin K metabolism and function can be significantly impaired by the administration of coumarin-related compounds such as warfarin. These pharmacological agents have a well-established role in anticoagulant therapy and are finding increased usage in the treatment of arterial and venous thromboembolism associated with acute myocardial infarction, atrial fibrillation, mitral stenosis, stroke, and general surgery (Sadowski et al., 1991). Resistance to the pharmacological effects of warfarin caused by the consumption of vegetables containing large amounts of vitamin K_1 (Kempin, 1983; Karlson et al., 1986; Oren and Shvartzman, 1989) has been observed. In light of the significant contribution that certain edible vegetable oils can make to the daily intake of vitamin K_1, patients undergoing anticoagulant treatment with warfarin should be advised to limit their use of vegetable oils to those containing low amounts of vitamin K_1 (peanut, corn, sunflower, safflower). Alternatively, the oils may be stored in clear glass containers and illuminated with daylight to decrease the vitamin K content. Current trends in the use of warfarin anticoagulant therapy indicate that lower dosages of warfarin will be used in the treatment of thromboembolic diseases (Sadowski et al., 1991; Wessler et al., 1987). These lower dose therapies will most likely be more sensitive to dietary vitamin K intakes and result in future clinical practice that includes dietary counseling for patients taking warfarin at the lower end of the dose range. The lack of a solid database for the vitamin K content of foods is a serious limitation for developing effective strategies for lower dose warfarin therapy. We are currently addressing this problem by developing a larger and more accurate database for the vitamin K content of foods, beverages, and condiments.

LITERATURE CITED

Bauernfeind, J. Tocopherols in food. In *Vitamin E: a comprehensive treatise*; Machlin, L. J., Ed.; Dekker: New York, 1980; pp 99–167.

Bunnell, R. H.; Keating, J.; Quaresimo, A.; Parman, G. K. Alpha-tocopherol content of foods. *Am. J. Clin. Nutr.* **1965**, *17*, 1–10.

Chow, C. K.; Draper, H. H. Oxidative stability and antioxidant activity of the tocopherols in corn and soybean oils. *Int. J. Vit. Res.* **1974**, *44*, 396–403.

Fraser, J. D.; Price, P. A. Lung, heart and kidney express high levels of mRNA for the vitamin K-dependent matrix gla protein. Implications for the possible functions of matrix gla protein and for the tissue distribution of the γ-carboxylase. *J. Biol. Chem.* **1988**, *263*, 11033–11036.

Haroon, Y.; Bacon, D. S.; Sadowski, J. A. Liquid-chromatographic determination of vitamin K_1 in plasma with fluorometric detection. *Clin. Chem.* **1986**, *32*, 1925–1929.

Hauschka, P. V.; Lian, J. B.; Cole, D. E.; Gundberg, C. M. Osteocalcin and matrix gla protein: Vitamin K-dependent proteins in bone. *Physiol. Rev.* **1989**, *69*, 990–1047.

Karlson, B.; Leijd, B.; Hellstrom, K. On the influence of vitamin K-rich vegetables and wine on the effectiveness of warfarin treatment. *Acta Med. Scand.* **1986**, *220*, 347–350.

Kempin, S. J. Warfarin resistance caused by broccoli. *N. Engl. J. Med.* **1983**, *308*, 1229–1330.

Matschiner, J. T.; Doisy, E. A. Bioassay of vitamin K in chicks. *J. Nutr.* **1966a**, *90*, 97–100.

Matschiner, J. T.; Doisy, E. A. Vitamin K content of ground beef. *J. Nutr.* **1966b**, *90*, 331–334.

National Research Council. *Designing Foods*; National Academy Press: Washington, DC, 1988; pp 24–26.

National Research Council. *Recommended dietary allowances*, 10th ed.; National Academy Press: Washington, DC, 1989.

Oren, B.; Shvartzman, P. Unsuspected source of vitamin K in patients treated with anticoagulants: a case report. *Family Practice* **1989**, *6*, 151–152.

Price, P. A. Role of vitamin K-dependent proteins in bone metabolism. *Annu. Rev. Nutr.* **1988**, *8*, 565–583.

Sadowski, J. A.; Bovill, E. G.; Mann, K. G. Warfarin and the metabolism and function of vitamin K. In *Recent Advances in Blood Coagulation*; Poller, L., Ed.; Churchill Livingstone: Edinburgh, 1991; pp 93–118.

Schneider, D. L.; Fluckiger, H. B.; Manes, J. D. Vitamin K_1 content of infant formula products. *Pediatrics* **1974**, *53*, 273–275.

Simpson, K. L. Relative value of carotenoids as precursors of vitamin A. *Proc. Nutr. Soc.* **1983**, *42*, 7–17.

Statistical Analysis System Institute. *SAS user's guide: statistics*, 5th ed.; SAS Institute: Cary, NC, 1985.

Suttie, J. W. Vitamin K. In *The fat-soluble vitamins*; Diplock, A. T., Ed.; Technomic Publication: Lancaster, 1985; pp 225–311.

Suttie, J. W. *Current advances in vitamin K research*; Elsevier Science Publishers: Amsterdam, 1988.

Wessler, S.; Becker, C. G.; Nemerson, Y. The new dimensions of warfarin prophylaxis. *Adv. Exp. Med. Biol.* **1987**, *214*, 329 pp.

Zonta, F.; Stancher, B. Quantitative analysis of phylloquinone (vitamin K_1) in soybean oils by high-performance liquid chromatography. *J. Chromatogr.* **1985**, *329*, 257–263.

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