Chapter 3

Vitamin K_2 Rich Food Products

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Additional information is available at the end of the chapter

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Abstract

Naturally, vitamin K exists in two bioactive forms mainly phylloquinone (vitamin K_1) and menaquinones (vitamin K_2). Phylloquinone is mostly found in green leafy vegetables such as kale, spinach, broccoli, and vegetable oils. However, menaquinones abundantly occurs in fermented vegetable products as menaquinones-7 (MK-7) and in animal-based products as menaquinone-4 (MK-4). Diverse concentrations of menaquinones are present in various dietary sources such as fermented pulses and milk-based products, cheese, meat, and animal organs. Presently, MK-7 and MK-4 contribute about 24 and 7%, respectively, of the total vitamin K dietary intake in the population consuming fermented products regularly. However, about 10% of menaquinones are pooled in the liver out of total intake of vitamin K. Conclusively, fermented soybean products and fermented milk-based products such as cheese and soured milk contain ample amount of MK-7, whereas animal organs, meat, fish, and egg contain appreciable amount of MK-4.

Keywords: vitamin K_2, menaquinones, fermented soybean, fermented milk, meat, cheese, poultry products

1. Introduction

Vitamin K is an indispensable anti-hemorrhagic fat soluble nutrient important for posttranslational modification of the proteins. Generally, these proteins are called vitamin K–dependent or Gla proteins. These coagulation proteins are produced in liver and played an active role in blood-clotting cascade. Moreover, during γ-carboxylation process, vitamin K hydroquinone is oxidized to its epoxide. When vitamin K is insufficient in blood-circulating system, carboxylation of vitamin K–dependent proteins is hampered and synthesis of undercarboxylated proteins is high that affects the Coagulation *cascade* parameters such as bleed and clotting times, and prothrombin and partial prothrombin times. Additionally, inadequacy of vitamin K also affects the bone mineral density (BMD) that leads toward higher bone fracture rate among population especially postmenopausal women and increased the risk of coronary artery diseases [1, 2].

Vitamin K deficiency is one of the alarming dilemmas among newborns, teenagers, and postmenopausal women. Neonates and their nursing mothers are 33.3% and 65% deficit in vitamin K, respectively [3]. Moreover, gastrointestinal disorders, unnecessary use of antibiotics, and alcoholics are some potential causes of vitamin K deficiency that hinder the fat incorporation in the body, and thus absorption of this vitamin is reduced [4]. Similarly, continuous utilization of broad-spectrum antibiotics suppresses the synthesis of vitamin K in the intestinal gut, whereas antagonist drugs badly effect to vitamin K functioning that delays the blood coagulation and necessary modifies certain protein which are indispensable for bone health [5]. Likewise, inflammatory bowel disease individual also showed vitamin K deficiency prevalence that declined the bone mineral density possibly due to its malabsorption [6].

The ingestion of vitamin rich dietary sources is rational approach to manage the vitamin K deficiency population [7]. Additionally, supplementation of vitamin K in the diet is also improved the serum vitamin K concentration [8, 9]. In this context, pharmacological dose of vitamin K (45 mg/day) is effective to ameliorate problem of bone fractures [10]. Therefore, more osteocalcin carboxylation is attained via consumption of well above recommended dietary requirement amount of vitamin K [11].

Vitamin K predominantly, naturally, presents in the form of phylloquinone (vitamin K_1) and menaquinone (vitamin K_2). Primarily, phylloquinone is present in green leafy vegetables such as spinach, kale, broccoli, and certain vegetable oils [12]. However, menaquinones are present in the fermented soybean and animal products [8].

Fermented soybean (natto) is one of the richest sources of menaquinones principally menaquinone-7 (MK-7) (882–1034 μg/100 g) among other fermented plant and animal-based food products [8, 13]. Menaquinone-7 containing natto is prepared by the fermentation process with *Bacillus subtilis*. Raw soybean is converted into slimy and sticky food predominantly owing to glutamic residues [14]. This menaquinone is also available in other food products such as cheese, meat and meat-based products, and fermented milk. Menaquinones are also synthesized by intestinal microflora such as *Escherichia coli*, *Bacteroides vulgatus,* and *Bacteroides fragilis* [15].

From total vitamin K dietary intake, menaquinone-4 (MK-4), menaquinone-7 (MK-7), and phylloquinone contribute around 7, 24, and 60%, respectively [16]. Humans and laboratory animals have ability to transform phylloquinone into MK-4 and MK-7 by rearrangement of integral side chain that has the ability to strengthen the bone [17]. In both phylloquinone and menaquinones, total vitamin K is about 1.16 μg/kg body weight is required for normal functioning. Menaquinone-7 normally stored around 10% in the liver. However, only 5–25% of ingested vitamin K is catabolized to MK-4 followed by the conversion of menaquinones in the liver via prenylation [10].

2. Fermented soybean food products

Traditionally, *Bacillus subtilis* fermented soybean food products are consumed in different parts of world. Among the fermented soybean products, natto is attained special attention which is consumed in Japan, whereas similar products such as kinema is produced in India, Satlyangser and Bari in Bhutan, Thua-Nao in Thailand, Tao-si in Philippines, Douchi in China and Dawadawa in Nigeria, Pepok in Myanmar. Kinema is similar natto fermented soybean which is originated from south China and expanded in Nepal, India, Burma, Thailand, and Japan [18–20].

Soybean conquers special attention in the public owing to its protein and fat contents. Numerous cultivars are currently available for household consumption. Among, yellow, green, and black soybeans are commonly used after cooking or fermentation. Bacillus fermented products such as natto and cheonggukjang are also consumed [21, 22]. *B. subtilis* fermented soybean has slimy appearance, softer texture, and white goosy substance with distinctive rotten flavor. Moreover, fermentation also removes the beany odor of raw soybean completely and improves its hedonic response [19]. However, large number of population does not like its slimy appearance and powerful rotten odor of fermented soybean such as kinema, while other has enjoyable experience. Freshly prepared fermented soybean is consumed as a fried curry with boiled rice or mixed with vegetables or consumed with boiled rice, soup, and pickle [20].

Researchers are trying to identify the new strains that may have potential similar *B. subtilis* and have ability to produce ample amount of MK-7 in the soybean. In this context, *B. amyloliquefaciens KCTC11712BP* under its optimum conditions remarkably enhanced MK-7 concentration in cheonggukjang (fermented soybean) and has shorter production time than that of natto [23]. Menaquinones are produced by microorganisms during electron transport chain respiration process [24].

Moreover, natto is rich in menaquinones especially MK-7 followed by other menaquinones such as MK-5, MK-6, MK-8 which are ranged from 882–1034 μg/100 g, 7.1–7.8 μg/100 g, 12.7–14.8 μg/100 g, 78.3–89.8 μg/100 g, respectively [13]. Similarly, Berenjian et al. [25] also reported that MK-7 content in fermented soybean is varied from 800–900 μg/100 g. Moreover, Booth [26] also reported that natto contains 998 μg/100 g MK-7. Previously, Dajanta et al. explicated that low fat (15.6%), high protein (45.8%), and small seed size of soybean are ideal characteristics of soybean for nato preparation [22]. Moreover, fermentation with *B. subtilis* exerts better nutritional attributes and sensory acceptability of the developed natto. Earlier, *B. subtilis* fermented Pakistani soybean also improved the concentration of MK-7 ranged from 681.35 to 803.82 μg/100 g. Contrary, MK-7 was not present in freshly cooked or reconstituted spinach [2]. The details of menaquinones concentration in various fermented soybean products are summarized in **Table 1**.

Food	Type	Country	MK-4	MK-5	MK-6	MK-7	References
Natto	Fermented soybean	Netherlands	7.5	13.8	998	84.1	[13]
Natto	Fermented soybean	Japan	–	–	–	939	[12]
Hikiwari natto	Chopped natto	Japan	ND	–	–	827	[12]
Natto	Fermented black soybean	Japan	–	–	–	796	[12]
Natto	Fermented soybean	Japan	ND	–	–	87–102	[23]
Natto	Fermented soybean	Pakistan	–	–	–	668–881	[2]
Cheonggukjang	Fermented soybean	Korea	ND	–	–	112–461	[23]
Cheonggukjang	Fermented soybean	Korea	74–76	–	–	271–1171	[23]
Cheonggukjang	Fermented soybean extract	Korea	–	–	–	1674–3438	[23]
Sauerkraut	Fermented vegetables	Netherlands	0.4	0.8	1.5	0.2	[13]
Cotton tofu	Hard type	Japan	0.04	–	–	–	[12]

ND = not detected; (–) = unknown or not reported.

Table 1. Menaquinones content of various fermented soybean (μg/100 g or mL).

However, the level of MK-7 in natto is still less the recommended daily amount of 180 μg/day that needs the utilization of 20–22 g natto/day. Many consumers find natto unpalatable; therefore, the ingestion of sufficient MK-7 is impractical. In some countries such as Japan, China, Thailand, and India fermented soybean products are commonly consumed, whereas other consumers do not like the fermented soybean products due to unpalatable, slimy, and sticky in nature, so the ingestion of MK-7 is insufficient among the population. Furthermore, the digestion and utilization of MK-7 from fermented soybean products are less efficient in humans with aging. Hence, there is a need for production of concentrated, supplementary MK-7 in the diet [25]. The extracted MK-7 with oil is consumed in various functional foods to fulfill the recommended requirement of vitamin K.

2.1. Natto

Natto is a Japanese traditional food prepared by fermentation of soybean with *B. subtilis natto*. The sterilized soybeans are fermented at 40°C for 14–18 h till it was fully covered with a viscous, sticky, and string-like material on surface. The resultant fermented soybean has characteristic odor and musty flavor [28].

2.2. Thua nao

For thua nao preparation, washed soybeans are soaked in water at ambient temperature for 16 h. Subsequently, soaked soybeans are autoclaved at 121°C for 40 min and cooled to 55°C after removing water. Powder culture of *B. subtilis* is mixed and incubated at 42 °C about 24 h for fermentation. Afterwards, fermented soybeans are placed at 4°C to hamper the bacterial activity.

2.3. Kinema

Cleaned and pre-soaked soybeans are autoclaved at 121°C for 35 min and cooled to 30–35°C. The soybean is inoculated with active culture of *B. subtilis*. The inoculated soybeans are placed for fermentation at 37°C for 48 h at 85% RH. The activity of bacteria is reduced by using the refrigeration temperature for 12 h. Fresh kinema is immediately consumed because its shelf life is about 2–3 days in summer and 5–7 days in winter without refrigeration. After sun drying, it can be stored for several months [18].

2.4. Hawaijar

Generally, small-sized soybean seeds are used for the production of hawaijar. Soybean seeds are boiled without soaking and packed loosely in bamboo basket lined with fig or banana leaves. Natural fermentation process is completed within 3–5 days. Mixed microflora including *B. subtilis*, *B. cereus*, *B. licheniformis*, *Staphylococcus sciuri*, *Staphylococcus aureus*, *Providencia rettgeri*, *Alcaligenes* sp. are fermented organism present in the final product. Production of mucilage and ammonia flavor is the indicator of quality hawaijar [18].

2.5. Cheonggukjang

Washed soybean seeds are soaked in tap water for 12 h. They are autoclaved at 121°C for 30 min and cooled up to 40°C prior to inoculation with pre-culture cell suspension of *Bacillus amyloliquefaciens strain KCTC 11712BP*. General for the preparation of cheonggukjang inoculated soybean seeds were placed in fermented for 48 h [28].

3. Menaquinones synthesizing organisms

Menaquinones are commonly synthesized by the action of intestinal microflora *B. vulgatus*, *B. fragilis,* and *E. coli* in human large intestine during electron transport chain reaction of respiration. Commercially, MK-7 was produced by action of bacteria such as *E. coli*, *Flavobacterium,* and *B. subtilis natto*. Moreover, among the fermented microflora, *B. subtilis* is consider one of the best options for the production of MK-7 due to its safety aspects as well as potential to synthesis the range of menaquinones such as MK-4 to MK-8 [15, 24, 29]. These hydrolytic bacteria are significantly consumed and reduced the indigestible oligo- and polysaccharides. The *Bacillus* species also lowered the activity of anti-nutrients of the soybean that hamper the availability of nutrients such as proteins and bioactive molecules [30].

B. subtilis is rod shaped, aerobic, heat resistant, spore forming Gram-positive bacteria. It has potential to synthesis number of enzymes such as proteolytic, amylolytic, and lipolytic enzymes during fermentation. The colonies of *B. subtilis* are irregular with hair-like structure having somewhat sliming appearance. Food Drug Administration granted the status of generally *recognized* as safe (GRAS) to the *Bacillus subtilis* and its close relative strains due to the lack of pathogenicity [20].

Administration of high single dose of MK-7 (2000 mg/kg) did not impart any toxic effect in animal modeling study in both genders. Moreover, prolonged treatment of MK-7 is considered also safe for human consumption due to its non-toxic effect on biochemical, hematological, urinary, and histopathological parameters [31].

Recently, Indian researcher Puri et al. identified a *B. subtilis* strain (*Bacillus subtilis MTCC 2756*) for the biosynthesis of menaquinone-7 for commercial purposes [32]. They found that addition of Tween 80 in fermentation medium significantly boost the MK-7 yield. Likewise, for the production of MK-7, groundnut meal is also used as a substrate owing to its protein and oil quality with strong minerals and vitamins profile using *Flavobacterium* sp. *SP-L-01* [33].

4. Stability of menaquinones

The vitamin K_2 was quite stable at room temperature for a period of up to 3 years. However, its concentration in final product was little affected by storage timed. Therefore, it is recommended that the menaquinone-7 rich product should be stored not more than 15°C temperature in a dry, cool, and dark place away from humidity, high heat, and sunlight.

5. Nutritional profile of fermented soybeans products

Fermented soybean is demonstrated higher amount of protein than raw soybean. The higher content of protein in fermented soybean might be elevated due to the microbial synthesis of single cell protein or rearrangements of molecules or enzymes followed by mortification of other moieties [19]. Premarani et al. explicated the impact of fermentation on the proximate composition of hawaijar [34]. They inferred that natural fermented soybean had 62.1% moisture, 26.02% soluble protein 24.36% crude fat, 8.2% crude fiber, 1.42% ash, and 3.8% free amino acids content nonetheless, inoculation with bacteria increases these parameters. However, hawaijar prepared from different soybean varieties showed non-momentous differences in lipid, fatty acid, and amino acid contents [35]. The nutritional profile of some fermented soybean was listed in **Table 2**.

Food	Moisture	Crude protein	Crude fat	Crude fiber	Ash	Carbohydrate	References
Kinema (traditional) dry basis	7.2	44.0	21.8	4.2	4.7	29.7	[79]
Kinema (pure culture) dry basis	6.8	45.1	23.0	4.8	4.5	27.4	[79]
Natto fresh weight basis	62.72	13.19	7.61	1.17	1.37	13.89	[2]
Fermented soybean	62.1	26.02	24.68	8.2	1.42		[34]
B. natto Itobiki	59–61	36–42	19–23	–	4.38–4.97	31–34	[37]
B. Natto NRRL B-3393	61	39–44	25–27	-	4.72–4.86	25–29	[37]

Table 2. Nutritional profile of menaquinones rich fermented soybean (%).

Likewise, natto has 40% protein and 24.68% fat contents. Controlled fermentation process improves the nutritional composition of natto than that of natural fermentation process [36]. Earlier, Wei and Chang delineated that the natto was prepared from four different soybean cultivars using *B. natto "Itobiki"* for moisture, protein, lipid, ash and carbohydrates as 59–61, 37–43, 20–23, 4–5, and 31–34%, respectively [37]. However, the natto synthesis through *B. natto NRRL B-3393* exhibited the values ranged from 61–62, 39–44, 25–27, 4.72–4.86, and 25–29%, for these attributes.

Similarly, free amino acid contents were enhanced 60-fold in fermented products [38]. Free fatty acids impart significant role in the development of unique flavor in fermented soybean. Earlier, Kiuchi et al. reported that carbon length of fatty acids was momentously increased during fermentation [39]. Moreover, the amount of vitamin B complex such thiamine, riboflavin, and niacin is momentously improved during *B. subtilis* fermentation process of cooked soybeans. Additionally, total folate concentration was enhanced during fermentation process of Tempeh (fermented soybean). Fermented soybeans such as kinema and natto have appreciable amount of mineral contents such as iron, magnesium, copper, zinc, sodium, and calcium [40–42].

6. Antioxidant potential of fermented soybean

Fermented soybean had higher amount of total phenolic, antioxidant capacities, and flavonoid contents in thua nao produce by black soybeans by pure culture of *B. subtilis TN51* compared with yellow soybeans and cooked non-fermented soybeans. Fermented black soybean and yellow soybean with *B. subtilis* TN51 exhibited higher amount of total phenolics 27.05 and 35.88 mgGAE/g extract than that of non-fermented products. Whereas total flavonoids contents of fermented black and yellow soybean were 3.50 and 1.38 mg catechin eq/g methanolic extract. However, contents of total phenolics and flavonoids were significant less in non-fermented black and yellow cooked soybeans. Likewise, 2,2-diphenylpicrylhydrazyl (DPPH)-antiradical activity (IC_{50}, mg/mL), and lipid peroxidation inhibition potential were higher in fermented black and yellow soybean compared with non-fermented cooked soybean [22].

Total phenol content of kinema was 144% higher than the raw soybean. Moreover, kinema has better free radical scavenger ability and metal chelating power and improved reducing power than that of non-fermented soybean. Therefore, it is suggested that kinema may has potential used as designer foods to alleviate oxidative stress [43]. Likewise, *B. subtilis* fermentation inclines to improve total polyphenolic and anthocyanins content about 10 and 250% during natto preparation from black soybeans, respectively. Moreover, DPPH radical scavenging activity has positive association with fermentation time and concentration of black soybean [19].

Fermentation increases about 58% content of phytosterol in kinema [43]. Later, Moktan et al. [44] reported that the kinema had 144%, 44%, 147%, and 92% higher total phenolics content, antioxidant activity, DPPH scavenging activity, and Fe^{2+}-chelating activity, respectively, compared to non-fermented cooked soybean. Similarly, better total phenolic contents and

DPPH activity were observed in Bacillus fermented soybean than that of soaked or cooked soybean [19].

During fermentation process of soybean, peptides are released by the hydrolysis of soybean proteins. Specific bioactive peptides such as glycinin and β-conglycinin are synthesized through the hydrolysis of soybean proteins. These bioactive peptides may act as regulatory compounds and have potential to minimize the physiological dysfunctions such anti-diabetic and anticancer activities [45].

Generally, fermented products are still widely synthesized by traditional methods. Consequently, it was recommended to develop standard operating producers and adhere with the good manufacturing practice (GMP) for individuals directly involved in its production for ensuring its safety [43].

7. Sensory response of fermented products

Sensory response including color, flavor, odor, texture, and overall acceptability is the main contributing parameters for the acceptance of products. Sensory evaluation of fermented soybean is mostly carried out using seven-point hedonic scale. The prepared natto obtained higher scores for color, appearance, taste, and viscosity than non-fermented cooked soybean [46]. Similarly, chungkukjang flavor, taste, and overall acceptability are evaluated using nine-point hedonic scale and reported that fermented soybean has high savory flavor and lower bitterness than traditional natto [47].

Moreover, soybean fermented with *B. subtilis TN51* has superior aroma than that of conventionally fermented soybean [27]. In another study, sensory traits of natto, *that are,* color, aroma, stickiness, bitterness, sweetness, sourness, and chewiness were determined through continuous linear intensity-scale of 10 cm with multiple demographic panelists such as Chinese, Japanese, and American. There were non-significant variations observed in sweetness or sourness and flavor in commercial available natto and laboratory prepared similar product [37].

8. Animal-based vitamin K_2 food products

8.1. Meat

Concerning the vitamin K, only plants and fermented food commodities are considered as a major natural source, but limited attention has been paid to meat for its menaquinones contents. Recently, Rødbotten et al. reported that cattle meat such as Jersey and Norwegian Red have better amount of menaquinones predominately MK-4 [48]. Jersey meat has higher amount of MK-4 in *M. longissimus dorsi* (LD), *M. biceps femoris* (BF), and *M. psoasmajor* muscles compared to Norwegian Red Cattle. Some traces of MK-6 and MK-7 were also detected in both types of cattle meats. Moreover, it is suggested that vitamin K_2 content has no association with intramuscular fat and tenderness of meat. Contrary, Fujiwara et al. reported that poultry birds rely on natto did not improve the menaquinones content of meat [49]. Previously, Elder et al. [50] quantified the MK-4 in beef, chicken, fish, and liver of calf available in retail outlets or fast food restaurants of various cities of USA and reported that MK-4 was present in chicken in substantial amount ranged from 6.3 to 22.1 μg/100 g as compared to other tested animal meat and meat products (**Table 3**).

Meat	Type	Country	MK-4	MK-6	MK-7	Reference
Chicken	Breast meat	Netherlands	8.9	–	–	[13]
Chicken	Leg meat	Netherlands	8.5	–	–	[13]
Chicken	Thigh raw	Japan	ND	-	27 ± 15	[12]
Chicken	Leg and thigh ng/g	Japan	600	ND	ND	[12]
Chicken	Fresh ng/g	Japan	89.9	ND	ND	[12]
Beef	Chuck, raw	Japan	0.6	-	15	[12]
	Beef raw	Netherlands	1.1	–	–	[13]
Beef	Fresh raw ground beef	USA	4.9	–	–	[50]
Beef	Fresh raw ground beef (medium fat)	USA	8.1	–	–	[50]
Beef	Fresh raw ground beef (high fat)	USA	7.4	–	–	[50]
Bovine beef	Fresh beef (ng/g)	Japan	34.3	0.3	0.3	[12]
Cattle (Jersey)	M. Biceps Femoris	Norway	4.85	0.004	0.006	[48]
	M. psoas major	Norway	2.46	–	–	[48]
	M. longissimus dorsi	Norway	3.39	–	–	[48]
Cattle (Norwegian Reg)	M. Biceps Femoris	Norway	3.02	0.006	0.082	[48]
	M. psoas major	Norway	1.82	–	–	[48]
	M. longissimus dorsi	Norway	2.43	–	–	[48]
Beef	Minced meat	Netherlands	6.7	–	–	[13]
Beef Product	Salami	Netherlands	9.0	–	–	[13]
Pork	Thigh, raw	Japan	ND		6 ± 2	[12]
Pork	Fresh pork meat (ng/g)	Japan	9.4	0.3	0.3	[12]
Pork	Pork meat chop (ng/g)	Japan	31	ND	1.2	[12]
Horse	Fresh house meat ng/g	Japan	2.0	0.2	2.3	[12]
Luncheon	Meat	Netherlands	7.7	–	–	[13]
Hare	Leg meat	Netherlands	0.1	–	–	[13]
Deer	Back meat	Netherlands	0.7	–	–	[13]
Goose	Leg meat	Netherlands	31	–	–	[13]
Goose	Liver paste	Netherlands	369	–	–	[13]
Duck	Breast meat	Netherlands	3.6	–	–	[13]

Table 3. Menaquinones contents of meat of various fresh meat (μg/100 g).

Some studies indicated that thigh raw chicken meat contained the menaquinone-7 about 27 ng/g [21], whereas other only reported menaquinone-4 in both leg and breast meat of chicken ranged from 89.9 ng/g to 8.9 μg/100 g [13, 21]. Similarly, beef meat including raw, raw ground low, medium, and high fat meats from Japan, Netherlands, and USA contained menaquinone-4 ranged from 0.6 to 8.1 μg/100 g. However, Japanese origin beef meat contained menaquinone-7 as 15 μg/100 g. Likewise, cattle meat including Jersey and Norwegian *Biceps Femoris* meat merely contained MK-4, MK-6, and MK-7, whereas other parts did not contained MK-7, but their amount is very low [13, 21, 48, 50]. Additionally, pork and horse fresh meat contained the limited amount of MK-7 and all other tested meat such as luncheon, hare, deer goose, and duck contained only MK-4 (**Table 3**).

In various countries, people used the organs of animal as a source of meat. Therefore, concentration of vitamin K_2 is also very important to know in the commonly consumed organs such as liver, kidney, and heart. Hirauchi and coworkers reported that the organs meat of horse, chicken, and pork had significant amount of MK-4 compared with long-chain menaquinones (MK-7 to MK-13) and phylloquinone [51]. However, bovine liver was rich in MK-13 (215 ng/g) followed by MK-12 (215.6 ng/g), whereas the lowest concentration was noticed of MK-9 (15.3 ng/g). Other livers of various tested animal contained traces of higher menaquinones. The higher amount of long-chain menaquinones are possibly synthesized by gut microflora and stored in liver [52].

However, roasted beef contained 2–4 μg/100 g of MK-4, while other menaquinones such as MK-5, MK-7 and MK-8 were also present with low concentration [53]. Few publications are available regarding the vitamin K_2 content of meat (**Tables 4** and **5**). Previously, it was reported that beef meat has limited amount of vitamin K_2 without specifying the type of muscle and breeds [50, 53].

Meat	Type	Country	MK-4	MK-5	MK-6	MK-7	MK-8	Reference
Beef liver	Raw (μg/100 g)	USA	0.4	–	–	–	–	[50]
Beef liver	Pan-fried (μg/100 g)	USA	0.4	–	–	–	–	[50]
Beef liver	Braised (μg/100 g)	USA	1.9	–	–	–	–	[50]
Beef liver	Raw (ng/g)	USA	8.2	–	24.5	181.8	48.4	[51]
Beef liver	Raw (ng/g)	Finland	6.8	ND	9.44	25.6	13.8	[53]
Beef liver	Fresh heart (ng/g)	Japan	21.7	–	2.8	0.9	ND	[51]
Calf liver	Raw (μg/100 g)	USA	5.0	–	–	–	–	[50]
Calf liver	Pan-fried (μg/100 g)	USA	6.0	–	–	–	–	[50]
Calf liver	Braised (μg/100 g)	USA	1.1	–	–	–	–	[50]
Chicken Liver	Raw (ng/g)	Japan	39.6	–	0.3	ND	0.9	[51]
Chicken Liver	Raw (μg/100 g)	USA	14.1	–	–	–	–	[50]
Chicken Liver	Pan-fried (μg/100 g)	USA	12.6	–	–	–	–	[50]

Meat	Type	Country	MK-4	MK-5	MK-6	MK-7	MK-8	Reference
Chicken Liver	Braised (µg/100 g)	USA	6.7	–	–	–	–	[50]
Chicken heart	Fresh (ng/g)	Japan	142.6	–	0.1	ND	ND	[51]
Horse liver	Raw (ng/g)	Japan	2.1	–	1.0	2.3	1.2	[51]
Horse heart	Fresh heart (ng/g)	Japan	0.4	–	0.2	ND	ND	[51]
Pork heart	Raw (ng/g)	Finland	10.8	ND	ND	16	25	[53]
Pork liver	Fresh	Japan	1.2		0.2	1.1	ND	[51]
Pork	Raw	Netherlands	0.3	–	–	0.3	–	[13]
Pork	Raw Liver (ng/g)	Japan	5.9	–	0.4	6.1	5.6	[51]

ND = not detected; (–) = unknown or not reported.

Table 4. Vitamin K-2 content of different organ meats.

Food	Type	Country	MK-4	MK-5	MK-6	MK-7	Reference
Beef product	Hot dogs, regular fat	USA	5.7	–	–	–	[50]
Beef product	Ham roasted and pan broiled	USA	5.1	–	–	–	[50]
Beef product	Bacon (raw, pan-fried, microwaved, cooked and baked)	USA	5.6	–	–	–	[50]
Beef product	Beef meat roasted (ng/g)	Finland	28	1.2	ND	1.17	[53]
Beef product	Beef products	USA	1.7–8.1	–	–	–	[50]
Beef product	Roasted beef		2–4	–	–	–	[53]
Beef product	Broiled ground beef (low-fat steak)	USA	1.7	–	–	–	[50]
Beef product	Broiled ground beef (medium fat)	USA	7.2	–	–	–	[50]
Beef product	Broiled ground beef (high fat)	USA	5.1	–	–	–	[50]
Pork product	Loin (raw, broiled, pan-broiled, braised)	USA	0.9	–	–	–	[50]
Pork product	Meat franks, regular fat	USA	9.8	–	–	–	[50]
Pork product	Pork steak	Netherlands	2.1	–	–	0.5	[13]

ND = not detected; (–) = unknown or not reported.

Table 5. Vitamin K-2 content of different animal meat-based products (µg/100 g).

8.2. Animal-based sea foods

Fishes such as rainbow trout contained MK-4 (31 ng/g), MK-5 (0.9 ng/g), and MK-7 (2.0 ng/g), whereas MK-6 and MK-8 were not present (**Table 6**). Similarly, pike-perch also contained these menaquinones along with MK-6. Baltic herring and salmon only contained MK-4. Moreover, plaice and eel contained MK-4 as 0.2 and 1.7, MK-6 as 0.3 and 0.1, and MK-7 as 1.6 and 0.0, respectively. Horse mackerel from Netherlands and Japan only contained MK-4 content (0.4 and 0.6 μg/100 g). Furthermore, shrimp also had MK-4 (0.2 μg/100 g). Canned crab and tilapia fillets did not contain any form of menaquinones [13, 21, 50].

Food	Type	Country	MK-4	MK-5	MK-6	MK-7	MK-8	Reference
Fishes	Rainbow trout (ng/g)	Finland	31	0.9	ND	2.0	ND	[53]
	Pike-perch (ng/g)	Finland	1.9	0.49	0.52	4.9	ND	[53]
	Baltic herring (ng/g)	Finland	2.07	–	ND	ND	ND	[53]
Fish	Mackerel	Netherlands	0.4	–	–	–	–	[13]
	Plaice	Netherlands	0.2	–	0.3	0.1	1.6	[13]
	Eel	Netherlands	1.7	–	0.1	0.4	–	[13]
	Salmon	Netherlands	0.5	–	–	–	–	[13]
Fish	Horse mackerel, raw	Japan	0.6	–	–	ND	–	[12]
	Mackerel, raw	Japan	1.0	–	–	ND	–	[12]
Crab	Canned	USA	ND	–	–	–	–	[50]
Shrimp	Cooked and canned	USA	0.2	–	–	–	–	[50]
Salmon	Raw, Alaska wild	USA	0.3	–	–	–	–	[50]
Tilapia fillets	Raw and baked	USA	ND	–	–	–	–	[50]

ND = not detected; (–) = unknown or not reported.

Table 6. Menaquinones contents of various sea foods (μg/100 g).

8.3. Milk

Fresh milk having varied amount of fat also contained some amount of menaquinones especially MK-4. Sheep and cow whole milk contained about 17.4 and 8.60 ng/g of MK-4, respectively, while menaquinones were not detected in goat and donkey milk [54]. Moreover, milk having 1% fat had 0.4 μg/100 g of MK-4, whereas milk with higher amount of fat (2%) and whole milk showed more MK-4 contents as 0.5 and 1.0 μg/100 g which is available in retail outlets of USA [50].

There are various microorganisms such as *L. lactis* subsp. *cremoris*, *L. lactis* subsp. *Lactis,* and *Leuconostoc lactis* which have potential to produce long-chain menaquinones like MK-7 to

MK-10 about 230 nmol/g of dry cells. Moreover, these strains also have capacity to synthesis the ample amount of long-chain menaquinones in reconstituted non-fat dry milk and soy milk. Therefore, the milk-based fermented foods have significant amount of menaquinones and considered as an important dietary sources of vitamin K_2 [55]. Earlier, it was documented that the human milk only contained phylloquinone, but menaquinones were not detected [56].

Some of the fresh milk only contained MK-4 and other menaquinones are not detected or contained in the whole milk with varied concentration of fat from different animals (**Table 7**). Likewise, various creams and dressing also had MK-4 as source of vitamin K2. Interestingly, fermented milk and sourced milk contained higher amount of long-chain menaquinones such as MK-6, MK-7, MK-8, and MK-9 while MK-4 and MK-5 were not present. Similarly, butter milk also contained MK-4 to MK-8 but in limited quantity, butter contained only MK-4 (15 μg/100 g).

Food	Type	Country	MK-4	MK-5	MK-6	MK-7	MK-8	MK-9	Reference
Fresh Milk	1% fat	USA	0.4	–	–	–	–	–	[50]
Fresh Milk	2% fat (Regular and chocolate)	USA	0.5	–	–	–	–	–	[50]
Fresh Milk	Whole milk	USA	1.0	–	–	–	–	–	[50]
Fresh Milk	Cow 3.5% fat (μg/L)	Italy	8.60	–	–	–	–	–	[54]
Fresh Milk	Buffalo 5.0% fat (μg/L)	Italy	ND	–	–	–	–	–	[54]
Fresh Milk	Sheep 5.5% fat (μg/L)	Italy	17.4	–	–	–	–	–	[54]
Fresh Milk	Goat 5.0% fat (μg/L)	Italy	ND	–	–	–	–	–	[54]
Fresh Milk	Donkey 1.0% fat (μg/L)	Italy	ND	–	–	–	–	–	[54]
Fresh Milk	Whole milk	Japan	2.03	–	–	ND			[12]
Fresh Milk	Whole milk	Netherlands	0.8	0.1	–	–	–	–	[13]
Yoghurt	Yogurt plain (ng/g)	Finland	3.6	1.01	ND	ND	ND	ND	[53]
Yoghurt	Whole milk	Japan	0.6	0.1	0	0.2	–	–	[51]
Yoghurt	Skimmed milk	Japan	0	0	0	0.1	–	–	[51]
Yoghurt	Yogurt, plain (whole milk)	Japan	1.0	–	–	0.1	–	–	[12]
Yoghurt	Whole yoghurt	Netherlands	0.6	0.1	–	–	0.1		[13]
Yoghurt	Fortified MK-7	Netherlands		–	–	11.65	–	–	[57]
Cream	Ice cream Regular fat (vanilla and chocolate)	USA	2.6	–	–	–	–	–	[50]

Food	**Type**	**Country**	**MK-4**	**MK-5**	**MK-6**	**MK-7**	**MK-8**	**MK-9**	**Reference**
Cream	Cream	Japan	8	–	–	ND	–	–	[12]
Cream	Whipping cream	Netherlands	5.4	–	–		–	–	[13]
Dressing	Mayonnaise (whole egg type	Japan	17	–	–	ND	–	–	[12]
Dressing	Mayonnaise (egg yolk type	Japan	38			ND	–	–	[12]
Chocolate	Market (brand or type is no specified)	Netherlands	1.5	–	–	–	–	–	[13]
Buttermilk	Market (brand or type is no specified)	Netherlands	0.2	0.1	0.1	0.1	0.6		[13]
Butter	Market (brand or type is no specified)	Netherlands	15.0	–	–	–	–	–	[13]
Soured milk	(ng/g)	Finland	5.7	2.93	1.7	4.1	20.1	47	[53]
Fermented milk	Mesophilic fermented milk (MFM) ng/g	France	–	–	1.3–4.9	1.2–6.1	7.237.9	29–145	[58]
Fermented milk	MFM (ng/g)	Germany	–	–	2.1–6	4.1–6.3	31–42	88.4–198.5	[58]
Fermented milk	MFM (ng/g)	Poland	–	–	0.5–11.9	3.2–10.9	7.1–89.3	17–414.2	[58]

ND = not detected; (–) = unknown or not reported.

Table 7. Menaquinones contents of various dairy products (μg/100 g).

Recently, Knapen et al. delineated that vitamin K fortified foods are healthy choice to increase the nutritional intake of MK-7 [57]. The fortified yoghurt drink containing MK-7 about 28 μg/ml has similar absorption pattern as the soft gel containing same amount of pure menaquinone-7. It is therefore suggested that to fortify food products that are ideal choice among the public to enhance the nutritional intake of menaquinones in the body.

8.4. Yoghurt

Thermophilic bacteria such as *Lactobacillus delbrueckii*, *Streptococcus thermophilus,* and *Bifidobacterium* which are mostly used a lactic acid bacteria starter culture not have ability to produce the menaquinones. Therefore, yogurt type milk-based products prepared with pure culture of thermophilic bacteria have limited or no menaquinones. However, among other milk-based fermented products, 60% contained some amount of vitamin K_2 (**Table 7**). The mesophilic lactic acid bacteria species which as used as starter culture for the fermentation have a capability to produce ample amount of vitamin K_2[53, 58]. However, yoghurt including plain, whole and skimmed milk contained higher amount of MK-4, whereas very low concentration of other menaquinones such as MK-5, MK-6 and MK-7 was present (**Table 7**).

Fortified yoghurt drink with MK-7 significantly improved serum concentration from 0.38 ng/ml to 2.00 ng/ml, whereas yoghurt supplemented with MK-7 along with other vitamins increased better serum MK-7 level as 2.17 ng/ml. Fortified MK-7 yoghurt and soft gel containing MK-7 showed statistically non-significantly variations [57].

8.5. Cheeses

Soft cheese as well as blue cheese have tremendous amount of vitamin K$_2$ as 1100 and 700 ng/g [58]. Earlier, menaquinones content of these cheeses has never been reported because soft and blue cheeses were not evaluated in respect of their vitamin K$_2$ content. These cheeses have higher amount of menaquinones possibly due to the activity of lactic acid bacteria particularly *Leuconostoc* species and yeasts or molds which are involved in ripening of cheeses. Most of the soft (from table name) and blue cheeses characterized had high contents of vitamin K$_2$ [59]. Generally, MK-9 was present in soft and blue cheese almost fourfold than that of MK-8. It is suggested that *lactococci* is responsible for the production of MK-9 in the dairy products. However, these bacteria also produced MK-8 comparatively constant ratio. Likewise, *propionibacteria* also synthesized the MK-9 as a key menaquinone in cheese. Menaquinone-9 concentration was higher in Norwegian Jarlsberg cheese trailed by Swiss Emmental cheese. However, Appenzeller or Gruye′re cheeses had extremely low concentrations of MK-9. Additionally, Comte and Raclette cheeses contained lesser amount of MK-9 than both Jarlsberg and Emmental cheeses (**Table 8**).

Food	Type	Country	MK-4	MK-5	MK-6	MK-7	MK-8	MK-9	Reference
Cheeses	Hard cheeses (μg/100g)	Netherlands	4.7	1.5	0.8	1.3	16.9	-	[13]
	Soft cheese (μg/100g)	Netherlands	3.7	0.3	0.5	0.5	1.0	-	[13]
	Curd cheese (μg/100 g)	Netherlands	0.4	0.1	0.2	0.3	5.1	-	[13]
Semi-hard cheese	Semi-hard cheese (ng/g)	Netherlands	–	–	14.5–34.5	0–14.1	33.9–73.1	100–321	[58]
	Semi-hard cheese (ng/g)	Denmark	–	–	16.1–19.8	7.1–13.5	25–35.8	115.3–185.1	[58]
	Semi-hard cheese (ng/g)	Poland	–	–	9.8–15.8	ND	27.8–56.4	124.5–166.3	[58]
Soft cheese	Soft cheese (ng/g)	France	–	–	13.7–25.9	0–17.1	89.2–139.9	176.1–939.7	[58]
Cheese	Edam type (ng/g)	Finland	33	10.2	5.6	12.6	105	300	[53]
	Emmental type (ng/g)	Finland	52.3	ND	Traces	Traces	ND	Nd	[53]
Blue cheese	Blue cheese (ng/g)	France	–	–	14.4–35.4	24.6	59.8	189–230	[58]
	Blue cheese (ng/g)	England	–	–	96.7	223	103	301	[58]
Cheddar	Hard cheddar (ng/g)	England	–	–	8.7–29.9	0–23.1	10.5–61.8	0–66.9	[58]

Food	Type	Country	MK-4	MK-5	MK-6	MK-7	MK-8	MK-9	Reference
	Cheshire hard cheese (ng/g)	England	–	–	15.7	Nd	57.9	241	[58]
Leicester	Leicester hard cheese (ng/g)	France	–	–	20	21.5	47.6	162.4	[58]
Cheese	Appenzeller (ng/g)	Swiss	43–52	–	–	–	–	20	[59]
	Comte (ng/g)	France	55–84	–	–	–	–	52–60	[59]
	Emmental (ng/g)	Swiss	81–86	–	–	–	–	222–314	[59]
	Gruyere (ng/g)	Swiss	81–96	–	–	–	–	ND	[59]
	Jarlsberg (ng/g)	Norway	84	–	–	–	–	652	[59]
	Raclette (ng/g)	Swiss	50	–	–	–	–	47	[59]
Cheese	Chedder cheese (μg/100 g)	USA	10.2	–	–	–	–		[50]
	Swiss cheese (μg/100 g)	USA	7.8	–	–	–	–	–	[50]
	Mozzarella cheese (μg/100 g)		-	–	–	–	–	–	[50]
	Processed cheese ((μg/100 g)	Japan	5	–	–	0.3	–	–	[12]

Table 8. Menaquinones contents of various cheeses

Positive correlation was found in propionate concentration and viable propionibacterial cell count which is contributed toward the production of MK-9 in cheeses [59]. Earlier, different reports showed that components of menaquinones are varied among the types of cheeses. In this context, menaquinones concentration is better in Edam-type cheeses than Emmental-type cheeses-specific bacterial activity [53]. Starter culture has prime importance during the preparation of cheese with higher amount of menaquinones. Commonly, Swiss-type cheeses are prepared with *propionibacteria* and lactic acid bacteria, while Edam-type cheese are produced with the action of lactic acid bacteria only such as *Lc. lactis* ssp. *Cremoris* and *Lactococcus lactis* ssp. *Lactis* which are mainly responsible for the synthesis of MK-8 and MK-9 [60]. Moreover, *Propionibacterium freudenreichii* isolated from Swiss-type cheese has a potential equivalent to the *Bacillus subtilis* to produce menaquinone-9 in milk whey [61].

Long-chain menaquinones such as MK-6 to MK10 was not present in Comte hard cheese produced in France. Likewise, these menaquinones were not present in the Emmental hard cheese while some amount of MK-10 and MK-11 was detected. Interestingly, mozzarella cheese did not have any type of menaquinones because during its production process no fermentation is involved [58]. Accordingly, further research is required to evaluate the stability of menaquinones in cheese that are stored for a long time [59].

8.6. Egg

Similar to the other animal-based products, hen egg also contained considerable amount of MK-4, whereas MK-7 was not detected or not quantified by the researchers. Egg yolk contained greater concentration of the MK-4 (31.4–64 μg/100 g) than that of egg white (0.9–7 μg/100 g). Additionally, cooking also increased the MK-4 content in the egg might be due to loss of moisture content compared with whole fresh egg (**Table 9**). In this context, whole fried egg contained 9.0 μg/100 g and hard cooked whole egg contained 7.0 μg/100 g compared to fresh whole egg 5.6 μg/100 g [13, 21, 50].

Food	Type	Country	MK-4	MK-6	MK-7	Reference
Egg	yolk	Netherlands	31.4	0.7	–	[13]
Egg	albumen	Netherlands	0.9	–	–	[13]
Egg	Whole and raw	Japan	7	–	ND	[12]
Egg	Raw yolk	Japan	64	–	ND	[12]
Egg	White fresh raw	USA	0.4	–	–	[50]
Egg	Yolk fresh raw	USA	15.5	–	–	[50]
Egg	Whole and fresh	USA	5.6	–	–	[50]
Egg	Whole and fried	USA	9.0	–	–	[50]
Egg	Whole and hard cooked	USA	7.0	–	–	[50]

Other menaquinones were not detected or quantified.

MK-7 was not detected in fresh whole egg and raw egg yolk.

Table 9. Menaquinones contents of hen egg (μg/100 g).

8.7. Fast foods

Elder et al. reported that various fast food products including hamburgers, sandwiches, burrito, taco, pepperoni, and shakes contained MK-4 [50]. Regular hamburger contained lower amount of MK-4 which was subsequently increased by the addition of cheese or sauces or both in the hamburgers. Likewise, Chicken sandwich contained relatively higher amount of MK-4 as 2.7–10.6 μg/100 g than that of hamburger due to higher amount of chicken that possibly contained higher amount of MK-4. Burrito prepared with beans, beef, or chicken contained MK-4 ranged from 0.6 to 2.7 μg/100 g. Pepperoni contained almost similar amount MK-4 as present in the burrito. Shakes available in USA market including chocolate and vanilla also have some amount of MK-4 (**Table 10**).

Food	Type	Country	MK-4	Reference
Hamburger	Regular, with cheese, sauces, and both	USA	1.4–2.9	[50]
Sandwich	Prepared the various meat-based products chicken sandwich	USA	2.7–10.6	[50]
Sandwich	Fish sandwich	USA	0.3	[50]
Burrito	Burrito with bean, beef, and chicken	USA	0.6–2.7	[50]
Taco	Taco regular, with beef, chicken, or cheese	USA	1.0–4.5	[50]
Pepperoni	Pepperoni (regular, thin, and thick crust) or meat and vegetables	USA	1.9–2.1	[50]
Shakes	Shakes, chocolate, and vanilla	USA	3.4	[50]

Other menaquinones were not quantified in this study.

Table 10. Menaquinones contents of various fast foods (μg/100 g).

9. Bioavailability

The Food and Nutrition Board established the RDA level for vitamin K as 65 and 80 μg for adult women and men, respectively [62]. The adequate intake of vitamin K from food sources is relative higher about 120 μg/day and 90 μg/day for men and women, respectively [63, 64]. Neonates need approximately 2–2.5 μg/day of vitamin K that progressively increases up to 30–55 μg/day in children.

Both active forms of vitamin K, *that is,* phylloquinone and menaquinones, have similar absorption and assimilation pattern. However, relative few studies were carried out to estimate the absorption efficiency, including transportation, distribution, and cellular uptake of various menaquinones [10, 65]. Absorbed vitamin K is transported mainly through lymphatic system in chylomicrons to the hepatic tissue which is main storage organ for long-chain dietary forms of vitamin K [2].

Gut absorption of all dietary forms of vitamin K appears to occur through the common pathway like most of dietary lipids. Bile acids and pancreatic enzymes accelerate the solubility, emulsification, and assimilation of vitamin K into mixed micelles in digestive system. In enterocytes, vitamin K is attached with chylomicrons and enters in lymphatic circulation system. The bioavailability of vitamin K dietary forms is positively associated with dietary lipids and integrity of food matrix [66, 67].

It was reported that isoprenoid side chain length was changed during cellular uptake, transportation, and storage of long-chain menaquinones. Variations were observed in absorption and transportation of vitamin K dietary forms such as phylloquinone, menaquinones (MK-4 and MK-9) after equivalent amount administration of respective form. Postprandial plasma concentration and absorption of MKs are relatively less than phylloquinone, and its uptakes are more in tissues.

In contract to phylloquinone, which is principally fund in triglyceride-rich lipoproteins during postprandial as well as fasting condition, menaquinones are reallocated from triglycerides-rich lipoproteins to low-density lipoproteins (LDL) in and after postprandial consumption of vitamin K. Whereas shorter-chain menaquinones, *that is,* MK-4 were redistributed earlier and incorporated with high-density lipoproteins (HDLs) than MK-9. Moreover, only MK-4 is transported via high-density lipoproteins (HDLs) [10, 68].

The clearance of shorter-chain menaquinones was quick, while other was detected after days in plasma. Likewise, MK-7 has same plasma kinetics with higher half-life of 72 h than that of MK-4 and phylloquinone [9, 13, 69–71]. Nevertheless, no information of plasma kinetics is available of other long-chain menaquinones. High concentration of MK-4 was found in non-hepatic tissues of the body after the ingestion of phylloquinone. This might be due to the conversion of phylloquinone to MK-4. The exact phenomenon is still unclear; however, some researchers suggested that it was converted to other menaquinones via prenylation. In this context, deuterium labeled MK-4 was administrated to mice which are converted to MK-4 via integral side chain removal through prenylation. Likewise, ingestion of MK-7 also increases the serum MK-4 level considerably [2, 12, 17, 69, 71]. Contrary, in germ-free rats, MK-4 and phylloquinone content were increased in extrahepatic tissues through administration of their respective supplements after deficient condition. Moreover, MK-4 concentration was enhanced by phylloquinone administration. They also inferred that the conversion of phylloquinone in to MK-4 in extraheptic tissues did not require the intestinal bacterial population. This conversion is purely biochemical and remain unclear thus far [72]. Optimal daily vitamin K_2 especially MK-4 intake as well as sufficient serum concentration is required to activate Vitamin K-dependent proteins [27, 73].

10. Demographic study

Progressive administration of MK-7 momentously increased the level of plasma MK-7; nonetheless, MK-4 supplementation did not enhance the MK-4 concentration in healthy individuals. Therefore, lower dose of MK-7 (45–90 μg/day) is considered to be effective for ameliorating the physiological dysfunctions [69]. Prime circulating form of vitamin K is phylloquinone, whereas menaquinones (MK-9 to MK-13) are abundantly present in liver. Stored vitamin K is rapidly depleted from the body, and almost 60–70% of absorbed vitamin K is finally lost from body through urine (20%) and faces (40–50%) [74, 75].

Various demographic studies were carried out to estimate the level of circulating MK-7 level in normal and unhealthy subjects. In 1990, study was conducted in London to estimate the level of MK-7 in young and elderly normal subjects. They found that serum concentrations ranged from 0.293 to 0.328 ng/ml in healthy individuals. Jamal et al. also assessed the circulating concentration in patients with hip and vertebral fractures subjects and noticed less amount (0.039 and 0.148 ng/ml) compared to normal subjects [76]. Additionally, French young and elderly women had non-significant varied amount of MK-7 (0.221–0.241 ng/ml), whereas hip fracture old women had 0.120 ng/ml of MK-7.

Japanese healthy adults and vertebral fracture older women had 3.820 and 3.290 ng/ml of MK-7, whereas elderly normal women had significantly higher amount of MK-7 (6.260 ng/ml) might be due to higher consumption of natto which are rich with MK-7. However, postmenopausal women contained less amount of serum MK-7 (0.75–1.10 ng/ml) as compared to normal adults (1.214ng/ml). Moreover, postmenopausal women from Osaka Japan having lower bone mineral density (BMD) showed lesser amount of circulating MK-7 than that of normal BMD women [77].

Likewise, Kaneki et al. reported the serum levels of MK-7 in postmenopausal women from United Kingdom, Hiroshima, and Tokyo [78]. They inferred that Tokyo women had higher amount of MK-7 as 5.26 ng/ml followed by women lived in Hiroshima 1.221 ng/ml and the lowest concentration as 0.371 ng/ml was noticed in United Kingdom population. They also reported that natto intake has positive association with serum concentration of MK-7 in elderly women living in Tokyo, Japan. Serum MK-7 level was maximum (7.91 ng/ml) in women that consumed natto twice or more in a week, whereas MK-7 level was decreased as 2.81 and 0.873 ng/ml in women when the intake of natto was reduced once or less than once in a week, respectively.

Recently, Knapen et al. demonstrated that the intake of MK-7 fortified yoghurt momentously increased the plasma concentration of MK-7 from 0.28 to 1.66 ng/ml after 14 weeks of intervention in postmenopausal women and healthy men of aged 45–65 years from the Limburg, Netherlands [57]. The regular intake of MK-4 was momentously lowered (29%) cardiovascular problems in hemodialysis patients of Poland. Although lower serum value of MK-4 in hemodialysis subjects might be due to the less intake of vitamin K_2 or probably slow conversion rate of phylloquinone to menaquinones, MK-4 intake is positively related with the amount of protein and fat consumed [73].

In Japanese young women, average consumption of vitamin K was adequate 230.2/day and nearly 94% individuals consume adequate intake level of vitamin K. There mean daily intake of MK-4 and MK-7 was 16.9 and 57.4 μg/day, respectively. Both menaquinones, *that is,* MK-4 and MK-7 contribute almost 30% of the daily requirement of vitamin K in the body [12].

11. Conclusion

Vitamin K_2 is present in numerous in varied concentration of long-chain menaquinones and their types. Fermented soybean of all region of the world contained abundant concentration of MK-7 compared with other menaquinones. Fermentation process is facilitated by action of bacteria which attained the status of generally recognized as safe (GRAS) due to their non-pathogenicity. However, animal-based products such as fresh meat of caw, buffalo, other animals, milk, fish, and egg contained greater amount of MK-4 contents. Additionally, fermented milk-based products such as cheese, source milk, butter milk, and menophilic fermented milk contained ample amount of long-chain menaquinones and MK-4 content were limited in these products due to the bacterial action. Some non-fermented cheese did not contain any form of vitamin K_2. During the physiological functioning, MK-4 is converted in to MK-7 which is more effective to curtail the vitamin K deficiency–associated dilemma.

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