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Applied nutritional investigation

Vitamin D: Can fish food–based solutions be used for reduction of vitamin D deficiency in Poland?

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ABSTRACT

Objective: The multitude of diseases promoted by vitamin D deficiency makes providing the human organism with a constant and sufficiently high supply of this compound a high priority. The aim of this study was to verify the extent to which fish present in the Polish diet can satisfy the body's requirement for this compound. The obtained data would help to evaluate whether a diet rich in fish may be a solution for vitamin D deficiency.

Methods: Cholecalciferol and ergocalciferol in muscle tissues of fish species popular in the Polish market were determined by means of high-performance liquid chromatography. Based on these updated data, and on data regarding fish consumption, it was possible to assess the level of vitamin D intake provided by fish consumption.

Results: This study proved that some of the investigated species of fish are a good source of vitamin D_3. Among wild fish, Baltic salmon and herring contained the highest amount of cholecalciferol. Surprisingly, the highest content of this compound was observed in lean tilapia, farmed in China. Ergocalciferol also was found in the studied fish samples.

Conclusion: Analysis of vitamin D content in various fish species indicated that the disproportion between requirement and supply seems too vast to enable eradication of vitamin D deficiency by fish food–based solutions. Still, increasing fish consumption or changing consumption patterns could be beneficial and result in noticeable improvements in vitamin D status.

Introduction

Vitamin D is a group of fat-soluble secosteroids that exhibit a wide range of physiological activities, mainly with regard to calcium and phosphorous homeostasis, and to the maintenance of a normal skeleton function and structure.

There are two physiologically important forms of vitamin D, which differ in their side-chain construction. They are ergocalciferol (vitamin D_2), which naturally occurs in plants, and cholecalciferol (vitamin D_3), which is found in animal organisms.

Although cholecalciferol can be synthesized by skin cells exposed to sunlight (290–315 nm), there are several factors that affect the skin's production of vitamin D. The widespread use of sunscreen or wearing protective head gear and clothing, as well as other strategies meant to protect the body against the harmful effects of ultraviolet (UV) radiation, can lead to significantly lower vitamin photosynthesis [1–4]. Dark skin pigmentation is also correlated with a risk for vitamin D deficiency, because the melanin present in dark skin competes with 7-dehydrocholesterol for absorption of UVB radiation. Such a competition prevents cholecalciferol formation [2,5]. Older individuals are at higher risk for vitamin D deficiency as a result of decreased quantities of skin 7-dehydrocholesterol, lower renal production of calcitriol (active form of vitamin D), and limited sun exposure [2]. Another factor enhancing cholecalciferol deficiency or insufficiency is latitude. From October to March, individuals living above a 35-degree latitude are deprived of UVB radiation capable of cholecalciferol photosynthesis [6,7]. At higher latitudes (e.g. in Poland), this period of deprivation is even longer.

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All of the just-cited factors lead to the conclusion that a dependence on sun exposure as the sole source of vitamin D may cause significant cholecalciferol deficiency. This deficiency may in turn result in a number of diseases and dysfunctions such as rickets, osteoporosis, muscle weakness, bacterial and viral infections, various autoimmune diseases (e.g., type 1 diabetes, multiple sclerosis, psoriasis), hypertension, cardiovascular disease, and many types of cancer [3–6,8,9].

The multitude of diseases promoted by vitamin D deficiency explains why providing the human organism with a constant and sufficiently high supply of this compound should be treated as a high priority, especially in light of the low vitamin D status observed in several regions of the world [10,11]. One of the regions where significantly lower vitamin D status was observed is northern Europe. This effect was strongly pronounced in Poland [7,12–14]. Vitamin D status is determined as the blood concentration of serum 25-hydroxyvitamin D [S-25(OH)D] [15]. It is considered that the blood concentration of S-25(OH)D should at least be 50 nmol/L [16]. Levels of S-25(OH)D ranging between 25 and 50 nmol/L are considered insufficient; range <25 nmol/L is vitamin D deficiency [2,17].

Study carried out in northern Europe demonstrated that 87% of Polish girls (n = 61) and 91% of Polish women (n = 65) were characterized by insufficient (<50 nmol/l) S-25(OH)D levels [12]. It was also reported that 33% of examined girls and 25% of women in Poland had S-25(OH)D levels <25 nmol/L, which qualified them as vitamin D deficient [12]. Percentage of insufficiency observed in postmenopausal women in Poland (n = 152) was the highest of all 25 studied countries and exceeded 45; 12.5% of postmenopausal women were suffering from vitamin D deficiency [14]. According to a study of newborns, insufficiency and deficiency of this nutrient was observed respectively, in 46.3% and 53.7% of the studied infants (n = 41) [13].

Strategies that may help to prevent cholecalciferol deficiency are increased exposure to UVB radiation, vitamin D supplementation, fortification of food products, and sufficient dietary intake. An excessive exposure to UV light may result in skin cancer, so an increased dietary intake should be promoted, as safe and fairly efficient. Intestinal absorption of 1 μg of cholecalciferol daily increases S-25(OH)D by 1 nmol/L [1], although this effect may be influenced by several factors, such as total vitamin D intake or the initial S-25(OH)D concentration [18]. No differences were observed for various dietary sources of vitamin D [19].

It is well established that the best supplementation sources available are fish, fish liver, and fish oil [20–23]. In Europe, the lowest levels of vitamin D deficiency occurred in Norway, a country with a traditionally high intake of fish and fish oils [24]. In Japan, fish contributes as much as 90% of dietary cholecalciferol [25].

Because Poland is a country with one of the lowest vitamin D statuses in Europe [7,12–14], it seems important to determine the content of vitamin D in fish species popular in the Polish market. Based on these updated data, as well as on data regarding fish consumption, it would be possible to verify the extent to which fish present in the Polish diet can satisfy the body's requirement for cholecalciferol. The obtained data also would enable an evaluation of whether a diet rich in fish may be a solution for eradication or reduction of vitamin D deficiency.

Materials and methods

Fish samples

Content of vitamins D_3 and D_2 in muscle tissues of 11 popular fish species present in the Polish market were determined. The species taken into consideration were: Baltic cod (*Gadus morhua callarias*), Baltic herring (*Clupea harengus membras*), Baltic salmon (*Salmo salar*), mackerel (*Scomber scombrus*), Alaska pollock (*Theragra chalcogramma*), sole (*Limanda aspera*), farmed trout (*Oncorhynchus mykiss*), farmed carp (*Cyprinus carpio*), farmed Norwegian salmon (*Salmo salar*) as well as farmed sutchi catfish (*Pangasius hypophthalmus*), and farmed tilapia (*Oreochromis niloticus*). The latter two fish are relatively new to the Polish market and rarely investigated, although quite frequently consumed.

Ten composite samples of fish from each species were taken for analysis. Baltic fish were obtained from the Polish catch area during cruises of the r/v Baltica (cod, herring), or from fishing cutters (salmon). Imported fish in the form of frozen, skinned fillets, in 0.5- and 1-kg packages, were purchased in supermarkets. Farmed carp and rainbow trout were purchased fresh from supermarkets or fish farms.

All the samples caught during cruises of the r/v Baltica (herring, cod), or purchased in frozen form (mackerel, Alaska pollock, sole, sutchi catfish, tilapia, and Norwegian salmon) were stored before analysis at a temperature not exceeding −18°C.

Frozen fish were defrosted in a refrigerator, at a temperature of 2°C to 4°C. Drip loss was discarded, and fish samples were dried with paper towels. Whole fish were filleted and skinned. Fish fillets were then homogenized in a mixer (Multi Processor, Zelmer Poland) for ~60 sec at 1300g. Homogenized fish samples were freeze-dried in an Alpha 2-4 LSC freeze-drier (Christ, Germany).

Methods

Content of vitamins D_3 and D_2 were determined based on the validated procedure elaborated in the National Marine Fisheries Research Institute (validation included determination of method uncertainty and limit of quantitation (LOQ) as well as analyses of the certified reference materials (CRM): margarine CRM 122 and milk powder CRM 421—obtained recoveries ranged from 94% to 110%).

Table 1
Average contents of vitamins D_3 and D_2 in muscle tissue of examined fish

Species	Vitamin D_3 (μg/100 g muscle tissue)		Vitamin D_2 (μg/100 g muscle tissue)	
	Mean*	SD	Mean	SD
Farmed carp	$7.5^{a,d}$	6.15	$0.5^{c,d,f}$	0.24
Farmed rainbow trout	8^{a}	3.36	0.9^{c}	0.72
Farmed tilapia	38^{b}	7.70	0.4^{d}	0.02
Farmed sutchi catfish	0.3^{c}	0.02	0.3^{e}	0.02
Mackerel	4.7^{d}	3.02	1.5^{b}	1.01
Farmed Norwegian Salmon	$5.9^{a,d}$	3.58	0.7^{c}	0.11
Baltic cod	0.7^{e}	0.40	0.4^{f}	0.02
Baltic salmon	26.5^{f}	5.60	2.7^{a}	1.11
Baltic herring	8.8^{a}	3.72	3.5^{a}	2.36
Alaska pollock	0.3^{g}	0.04	0.3^{g}	0.04
Sole	4.4^{d}	2.16	$0.4^{d,e,f,g}$	0.15

Given values are the average for 10 independent samples, each analyzed in duplicate

* Mean values in columns with different letter indexes differ significantly $P \leq 0.05$.

Table 2
Dry weight and fat content of muscle tissue in examined fish

Species	Dry weight (%)		Fat content (%)	
	Mean*	SD	Mean	SD
Farmed carp	22.25^{a}	2.59	5.11^{a}	2.97
Farmed rainbow trout	26.99^{b}	1.47	7.40^{b}	1.62
Farmed tilapia	18.82^{c}	1.05	1.98^{c}	0.55
Farmed sutchi catfish	15.26^{d}	0.79	1.25^{d}	0.28
Mackerel	40.09^{e}	4.82	20.99^{e}	6.35
Farmed Norwegian Salmon	34.15^{f}	5.64	14.47^{f}	6.55
Baltic cod	18.52^{c}	0.79	0.08^{g}	0.02
Baltic salmon	31.79^{f}	3.91	12.06^{f}	3.88
Baltic herring	22.94^{a}	1.36	3.56^{h}	1.40
Alaska pollock	13.41^{g}	2.03	0.09^{g}	0.03
Sole	$15.01^{d,g}$	1.56	0.50^{i}	0.29

Given values are the average for 10 independent samples, each analyzed in duplicate

* Mean values in columns with different letter indexes differ significantly $P \leq 0.05$.