Vitamin D Fortification of Milk: A Review

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Abstract

Vitamin D deficiency is rising globally, mainly due to increase in in-door activities. The deficiency has been linked to the risk of chronic diseases such as cardiovascular and type 2 diabetes along with Osteomalacia in adults and rickets in children that causes deformities in joints, pain in bones, muscle weakening and in correct growth pattern. To overcome the issue, fortification of Vitamin D in various food and dairy products is being performed. The aim of this review article is to study the benefits of fortified milk, to learn the process of addition of vitamin D in fluid milk, its stability in dairy products and technological feasibility of vitamin D fortification in India. Vitamin D fortification of various fruit drinks is needed to improve their efficiency and prevent vitamin D deficiency in the general population as well as in different age groups.

Keywords: Dairy Fortification Fluid milk, fortified milk, vitamin D fortification, vitamin D deficiency.

Introduction

Vitamin D is a group of fat-soluble secosteroids that increases calcium, magnesium, and phosphate absorption in the intestine and several other biological effects. Vitamin D3 (also known as cholecalciferol) and vitamin D2 (ergocalciferol) are the most important compounds of this category in humans. The synthesis of cholecalciferol in the lower layers of the skin epidermis through a chemical reaction that is dependent on sun exposure is the major natural source of the vitamin (specifically UVB radiation). Cholecalciferol and ergocalciferol can be ingested from the diet and from supplements too. Only a few foods such as flesh of a fatty fish and egg yolk naturally contain a significant amount of Vitamin D and hence foods are fortified with the Vitamin D in order to meet the requirement of the body. Mushrooms when exposed to sun contribute a significant amount of this Vitamin. Vitamin D is vital for bone health since it is essential for calcium absorption. Low vitamin D status in terms of low serum 25-hydroxyvitamin D (S-25(OH)D) concentration has also been linked to the increased risk of some common chronic diseases, such as type 2 diabetes or cardiovascular disease (Theodoratou E. *et al.*, 2014). Low-fat milk, fat spreads, breakfast cereals, and some infant foods are some examples of vitamin D-fortified foods and instead of focusing on only a few basic items, a wider vitamin D fortification of different products has been suggested to better cover different population groups with different eating habits.(Cashman K.D. and Kiely M., 2016). Despite the abundance of sunshine, vitamin D insufficiency is common in India. Vitamin D fortification of basic foods is a potential technique for reaching the large population.

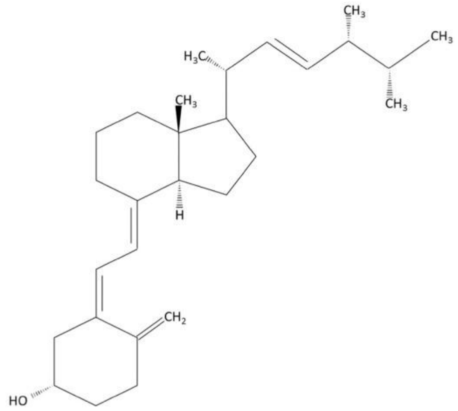

Figure 1: Chemical structure of ergocalciferol or vitamin D2.

Source: Eileen B. Yeh *et al.*, 2017

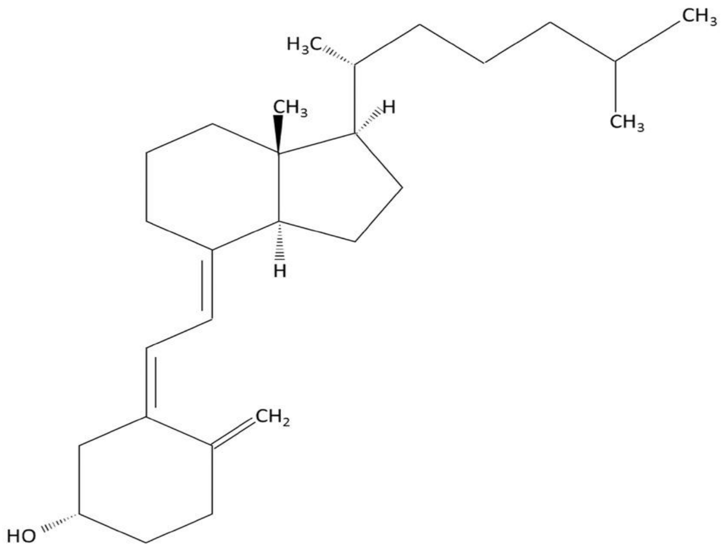

Figure 2: Chemical structure of cholecalciferol or vitamin D3.

Source: Eileen B. Yeh *et al.*, 2017

Table 1: Countries with a vitamin D fortification policy of fluid milk products.

Country	Vitamin D-Fortified Milk Products	Type of Fortification	Added Amount of Vitamin D	New Proposed Amounts of Vitamin D
Finland	Fluid milk products (milk, yoghurt, sour milk)*	Voluntary	1 µg/100 g	na
Norway	Extra low-fat milk (also lactose free)	Voluntary	0.4 µg/100 g	na
Sweden	Low-fat milk (max 1.5% fat)	Mandatory	0.38–0.50 µg/100 g	0.95–1.10 µg/100 g for milk <3% fat 0.75–1.10 µg/100 g for fermented milk <3% fat
Canada	Milk	Mandatory	0.825–1.125 µg/100 g	2 µg/100 g
United States	Fluid milk (also acidified milk and cultured milk), yoghurt	Voluntary ‡	1.05 µg/100 g for milk 2.225 µg/100 g for yoghurt §	na

* In regard to organic milk products, it is mandatory to add 1 µg/100 g vitamin D to homogenized fat-free milk (not allowed on other organic milk products).

‡ For milk products, only evaporated and non-fat dry milk are mandatorily fortified.

§ Maximum amount;

na = not applicable.

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The Benefits of Fortified Milk

Milk that has been fortified with additional nutrients is known as fortified milk. They are a good source of Vitamin A and Vitamin D, plus it is already rich in other vitamins and minerals. It's widely used all over the world to supplement people's diet with nutrients they might be missing. Fortification (adding nutrients that a product lacks) and enrichment (reintroducing nutrients lost during processing) were first developed to avoid nutrient deficiency diseases like rickets, bone weakening caused by a lack of vitamin D. Vitamin A palmitate and vitamin D3 are added to milk to make it more nutritious which are the most active and absorbable forms of these nutrients (Patrick Borel and Charles Desmarchelier, 2017 ; Vaibhav Kumar Maurya and Manjeet Aggarwal, 2017). Because these compounds are heat resistant, they can be added to milk before pasteurization and homogenization, which are heat treatments that kill bacteria and extend the shelf life of milk (R.A.Wilbey, 2014; T.Huppertz, 2011). Vitamin D may potentially play a role in the prevention of prostate, breast, and colorectal cancers, according to recent research (Grant and others 2007; Schwartz and Skinner 2007; Garland and others 2006; Bouillon and others 2006). Iron deficiency anaemia is a prevalent disease among children, especially in underdeveloped countries, and fortified milk can help avoid it. Milk in these areas is frequently supplemented with iron and other elements like zinc and B vitamins. Furthermore, fortified milk may help older children's cognitive function. In developing countries, several vitamin D fortification initiatives have been conducted which mostly included milk, milk products and margarine (Ritu G. and Ajay Gupta, 2014). According to the United States FDA regulations outlined in the PMO, allowable fortification concentrations for both vitamins A and D were 80 to 120 percent of the label claims. Intoxication, soft tissue injury, and kidney failure can all result from excessive vitamin A and D fortification of fluid milk (Jacobus and others 1992; Blank and others 1995).

In the 19th century, vitamin D fortification of milk nearly removed the public health concern of rickets. However, vitamin D deficiency has reemerged as a global health concern. Inadequate vitamin D status has resulted from current low vitamin D intakes and limited time in sunshine exposure (more time spent inside) (Dietary Guidelines Advisory Committee 2015). The acceptable range for vitamin D is 400 IU to 600 IU per quart of milk (PMO 2015).

Addition of Vitamin D in Fluid Milk Processing

Vitamin D is commonly added to fluid milk in the United States as synthetic Vitamin D3 (Public Health Service 1965). Synthetic Vitamin D3 is produced from irradiation of animal fat, usually from lanolin, the waxy secretions from sheep skin (Budvari 1996; Holick 1999; Smith 2016). Specific aspects in vitamin D fortification that should be emphasised, according to Murphy and Newcomer, 2001 are: (i) vitamin D concentrates must be added prior to pasteurisation process, (ii) in continuous pasteurisation systems (high temperature, short time: HTST), continuously metered vitamin addition must be used and the metering pump must be connected to HTST control panel to shut down during diverted flow and product recycle mode to ensure that vitamin D is added only in forward flow; (iii) the amount of vitamin used must be recorded and checked with the amount of fortified product to ensure that an accurate amount of concentrate is used; (iv) fortified products must be tested by a FDA certified laboratory.

Oil-based and water-dispersible vitamin premixes are the two types of vitamin premixes available. These can be used with a variety of dairy processing equipment (van Deutekom 2015). Vitamin D could be added to products by (i) metered injection or (ii) batch additions (Hicks et al., 1996). The point of adding vitamin D concentrate and the technique by which it is added are both determined by the type of vitamin concentrate. After product standardisation, oil-based vitamin concentrate must be added. Prior to fat separation, water-based vitamin concentrates must be added (Murphy & Newcomer, 2001). Adding vitamin concentrates after separation/standardization but before homogenization will help disperse the vitamins and stabilise them. Vitamin D is fat-soluble, which means it can concentrate more in the fat portion of the milk (Murphy & Newcomer, 2001; Patterson et al., 2010). Other methods for vitamin D fortification include cream homogenization and liposome encapsulation, which are achieved by directly homogenising a vitamin D emulsion into milk using an oil- and water-based preparation or a food-grade emulsification basis. Oil-based treatments are the best carrier of vitamin D (Kazmi, Vieth, & Rousseau, 2007; Upreti, Mistry, & Warthesen, 2002; Wagner et al., 2008).

Under or over fortification can occur when vitamins are added before separation and standardization, resulting in low fat products being under fortified and high fat products being over fortified. This occurs because vitamin A and D are fat-soluble, they will gradually become more concentrated in the milk fat portion of the milk. Therefore, it is recommended to add the vitamins after separation and standardization (PMO 2015).

Stability of fortified Vitamin D in dairy products

One of the most essential considerations in the fortification of dairy products is stability. As stated on the label, the vitamin added must be active until the end of the storage period. Since vitamin D3 is more stable than other forms of vitamin D during processing and storage in dairy products, it is commonly used for fortification (Greenbaum, 1973; Upreti et al., 2002). Vitamin D was stable in conventional thermal applications such as sterilisation at 115.6 C for 15 minutes or pasteurisation at 62.8 C for 30 minutes; however, Vitamin D is unstable at higher temperatures such as 232.2-260 C (Weckel, 1941).

Table 2: Summary of studies on vitamin D stability in milk.

Analyte	Result	Reference
Vitamin D3 in skim milk	25% loss by light exposure in 1.8 L plastic container after 10 days	
Vitamin D3 in UHT whole milk	20-57% loss caused by light during 12 weeks storage	Saffert et al., 2008
Vitamin D3 in UHT low fat milk	35-65% loss induced by light during 12 weeks storage	Saffert et al., 2009

Source: Yang Liu, 2013

Technological Feasibility of Vitamin D Fortification in India

1. Technical expertise to produce D2 and D3 is available. D3 is already produced and marketed in India (Ritu G and Ajay Gupta, 2014).
2. Methods of measuring vitamin D in foods are available and will be important in regulating and enforcing the levels of vitamin D added to foods (Ritu G and Ajay Gupta, 2014).
3. The selection of suitable fortification vehicles will play an important role in India. India has a plethora of suitable and readily available fortification vehicles, which have already been tested and proven in other parts of the world. Some examples are: milk

and milk products, *chapati* flour, rice, rice flour, soy milk, fruit juices, breakfast cereals, sugar, salt, *etc*. (Ritu G and Ajay Gupta, 2014)

Conclusion

The deficiency of vitamin D and its health consequences in India and worldwide calls for fortification of food. Milk being common food for both vegetarians and non-vegetarians can be fortified with vitamin D. The technological feasibility of vitamin D fortification in India could be capitalized. Emulsified, crystalline or encapsulated (e.g., liposome) forms of Vitamin D might be added to products. Vitamin D3 was found more stable in UHT whole milk. Although it is susceptible to degradation by light, heat and oxygen, many researchers have reported that these factors did not affect its activity and vitamin D was stable during processing and storage. Future studies can focus on the formulation of new products and maximizing the stability of the products flavour.

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