Trends in Food Science & Technology 70 (2017) 82–94

Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: www.elsevier.com/locate/tifs

Review

UV-irradiated mushrooms as a source of vitamin D_2: A review

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ARTICLE INFO

Keywords:
Vitamin D
Mushrooms
Irradiation
Bioavailability

ABSTRACT

Background: The deficiency of vitamin D has been widely reported all over the world and linked to several chronic diseases. Mushrooms are valuable nutritional foods with recognized bioactive properties, leading the application of UV irradiation to the production of significant amounts of vitamin D_2. In this context, cultivated species such as *Agaricus bisporus*, *Lentinula edodes* and *Pleurotus ostreatus* have been widely studied.
Scope and approach: However, there is still gap considering the knowledge of the most appropriate irradiation procedures (dose, intensity, distance between source and sample, exposure time) in order to maximize the content of vitamin D_2 in the mushrooms. This strategy will enable vitamin D_2-enhanced mushrooms to be commercially available at affordable costs. Considering the interest and potential of application, this review mentioned some of the physiological roles and sources of vitamin D, while the major focus was on mushroom's UV irradiation as a source of vitamin D_2. Also, topics related to its bioavailability and clinical studies evidencing the health benefits reported so far were also addressed.
Key findings and conclusions: UV-irradiated mushrooms present a high rate of conversion from ergosterol to vitamin D_2 at short treatment time and have the potential to increase serum 25-hydroxyvitamin D levels. Even though irradiated mushrooms exhibit some promising advantages, there is still a huge knowledge gap to allow for extraction, separation, recovery and purification of vitamin D_2 from irradiated mushroom at minimal process cost and high purity percentage to be utilized as bio-based ingredient to reduce vitamin D deficiency as well as present other health promoting benefits.

1. Introduction

Vitamin D, popularly referred to as ˝sunshine vitamin˝, plays an important role in several human metabolic processes such as calcium and phosphorus metabolism, and skeletal and neuromuscular homeostasis. It is mainly obtained endogenously after UV exposure, from dietary supplements and food sources (Elangovan, Chahal, & Gunton, 2017). The most well reported symptoms of vitamin D deficiency are rickets and osteomalacia arising from poor calcium and phosphorus mineralization; but other diseases such as cardiovascular disease, cancer, hypertension, stroke, diabetes, multiple sclerosis, rheumatoid arthritis, inflammatory bowel disease, periodontal disease, muscular degeneration, liver diseases, mental illness, and chronic pain have been also reported to be associated with the lack of vitamin D (Kalaras, Beelman, & Elias, 2012a). In this context, studies on vitamin D have received considerable attention over the years supported by the increasing number of reports of vitamin D deficiency, now prevalent in Europe, Middle East and North America.

There are various forms of this vitamin, but the most physiologically relevant ones are vitamin D_3 or cholecalciferol, which is the most biologically active form found in animals and humans produced after skin exposure to UVB radiation, and vitamin D_2 (ergocalciferol) found in some phytoplankton, invertebrates, yeast and mushrooms in response to UV radiation (Chen et al., 2015; Malaeb, Hallit, & Salameh, 2017). Populations from countries with temperate climate (> 30°N and > 30°S), i.e. regions where exposure to sunlight is limited especially during winter season, are subjected to little or no synthesis of vitamin D_3, and as such, dietary intake in the form of supplements or fortified foods is needed (Schoenmakers, Gousias, Jones, & Prentice, 2016).

Both forms of vitamin D have shown to be responsible for maintaining serum levels of 25-hydroxyvitamin D in humans (Koyyalamudi, Jeong, Pang, Teal, & Biggs, 2011). Vitamin D from sunlight, or dietary sources, is biologically inactive and undergoes two-step hydroxylation

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http://dx.doi.org/10.1016/j.tifs.2017.10.008
Received 31 August 2017; Received in revised form 16 October 2017; Accepted 18 October 2017
Available online 20 October 2017
0924-2244/

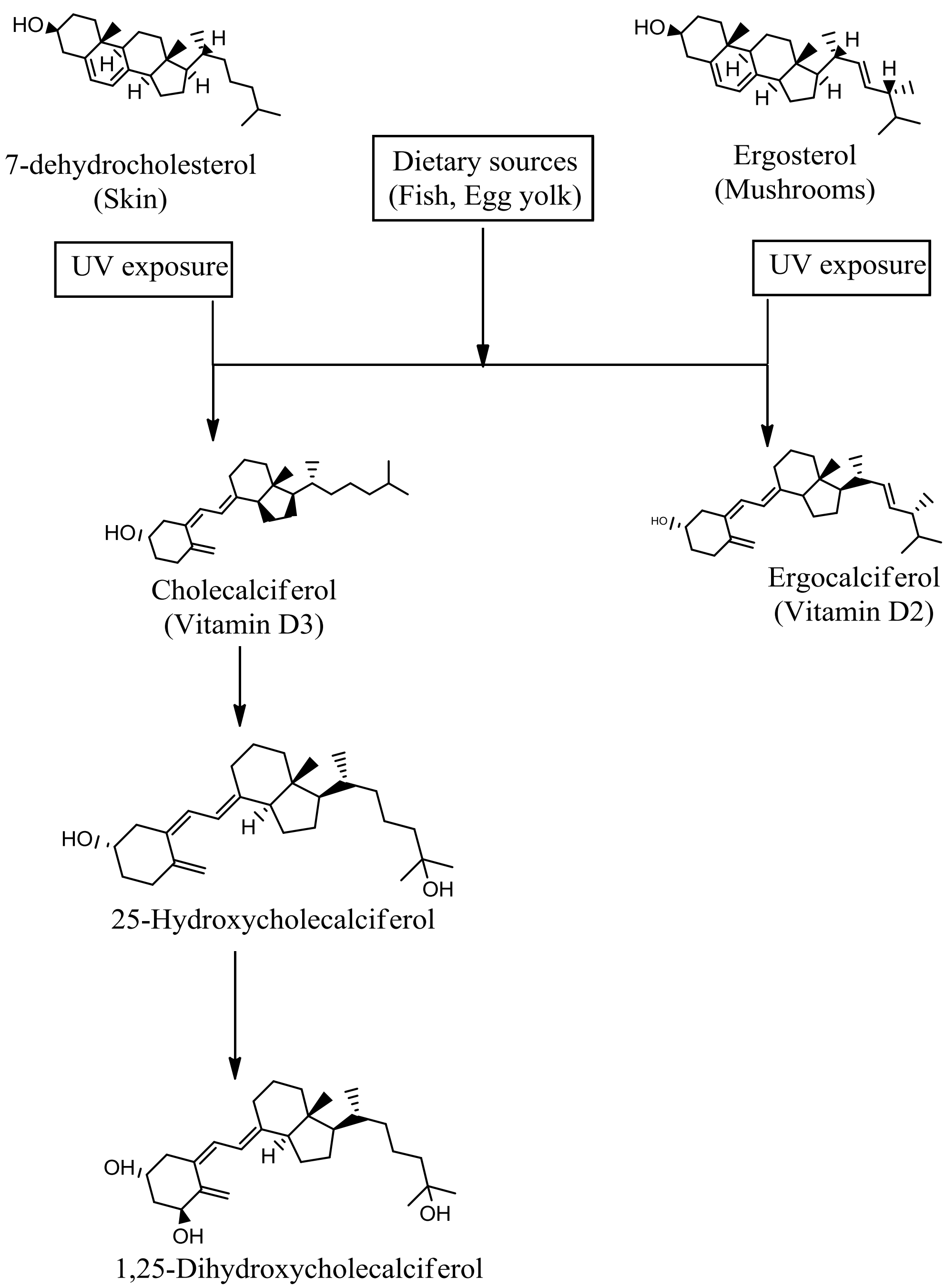

Fig. 1. Chemistry of vitamin d (adapted from Vuolo, Di Somma, Faggiano, & Colao, 2012).

to form 25-hydroxyvitamin D (calcidiol) and metabolically active 1,25-dihydroxyvitamin D (calcitriol), as shown in Fig. 1 (Harika & Eilander, 2013).

After vitamin D intake, it enters blood circulation, being transported to the liver where it becomes hydroxylated to form 25-hydroxyvitamin D [25(OH)D], the major circulating form of vitamin D. In the kidney, a second hydroxylation of the 25-hydroxyvitamin D occurs, resulting in the formation of 1,25-dihydroxyvitamin D, which is the most potent form of vitamin D. In fact, most of the physiological effects of vitamin D in the body are related to the activity of 1,25-dihydroxyvitamin D (Harika & Eilander, 2013).

Even the contribution of food ingestion to vitamin D levels is relatively not significant, some important dietary sources of vitamin D are fish, beef liver, cod liver oil, egg yolks; additionally, mushrooms exposed to sunlight have shown to be rich in vitamin D_2 (Guan et al., 2016; Itkonen et al., 2016; Kim & Bae, 2016).

Facing to the described importance of vitamin D, and identified health problems related to its deficiency, the present review will address topics such as vitamin D and its main roles, main sources and strategies for their production. An emphasis will put on mushroom UV-irradiation as a promising technique for vitamin D obtainment.

2. Vitamin D and its main roles

Vitamin D deficiency is still an unrecognized epidemic, especially among the elderly people. Nevertheless, some reported data are noteworthy, namely the one concerning United States (US), where over 50 % of elderly people are lacking from vitamin D (Jasinghe, Perera, & Sablani, 2007). In general, vitamin D deficiency is mostly prevalent in the Middle East and South Asia, while low levels have also been described across the USA and Canada. Individuals living in some European countries located at higher latitudes experience low 25(OH)D