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Open Access Journal of Mycology & Mycological Sciences
ISSN: 2689-7822

Vitamin D Enriched Edible Mushrooms: A Review

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Review Article

Volume 6 Issue 1

Received Date: December 18, 2022

Published Date: January 05, 2023

DOI: 10.23880/oajmms-16000170

Abstract

Vitamin D is one of the most important vitamins to human health as it plays a significant role in human's various physiological functions including metabolism of phosphorus and calcium, neuromuscular and skeletal homeostasis and is also effective against various diseases. Although it is found in two major forms, vitamin D_3 (from animal-derived products) and vitamin D_2 (from plant, mushrooms and yeast), it is reported that vitamin D_2 functions similar to vitamin D3 as both possess the ability to improve overall vitamin D levels in blood. Also, vitamin D_2 obtained from mushrooms do not show hypercalcaemic effects reported during the use of vitamin D_3. Hence, we aimed in this study to put mushrooms as a potential source of dietary vitamin D under the spot. Moreover, we mentioned examples of mushroom species reported to contain vitamin D in their composition. Some factors controlling the level of vitamin D in these mushrooms were also highlighted.

Keywords: Edible Mushrooms; Vitamin D Enriched; Letinula Edodes; Agaricus Bisporus; Pleurotus Ostreatus; Therapeutic Values

Introduction

The rapid growth of human civilizations has led to escalating pressures to develop new functional food products with nutritional characteristics having therapeutic all potentials. Mushrooms have been utilized in a wide variety of foods for thousands of years and have gained extensive attention in research communities and commercial ventures seeking to explore new and innovative applications in a diverse array of food products of therapeutic all potentials. Technological advances in the cultivation and processing of mushrooms have created new frontiers in the control of textures, flavours, and nutritional properties of fungi-based foods [1-10].

Edible mushrooms are an excellent source of proteins, minerals, polysaccharides, unsaturated fatty acids, and secondary metabolites [11-19]. Numerous studies have provided evidence for the protective effects of edible mushrooms against various chronic diseases [20-33]. Mushrooms have provided food for millennia and production methods and species diversity have recently expanded. Beside mushrooms, cultured fungal mycelia are now harvested as a primary product for food. Mushrooms and mycelia provide dietary protein, lipids and fatty acids, vitamins, fibre, and flavour, and can improve the organoleptic properties of processed foods (including meat analogues). Further, they are often key ingredients in nutritional or therapeutic supplements because of diverse specialised metabolites. Mycelia can also improve feed conversion efficiency, gut health, and wellbeing in livestock [34].

The most important vitamin is vitamin D (Sunshine vitamin) which is a fat-soluble vitamin plays a significant role in human's various physiological functions such as metabolism of phosphorus and calcium, neuromuscular and skeletal homeostasis and is also effective against various diseases [35,36]. Although it is found in two major forms, vitamin D_3 in animal-derived products and vitamin D_2 in mushrooms and yeast, it is reported that vitamin D_2 functions similar to vitamin D_3 as both possess the ability to improve overall vitamin D levels in blood. Also, vitamin D_2 obtained from mushrooms do not show hypercalcaemic effects as in the case of vitamin D_3 [37].

Mushrooms are a low-calorie food that packs a nutritional punch. Loaded with many health-boosting vitamins, minerals, and antioxidants, they've long been recognized as an important part of any diet. For instance, mushrooms raised with exposure to ultraviolet light are a good source of Vitamin D, an important component in bone and immune health. Mushrooms (Maitake, enoki, shiitake, oyster, crimini, morel, and chanterelle) are one of the few plant foods which contain ergo sterol, a precursor to vitamin D2 (Figure 1). The two major physiological forms of active vitamin D for humans are ergocalciferol D2 (Found in mushrooms and some dietary supplements) and cholecalciferol D3 (Found in animal sources and some dietary supplements). The current recommended Adequate Intake (AI) for Vitamin D for most adults is 5ug (200 IU). The amount of vitamin D2 in mushrooms can be significantly increased by exposing mushrooms to ultraviolet (UV) light [38].

Mushrooms as a Potential Source of Dietary Vitamin D

Recently, there is a growing concern about diseases associated with the deficiency of vitamin D in humans. As people stayed indoors, due to the COVID-19 pandemic, vitamin D levels are further affected. Many researches indicate vitamin D as a promising defensive or therapeutic agent against COVID, making this review more vital and important. Mushrooms, as a rich source of vitamin D along with various bioactive compounds [1-19], perform a significant role in resolving health issues [20-33]. Mushroom-based medicinal formulations and functional foods serve to deliver vitamins and nutrients to humans, thus helping in health problems, especially in developing countries. Evidence from pre-clinical and clinical analyses suggests that vitamin D_2 bioavailability in mushrooms is comparable with vitamin D from other sources [39].

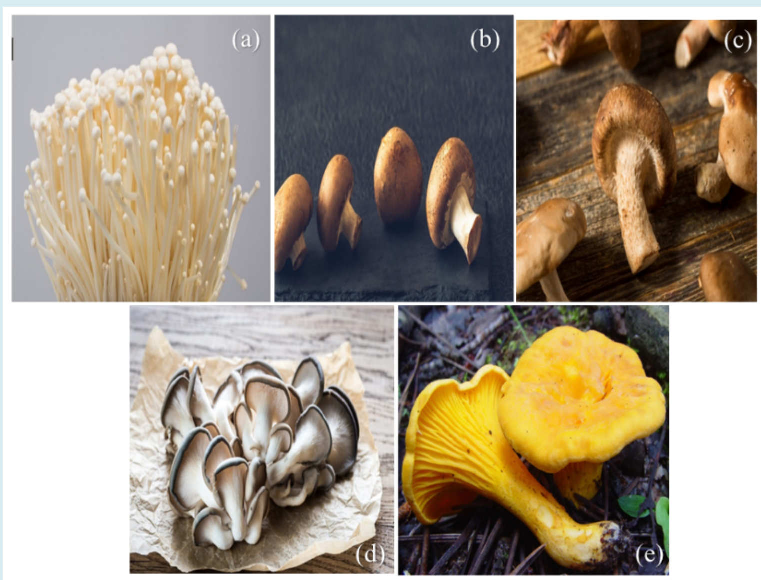

Figure 1: Flammulina velutipes mushroom
Cited in: https://twigscafe.com/27-types-of-gourment-medicinal-mushrooms/.
(**b**) **Agaricus bisporus**.
Cited in: https://twigscafe.com/27-types-of-gourment-medicinal-mushrooms/.
(**c**) **Shiitake mushroom Letinula edodes**.
Cited in: https://twigscafe.com/27-types-of-gourment-medicinal-mushrooms/.
(**d**) **Oyster mushroom Pleurotus ostreatus**.
Cited in: https://twigscafe.com/27-types-of-gourment-medicinal-mushrooms/.
(**e**) **Cantharellus cibarius,** (Photo was taken by: Scott T. Bates. Locality: USA, Arizona, White Mountains, and Hannagan Meadow (Cited in: https://mycoportal.org).

Vitamin D deficiency is highly prevalent in Egypt and worldwide. Mushrooms are important nutritional foods, and in this context shiitake (*Lentinula edodes*), button (*Agaricus bisporus*) and oyster (*Pleurotus ostreatus*) (Figure 1) mushrooms are known for their bioactive properties [33]. The application of ultraviolet (UV) irradiation for the production of substantial amounts of vitamin D2 is well established [40]. Levels of serum 25-hydroxy vitamin D (25-OHD), parathyroid hormone (PTH), calcium, phosphorus and alkaline phosphatase (ALP) were significantly ($p < 0.05$) improved in vitamin-D-deficient rats after feeding with UVB irradiated mushrooms for 4 weeks [40].

The ergocalciferol and 25-hydroxyergocalciferol contents in cultivated *Agaricus bisporus* and in five different wild mushroom species were determined by high-performance liquid chromatography (HPLC), using internal standard methods and the level of previtamin D-2 was screened by Mattila, et al. [41]. Wild mushrooms, especially Cantharellus cibarius and Cantharellus tubaeformis, contained high amounts of ergocalciferol, 12.8 and 29.82 mu g/100g of fresh weight; respectively [42]. Mattila, et al. [41] reported that about 90% of the total vitamin D content in the mushrooms studied was derived from ergocalciferol, whose content was remarkably high in wild mushrooms, especially in the genus Cantharellus (Figure 1).

Fractions containing up to 18% (w/w) ergosterol and other ergosterol derivatives can be obtained by 289 supercritical fluid extractions from Lentinula edodes mushroom. They can be further processed to induce partial 290 transformation of this provitamin D2 into vitamin D2 by UV-light irradiation (Figure 1). Then, the SFE extracts should 291 be dissolved in organic solvents such as methanol or ethanol, exposed at room temperature under WS-UV 292 or UV-C rather than UV-A light and as closer as possible to the UV source. WS-UV irradiation also induced 293 vitamin D4 formation although in lower amounts than vitamin D2 or lumisterol2 [42].

Pleurotus florida and *Pleurotus cornucopiae* are Oyster mushrooms that are widely grown all over the world. White Oyster mushroom, *Pleurotus florida* is a commonly grown mushroom species due to its high nutritional value, ease and low cost of cultivation. Begum, et al. [43], reported that Vitamin D2 from fruiting bodies of two Oyster Mushroom species, namely *Pleurotus florida* and Pleurotus cornucopiae, is quantified using a spectrophotometer at 264nm and it was observed that Vitamin D2 levels varied with different wavelengths used. Both the species, Vitamin D2 levels increased in the UV-B range than in the UV-A range. Moreover, between the two species under study, *Pleurotus florida* showed the highest Vitamin D2 accumulation potential at 280nm when exposed for 120 minutes. The level of Vitamin D2 increased to an optimum level at 120 minutes of UV exposure. Vitamin D2 levels obtained from *Pleurotus florida* and *Pleurotus cornucopiae* safe and can be used in the preparation of Vitamin D supplements in the future [43].

Since mushrooms provide nutritionally relevant amounts of B group vitamins and of the minerals selenium, potassium, copper, and zinc, they are a nutritious, low energy-dense food [44,45]. Presently, some larger commercial mushroom farms in the USA, Ireland, The Netherlands, and Australia expose fresh mushrooms to UV radiation, generating at least 10 μg D2/100 g FW; therefore, a 100 g serve would provide 50–100% of the daily required vitamin D to consumers. Exposing dried mushrooms to UV-B radiation can also generate nutritionally useful amounts of vitamin D2, although this practice is not widespread to date [40].

Several studies have shown that ultraviolet (UV)-treated mushrooms are a potential dietary source of vitamin D, as these mushrooms have a high rate of conversion of ergosterol to vitamin D_2. However, there are gaps in knowledge about the most appropriate irradiation conditions, including the source, dose, intensity, and duration of irradiation, for maximizing vitamin D_2 content in mushrooms [46,47]. UVB seems to be most effective in transforming ergo sterol to vitamin D_2 in both fresh and dried mushrooms. This knowledge is important for the mushroom industry in order to provide the market with vitamin D_2-enhanced mushrooms in a safe and affordable manner. Vitamin D_2 bioavailability is still unclear, and there is an urgent need to investigate the effectiveness, safety, and adequate amount of vitamin D_2-enhanced mushrooms for reducing vitamin D deficiency and maintaining vitamin D levels [48-51].

Sunlight, regular UV lamps, and pulsed UV lamps have the capability to raise the vitamin D2 concentrations to nutritional significance, although pulsed UV lamps may be the most cost-efficient method for commercial production of vitamin D-enhanced mushrooms, because of the low exposure time (often in 1–3 seconds) to achieve at least 10 μg/100 g FW [52]. Vitamin D-enhanced mushrooms contain high concentrations of vitamin D2, which is bioavailable and relatively stable during storage and cooking. Therefore, consumption of vitamin D-enhanced mushrooms could substantially contribute to alleviating the global public health issue of vitamin D deficiency [53].

Conclusion

Edible mushrooms represented by Maitake, enoki, shiitake, oyster, crimini, morel, and chanterelle have a rich history of use as an edible source and well-claimed medicinal properties. Worldwide mushroom consumption has increased markedly in the past four decades, and mushrooms have the potential to be the only non-animal, unfortified food source of vitamin D that can provide a substantial amount of vitamin D2 in a single serve. The vitamin D2 produced in mushrooms can very well take care of vitamin D deficiency in human and can be used in the preparation of Vitamin D supplements in the future.

Further research is required to determine the optimal level of UV radiation required to produce a nutritionally useful amount of vitamin D2 in mushrooms, along with optimal storage conditions and cooking methods. The physiological benefits of mushroom-derived vitamin D2 compared with solar-derived vitamin D3 also require further investigation.

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