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Natural ways of vitamin D supplementation – detailed evaluation of *Cantharellus cibarius*

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Abstract

Introduction and purpose: In the past, fungi were considered a very low-value meal, however in modern literature, they are increasingly more frequently studied for their nutritional and medical properties. They are being currently reconsidered as an abundant source of nutrients that may be incorporated in diets of individuals of special medical needs, such as obese and diabetic patients. The purpose of this review is to evaluate one of the most common edible mushroom species, *Cantharellus cibarius* (girolle, golden chanterelle) for its health promoting properties with particular emphasis on its vitamin D content. It was of considerable importance for us to analyse the amount of vitamin D in the mentioned mushroom, as this micronutrient deficiency is fairly common in the human population.

Material and method: The available literature was reviewed as provided by PubMed database and Google Scholar, with the use of keywords.

State of knowledge: Golden chanterelle mushroom is a valuable source of proteins, mineral ingredients like potassium, phosphorus, magnesium, iron and calcium, while containing low amounts of sodium and fat. The mushroom is especially valuable for its rich content of vitamin D, ranging up to 63 μg/100g fresh weight.

Conclusions: This paper may help other scientists expand their research on golden chanterelle properties. Moreover, girolle, as naturally containing many pro-health metabolites, may serve as natural supplementation of microelements.

Keywords: “Cantharellus cibarius”; “girolle”; ”golden chanterelle”; ”Vitamin D”; “nutritional”.

Introduction

A popular belief in society about fungi is that they may serve only as a tasty addition to dishes, but contain little to none nutritious properties. Although their low calorific value was considered a disadvantage in the past, modern trends in nutrition sciences make mushrooms appear as a valuable natural, vegan source of minerals, vitamins and fiber. (1) This particular nutritional profile may be beneficial especially for people with obesity, diabetes or maintaining a healthy diet or vegetarian/vegan with deficiencies. (2–5)

The *Cantharellus cibarius* mushroom, also known as golden chanterelle mushroom, is one of the most common edible fungi known to humanity. Girolle, which belongs to Basidiomycota, class Agaricomycetes, order Cantharellales, family Cantharellaceae, is a mycorrhizal mushroom growing in symbiosis with roots of at least 25-year-old trees. It can be collected in nature from June until October in both coniferous and deciduous forests. The mushroom is widespread in the world: it can be found in Asia, North America, Europe and Australia. (6–8) The famous features of chanterelle, which are commonly used to distinguish it from other mushrooms, are its yellow color, which also comes in orange or yellow-orange hues, a cap which is broadly curved with flat or shallowly depressed center with underside of the cap embraided in false gills. (7)

Chanterelles are known around the world as one of the finest edible wild mushrooms and their international trade value probably exceeds one billion dollars annually. (8) Vitamin D was discovered by McCollum as a factor, whose dietary absence is responsible for the development of rickets in the similar way vitamin A deficiency causes xerophthalmia. (9) Over the years it was found that vitamin D is not a single factor, but a group of fat-soluble compounds, secosteroids, with the two most important for humans being ergocalciferol, i.e. vitamin D_2 and cholecalciferol, i.e. vitamin D_3. (10)

Humans obtain vitamin D from food and through synthesis from cholesterol through exposure of the skin to sunlight, with D_2 coming mostly from irradiated yeasts and sun-exposed mushrooms and D_3 from fish-related products and endogenous synthesis, however both of them are eligible to be further modified in liver and kidneys to become active forms. (11)

Commonplace fortification of milk with vitamin D successfully eradicated rickets, but, in current times, the problem of vitamin D deficiency, although on a different level, is still prevailing in the general population, with the numbers of people affected allowing us to describe it even as a pandemic. (12) It is reported that vitamin D deficiency is noted between 13.0% and 40.4% of population in Europe, depending on the chosen deficiency threshold (13), and ranging worldwide up to 1 billion of people, with vitamin D insufficiency affecting almost 50% of global population; hospitalized patients, obese and elderly individuals are especially at risk of vitamin D deficiency, but the phenomenon is common in all age groups. (11,12) The deficiency of vitamin D in patients is usually asymptomatic or with non-specific symptoms like muscle twitching (fasciculations) and increased tiredness, but it should not be neglected, as D hypovitaminosis is an independent risk factor for total mortality in the general population. (14) Vitamin D deficiency is associated with higher risk of cancers, including breast, esophageal, ovarian, prostate and colon cancer (12) and may lead to development of depression. (15) Although vitamin D in human organisms comes mostly from skin synthesis, this method of acquisition is often weakened by modern in-door focused lifestyle, usage of sunscreens, higher concentration of melanin in skin and old age. (11,16) The importance of dietary supplementation of vitamin D should not be overlooked as it was proven that the supplementation of vitamin D decreases the total mortality rate, as mentioned before. (17) Vitamin D is also essential in prevention of chronic diseases, like cardiovascular ailments, osteoporosis and insulin-dependent diabetes, and also strengthens the immune system and benefits mental health. (12,15,18) As there are few natural dietary products that contain vitamin D in sufficient amounts, we would like to expand the knowledge on the content of this vitamin in chanterelles as a promising source of supplementation.

Purpose

A growing trend among scientists is to re-evaluate and study the properties of already known, yet neglected natural dietary products. Humanity is increasingly often searching for natural sources of needed microelements and nutrients. Edible fungi and their properties are an example of such natural ‘supplements’.

The purpose of this paper is to evaluate one of the most common edible mushroom species, *Cantharellus cibarius*, also known as girolle or golden chanterelle, for its vitamin D content. The goal was to summarize the data available in literature, as well as recent studies that address this subject.

Vitamin D content in chanterelle

The research to evaluate the vitamin D content in mushrooms has been conducted since the first half of the last century, shortly after the discovery of the vitamin D itself. Among other species, golden chanterelle mushroom has been proven to be an abundant source of sterols, including vitamin D precursor - ergosterol, and major vitamin D forms, such as vitamin D_2 and vitamin D_4.

The earliest study we were able to find comes from 1935, in which Scheunert and colleagues used McCollum's method that involved rat model of rickets to evaluate the vitamin D content of the edible fungi: *C. cibarius*, *Boletus edulis*, *Imleria badia* and *Gyromitra esculenta*. (19) Rats were fed a special rickets-inducing diet, with addition of different doses of mushroom extract. With this method scientists not only proved extracts of those mushrooms had rickets-protective properties, but also compared results with another study from 1929 that included *Agaricus campestris* (20), which did not exhibit similar properties. Their explanation was that mushrooms they used commonly grow in meadows and are usually more exposed to sunlight, in comparison to *A. campestris* which was cultivated under dark trees, hence the differences in the vitamin D content.

Mattila et al. (1996) expanded knowledge in this field by determining vitamin D_2 content of six mushroom species: *Agaricus bisporus*, *C. cibarius*, *Craterellus tubaeformis* (member of Cantharellaceae family, formerly *Cantharellus tubaeformis*; also known as funnel chanterelle), *Lactarius trivialis*, *Russula paludosa*, and *B. edulis* using high-performance liquid chromatography (HPLC). The highest mean concentration of vitamin D_2 of 29.82 μg/100g fresh weight was reported for *C. tubaeformis*. *C. cibarius* had the second highest concentration of 12.8 μg/100g fresh weight and the rest of species was below 6 μg/100g fresh weight. Combining their knowledge with other authors' results, Mattila et al. hypothesized that the morphology of the fruiting body of chanterelles with characteristically exposed lamellae may be partially responsible for its relatively high vitamin D2 content. Also, the darker body of the *C. tubaeformis* might increase its ability to absorb light. (21)

In a related study from 1999, a team of researchers that included some of the authors of aforementioned paper investigated bioavailability of vitamin D in *C. tubaeformis* by measuring changes of serum levels of its active forms in healthy human females. After a three-week supplementation period, serum 25-hydroxyvitamin D levels did not differ significantly between the group that had included lyophilized and homogenized mushrooms in their daily meals and the group that received vitamin D dietary supplement, and both groups had higher levels of serum 25-hydroxyvitamin D than the group without supplementation. Therefore, regularly consumed *C. tubaeformi*s (and, probably other mushrooms high in vitamin D) might be used as a dietary source of bioavailable vitamin D. (22)

Also in 1999, Mattila et al. conducted another research that tested changes of vitamin D content in a variety of dietary products: four species of fish, egg yolks and mushrooms: *C. cibarius* and *C. tubaeformis* that underwent procedures of oven-baking (fish), cooking (egg yolk) and pan frying (mushrooms).

Raw *C. cibarius* contained 9.3 μg/100g fresh weight or 83.8 μg/100g dry weight and *C. tubaeformis* contained 13.6 μg/100g fresh weight or 194.3 μg/100g dry weight, and after 5-minute pan-frying of the two samples of each mushrooms without addition of fats their vitamin D_2 content remained relatively the same on the levels - retention of vitamin D_2 on a dry matter basis reached 86 and 87% for *C. cibarius* and 99% for both of *C. tubaeformis* samples, and true retention (factor that relates the amount of nutrient to the loss of mass of the food after processing) was calculated at 80 and 82% for *C. cibarius* and 97% and 100% for *C. tubaeformis*. The authors also examined vitamin D loss during the 3- and 9-month storage period in the remainders of mushrooms frozen at -20°C.

After 3 months, *C. cibarius* and *C. tubaeformis* retained 101 and 115% of D_2 content, and after 9 months respectively 93 and 129%, however reliability of the results is questionable, as the excession over the 100% might be related to the inhomogeneity of the mushroom pools. (23) With a slight dose of uncertainty, authors concluded that thermal treatment and storage of chanterelles do not reduce their vitamin D_2 content.

Rangel-Castro et al. (2002) focused solely on vitamin D_2 content in dried fruiting bodies of the *C. cibarius*, with the aim to investigate if long stored chanterelles are still a valuable vitamin D source. They also included albino forms to determine whether the vitamin content is dependent on the color of the mushroom, and relied upon multiple samples of individual fruiting bodies, instead of pooling larger quantities of mushrooms. In this study vitamin D_2 concentration ranged from 1.2 to 63 μg/100g fresh weight (calculated from 12 to 630 μg/100g dry weight with arbitrary approximation of 90% water content of *C. cibarius*), with the mean of 14.3 μg/100g fresh weight. The differences of vitamin D concentration were negligible between fruiting bodies from the same cluster, but varied greatly between samples of different origin; it might be due to various factors contributing to differences in the sun exposure. However, there was no significant difference between albino and pigmented varietes. Overall, dried chanterelles retain their vitamin D_2 content for at least 2 to 6 years. (24)

The next study that focused on multiple mushroom species was published in 2007 by Teichmann et al. and included five cultivated and three wild grown mushrooms: white and brown button mushrooms, portabella (those three are varietes of *A. bisporus* mushroom), shiitake, oyster, *B. edulis, C. cibarius* and *C. tubaeformis*, with addition of canned white button mushroom and *C. cibarius* and irradiated samples of fresh white button mushroom and dried *C. tubaeformis*. Scientists used gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) to analyze sterols and HPLC to determine vitamin D_2 content in mushrooms, and were the first to depict sterol contents in *C. cibarius* and *C. tubaeformis*. Total sterol content of those mushrooms was respectively 17.3 and 57.2 mg/100g fresh weight and included ergosterol (in the concentrations of 24.7 and 16.8 mg/100g fresh weight) and six minor sterols. It is worth noticing that C. cibarius had the lowest ergosterol and total sterol content of all mushrooms. However, vitamin D_2 content was highest in *B. edulis* (58.7 μg/100g fresh weight), then *C. tubaeformis* (21.1 μg/100g fresh weight) and *C. cibarius* (10.7 μg/100g fresh weight). Canned *C. cibarius* had significantly lower ergosterol (10.6 mg/100g fresh weight) and total sterol content (33.0 mg/100g fresh weight), but vitamin D_2 content remained on a quite similar level of 12.1 μg/100g fresh weight. After 2 hours of UV-C irradiation, vitamin D_2 content per gram of dry weight in *C. tubaeformis* increased ninefold. (25)

Phillips et al. utilized GC and HPLC to examine 10 types of mushrooms, namely chanterelle, crimini (which is also a variety of *A. bisporus* mushroom), enoki, maitake, morel, oyster, portabella, vitamin D-enhanced portabella (UV-treated), shiitake, and white button, sampled from different retail markets from USA. (26) Mean vitamin D_2 concentration in chanterelle was 5.3 μg/100g fresh weight, placing it only behind maitake mushrooms (with mean concentration of 28.1 μg/100g fresh weight) and UV-irradiated portabella mushrooms (11.2 μg/100g fresh weight).

In comparison, untreated portabella mushrooms yielded 0.25 μg/100g fresh weight vitamin D_2 concentration, and white button and crimini mushrooms contained respectivelly 0.11 μg and 0.06 μg/100g fresh weight; Phillips also determined the moisture of each mushroom sample and reported that chanterelle had the highest vitamin D_2 content among examined mushrooms, at mean concentration of 49.2 μg/100g dry weight, also holding record of the highest-concentration single sample of 73.9 μg/100g dry weight. (26)

In the most recent study on the field we found, Phillips et al (2012) focused at the D_4 content in the exact same set of mushrooms as in the previous, related study. Concentration of this unusual vitamer in the *C. cibarius* was 1.62 μg/100g fresh weight, and its precursor 22,23-dihydroergosterol was 4.49 mg/100g fresh weight. It also exhibited positive correlation to vitamin D_2 across all of the examined mushrooms. Little is known about the role and function of natural vitamers other than D_2 and D_3, but scientists point that various natural and synthetic analogs may find application not only in rickets prevention, but also various fields of medicine including oncology, hematology, endocrinology and nephrology. (27)

The European Food Safety Authority recommends intake of vitamin D in the amounts of 10 μg/day for infants (under the age of 1 year) and 15 μg/day for children and adults of all ages. (28) Considering all of the above studies, chanterelle proves to be a valuable food product which, when included in the diet, may prove to be helpful to avoid vitamin D deficiencies, especially for vegan and vegetarian people who look for suitable dietary products to fulfill their estimated vitamin D intake. Moreover, vitamin D is retained even during cooking processes and excessive storage periods in dried or canned form, which enables its availability and increases attractiveness as a healthy, but not boring dish.

Other nutrients

We would also like to draw attention to the content of other vitamins found in *C. cibarius*. Although the vitamin D is the most abundant, golden chanterelle is also a good source of vitamin C and E. For the 100g of the dry weight of the mushroom we can receive around 0.86 ± 0.01 mg of ascorbic acid and 18 ± 1 μg for tocopherol. (2) Interestingly, the *C.cibarius* is also a source of vitamins from group B, containing a considerable amount of B12, reaching 1.09-2.65 μg of cobalamin in 100g of dry weight of the mushroom. (29)

The golden chanterelle mushroom is a potent source of macro and micro elements. According to U.S. Department of Agriculture (30) the 100g of mushroom contains for macro elements 57 mg of phosphorus (P), 506 mg of potassium (K) 13 mg of magnesium (Mg), 15 mg of calcium (Ca), and 9 mg of Sodium (Na). The content of microelements and trace elements in 100g of *C. cibarius* is 3,47 mg of iron (Fe), manganese (Mn), 0,71 mg of zinc (Zn), boron (B), 0,353 mg of copper (Cu), 0,286 mg of manganese (Mn), and 2,2 μg of selenium (Se). (30)

With the data provided by (31) we can estimate that the 100g of fresh *C.cibarius* contains between 4.09 ± 0.09 g of protein, 0.22 ± 0.04 g fats and 2.44 ± 0.33 g of carbohydrates. Golden chanterelle mushroom also contains dietary fiber (3,8g per 100g of the mushroom). (30)

It is worth mentioning that among edible mushrooms, very few look-alikes of C. cibarius contain toxins. That property makes it highly unlikely mushroom poisoning in *C. cibarius* is considered one of the safest to eat, with the exception of possible allergic reactions. (8)

Conclusion

This article summarized available data about health benefits of golden chanterelle consumption in context of vitamin D and other nutrients content. We hope that wider spread of knowledge about possible natural and vegan sources of vitamins, minerals and nutrients may prevent insufficiently nutritious dietary habits. Better understanding of various other than animal-based vitamin D sources may also help fighting with vitamin D deficiency in the populations of people who are unable to digest milk-based products or choose not to consume animal-origin products, as now they can protect themselves from vitamin D deficiency with a healthy, sufficient and vegan source. Our research could also be beneficial for dietitians and pharmacologists seeking new ways to develop natural based dietary supplements and drugs for patients.

Authors Contribution:

Conceptualization: Maria Naruszewicz; methodology: Aleksandra Midro, Przemysław Cetnarowski; software: Mateusz Kozik; check: Maria Naruszewicz, Aleksandra Midro, Nina Skalska-Dziobek, formal analysis: Weronika Małagocka; investigation: Karolina Chybowska; resources, Mateusz Orłowski; data curation: Maria Rozpłoch-Sapa; writing - rough preparation: Maria Naruszewicz, Przemysław Cetnarowski; writing - review and editing, Aleksandra Midro, Karol Zagórski; visualization: Mateusz Kozik supervision: Maciej Szymański; project administration: Maria Naruszewicz;

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