Let There Be Light: Leveraging Vitamin D in Mushrooms

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On May 27, 2016, the US Food and Drug Administration published new rules for the required Nutrition Labeling that must appear on food packaging. The changes were felt necessary to highlight important information (for instance, by declaring the calorie content per serving in much larger and bolder type than before) and to reflect new information and concerns about the connections between diet and obesity and other health issues. One change was to drop the requirement that content of vitamins A and C be reported, since deficiencies of these are rare today, but to require that the content of vitamin D and potassium be reported. The changes are currently in effect for manufacturers with $10 million or more in annual food sales.

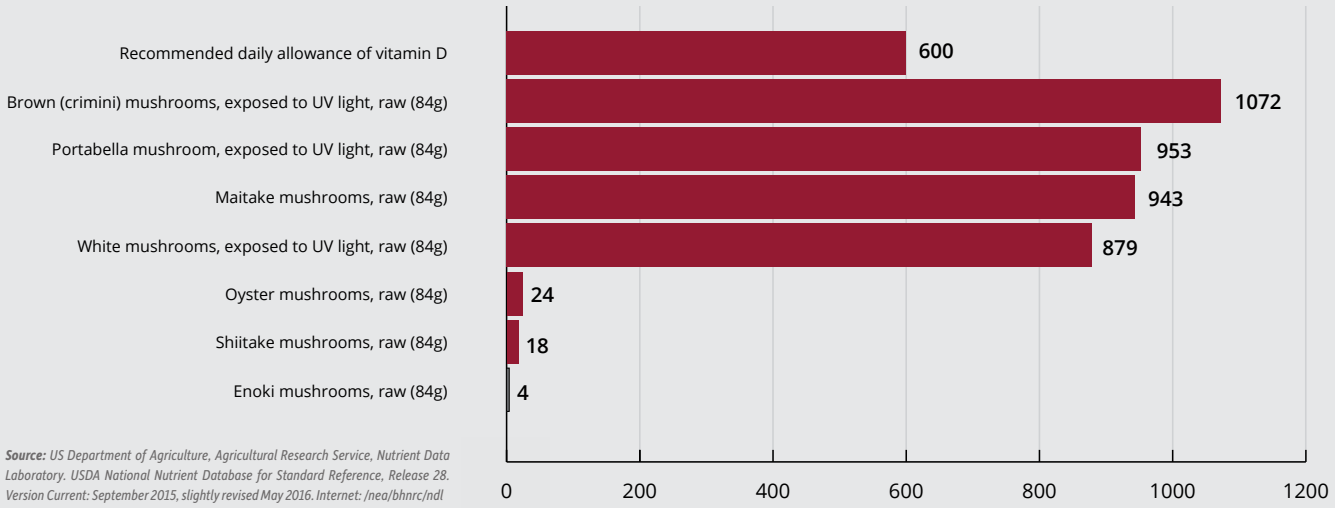
These changes follow recommendations from the 2015 Dietary Guidelines Advisory Committee Report. The importance of consuming enough vitamin D was considered so important that the report devotes an entire appendix to a listing of sources of vitamin D, something it does not do for other vitamins. The Scientific Report of the 2015 Dietary Guidelines Advisory Committee explicitly states that, "Vitamin D presents a unique case for the USDA Food Patterns, because it is not present in most of the food commonly consumed by Americans. Most intake in the US is from fortified food and supplements."[1]

The report acknowledges that vitamin D may be enhanced in the human body by exposure to sunlight, but their estimates assume little solar exposure for most of the population, mostly because of cold weather. USDA studies of the food intake patterns for Americans indicate that most people simply are not consuming enough foods containing vitamin D to meet the Recommended Daily Allowance (RDA), and are in fact falling far short of this. The Report (Fig.1) strongly suggests increasing the amount of vitamin D by consuming foods fortified with it.

Since commercial mushroom production typically takes place in the dark, mushrooms contain little vitamin D. Mushrooms growing in the wild, naturally exposed to daylight, have much higher vitamin D levels.[2]

Vitamin D IU** Levels in Mushroom Varieties

Portabella, white, Crimini and Maitake are tops in vitamin D.



Source: US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. USDA National Nutrient Database for Standard Reference, Release 28. Version Current: September 2015, slightly revised May 2016. Internet: /nea/bhnrc/ndl

The obvious solution is to expose mushrooms to sunlight, or to artificial light with similar qualities. The peak wavelengths for the conversion are at 269 nm, 280 nm, and 293 nm. The absorption peaks blend into a sort of continuum from about 255 to 300 nm, at the cusp between UV B and UV C light[3].

The notion that sunlight could not only produce vitamin D in the human body, but that irradiating foods could enhance vitamin D levels grew out of scientific work aiming to find the causes and cures of the disease rickets in the 1920s.

"Vitamin D" is actually a collection of closely related substances with very similar chemistries. The vitamin D produced by animal sources is labeled D_3 or *cholecalciferol* ($C_{27}H_{44}O$). Its precursor, *7-dehydrocholesterol*, is converted to D_3 by exposure to light at the wavelengths given above, which can penetrate human skin. The substance is also found in lanolin, produced by sheep and other wooly animals.

Vitamin D_2, or *ergocalciferol*, is produced from plant sources. Its formula is $C_{28}H_{44}O$, and it results from exposure of ergosterol to ultraviolet light. Ergosterol is a component of cell walls in yeasts and fungi, serving much the same functions in plants that hydrocholesterol does in animal cells.

One method of production of supplemental vitamin D is ultraviolet irradiation of yeast. Both D_2 and D_3 have the same effect of promoting calcium absorption that makes it so important for bone growth and prevention of rickets. There are three other forms of the vitamin, but D_2 and D_3 are the most common and important ones.

In view of the long history of creating vitamin D from precursors by irradiating milk, lanolin, yeast, and other foods with ultraviolet light, it is surprising that irradiation of mushrooms, with their high concentration of ergosterol, was a comparatively recent development, dating back to about 1990. Since then research on this phenomenon and its commercial use has increased rapidly. Irradiation by daylight is inefficient, so commercial growers turned to the use of mercury lamps, with their strong 254 nm line at the edge of the absorption of ergosterol. But irradiation with mercury lamps is still a relatively slow process. One study showed that irradiation with a mercury lamp raised the vitamin D content in *Agaricus bisporus* to eight times the RDA after an exposure for five minutes[4]. The

Nanometer (nm): a unit of length in the metric system, equal to one billionth (short scale) of a meter.

intense light from a pulsed flashlamps not only provides a much greater photon flux, but also a better overlap with the ergosterol absorption without the use of mercury. One study using a 3 Hz system with 505 electrical Joules per pulse showed that a level of 824% RDA in *Agaricus bisporus* could be achieved in just over a second of exposure. The pulsed light systems also have the benefit of generating little heat. These systems are commercially available and have been deployed extensively.

Leveraging the Sunshine Vitamin in Mushroom Marketing

There aren't many ways to obtain vitamin D, and there aren't many things you can harvest it directly from. (Cod liver oil was, for a time, the only good natural source. There is vitamin D in some oily fish, and very small amounts are in egg yolk and liver.) You can, however, irradiate some things with ultraviolet light and convert precursor substances into vitamin D_2 or D_3. Among these are lanolin, yeast, and mushrooms. Currently mushrooms are the only item in the produce aisle that can obtain vitamin D. And with consumption of mushrooms in the US increasing every decade since the 1960s[5], and now that vitamin D is required on food labels, highlighting mushrooms' vitamin D properties could give mushrooms a marketing boost.

[1] Appendix E-3.3, available online at https://health.gov/dietaryguidelines/2015-scientific-report/15-appendix-E3/e3-3.asp [2] P. H. Mattila et al. "Vitamin D Contents in Edible Mushrooms" J. Agricultural and Food Chemistry 42 (11) 2449 – 2453 (1994) [3] I.M. Heilbronn et al "The absorption spectrum of cholesterol and its biological significance with reference to vitamin D: Part I" Biochemical Journal 21 (1) 78 - 85(1927) [4] M.J. Feeny "Optimizing Vitamin D2 in Mushrooms" Mushroom News 54 (5) 2-24 (2006) [5] see, for instance, USDA report VGS295-01 March 2003, available at https://www.ers.usda.gov/webdocs/publications/39489/30836_vgs29501_002.pdf?v=41414 Mushrooms consumption has increased since 2003, as well.