



MUSHROOMS EQUAL WATER CONSERVATION

R. H. KURTZMAN, JR.

MICOLOGIA APLICADA INTERNACIONAL, 445 Vassar Avenue, Berkeley, CA 94708, U.S.A.
E-mail: rkurtzman@oystermushrooms.net

Some people have tried to make mushrooms sound like perpetual motion machines. The “ZERI” idea pushes that suggestion beyond reason¹. Of course, mushroom cultivation is not zero emissions, it involves carbon dioxide production. However, it is much cleaner than simple rotting and especially cleaner than burning on the ground. The common calculation of “biological efficiency” is useful, but exceeding 100% is in no way creating matter. However, it is efficient conservation of biological mass.

It is counter intuitive, but mushroom cultivation can be a method of water conservation. The basic arguments can be applied to all species, but because oyster mushrooms can be cultivated in a simple milieu, I will concentrate on them. Also, under primitive conditions, it has been calculated that 28 liters of water are required per kg of fresh oyster mushrooms⁶. Those 28 liters are a fraction of the water required by other crops⁷. Yet, I believe that by using modern methods and gravity ventilation, only a fraction of the 28 liters is required.

Ambient humidity would affect any actual results.

It must be understood that this discussion is theoretical, but it is based on experimental data. More experimental data is possible, but to simply prove stoichiometry, just to collect all water and carbon dioxide, would require a very special apparatus. Following the sources of water would require isotope tracers.

Many have found that the substrate must be about 65% water. It is interesting that it corresponds to the approximate water content of drained, pasteurized straw. That water is required for growth, but it cannot be consumed, unless it is replaced, because growth requires it as part of the environment. Oyster mushrooms are generally grown from plastic bags and it is nearly impossible to replace the water. However, mushrooms have no skin, cuticle or other moisture barrier thus, humid air is required. If we use the idea of 100% biological efficiency, but on a flush-consumed rather than an overall basis, we can make some interesting calculations.

If we start with 250 g of dry hemi-cellulose and cellulose substrate and 465 g (ml) of 60 C water. Then, at our first flush we harvest 100 g of mushrooms that are 10% dry matter⁴. We can calculate that 100 g CH₂O (substrate) + 96 g O₂ = 10 g CH₂O (mushrooms, dry wt.) + 54 g H₂O + 132 g CO₂. However, we need 90 g of water to give 10% dry matter mushrooms. While 54 g of water will come from the metabolism of the substrate, we need 36 g of additional water. So, do we need to add the 36 g of water? – No! Remember we have 65% water in the substrate, but we have removed 100 g of dry matter. So, $100/0.35 \times 0.65 = 185.7$ gm of water that are now in excess of the required 65% water. Then $186 - 36$ g = 150 g of water in excess of 65% of the substrate. We might get an additional 100 g of mushrooms in our second flush, giving us another 150 g of excess water and then 50 g of mushrooms in the third flush, leaving a total of 375 g of excess water.

I have neglected a few things that are important to the mushrooms, but of surprisingly little importance to our calculation. Protein is important, but the biggest difference in the metabolism that produces mushrooms is that the nitrogen from the substrate (straw, etc.) is conserved². That means that the nitrogen acts like the oxygen that becomes part of the mushroom, so the same amount of excess water is produced. Minerals will affect the outcome, but since they amount to only about 0.8% the weight of fresh mushrooms and they are not otherwise part of the water balance, they are not a significant source of error⁴. The largest source of error is probably lignin in the substrate. It is difficult to properly account for, because it depends on what is used for substrate and is so complex that exact composition is variable. However,

coniferyl alcohol C₁₀H₁₂O₃ is one of its several similar monomers which we can use and calculate in a similar manner that we used for carbohydrates: $100 \text{ g C}_{10}\text{H}_{12}\text{O}_3 + 194 \text{ g O}_2 = 10 \text{ g CH}_2\text{O} + 54 \text{ g H}_2\text{O} + 230 \text{ g CO}_2$. Notice that the percent carbon is greater in coniferyl alcohol and oxygen much lower. That means we get much more carbon dioxide, but the surprise is that we get the same amount of water. Of course, we also use much more oxygen. The same amount of water is freed by removing dry weight from the substrate. The result is the same water balance from our three flushes. We cannot grow mushrooms on lignin, alone, so the coniferyl alcohol-lignin calculation is totally theoretical, but it tells us that the metabolism of lignin, which is a natural part of our substrate material will also give us excess water.

If we have a lower biological efficiency, as always seems to be the case for *Agaricus*, we should have much more excess water. A biological efficiency of 50% means that we will get twice as much water from removing the substrate dry weight and a little more than twice as much from metabolism. Yet, we are told over and over, with no positive evidence, that casing is needed to supply water for the mushrooms. No one should doubt that, like all mushroom substrate, casing must be wet. It is also true that since casing is on the surface it will be a primary point of evaporation. However, since lower biological efficiency means more solids are metabolized, excess water will amount to more than 150% of the weight of mushrooms harvested. It seems a bit absurd that *Agaricus* could require casing for additional water. While the plastic bags commonly used for *Pleurotus* cultivation do restrict substrate-surface evaporation, they do not supply water for the mushrooms and fresh *Pleurotus* have about the same

moisture content found in fresh *Agaricus*⁴. While results with two different genera are poor proof, there seems to be no explanation why 100% + biological efficiency is not at all rare for *Pleurotus*, with no casing, but it is unknown for *Agaricus*. Yet, it is claimed that *Agaricus* requires added water in order to fruit. The water theory also ignores the several authors who have used several methods to establish that gas porosity is the primary requirement for casing³. So, we have a large number of *Agaricus* “experts” who believe a preconceived theory, in preference to scientific evidence. We can still ask why there is so much water loss, is it poorly designed-excessive velocity ventilation⁵?

In cold climates, there may be some practical ways to use some of the exhausted water vapor. Since cold air holds little water, heated buildings are generally dry. Moist air from mushroom houses could be sent to other building, except that it will be high in carbon dioxide. More practically, fresh air could enter through a heat exchanger made of glass and the water (distilled) could be collected, while the used air gives up its heat to the fresh air. Heat exchangers are already used by some growers and have also been used by malting plants. We can also note that heat of vaporization is also recovered when the water vapor is condensed. In warm climates a heat exchanger is also of value.

LITERATURE CITED

1. Chang, S. T. 2007. Mushroom cultivation using the “ZERI” principle: potential for application in Brazil. *Micologia Aplicada International* 19: 33-34.
2. Kurtzman, R. H., Jr. 1979. Nitrogen fixation by *Pleurotus*? *Mushroom Science* 10(1): 427-435.
3. Kurtzman, R. H., Jr. 1999. Casing properties: Required, desired beliefs. Pp. 490-497. Third International Conference on Mushroom Biology and Mushroom Products, Proceedings. Sydney.
4. Kurtzman, R. H., Jr. 2005. Mushrooms: Sources for modern western medicine. *Micologia Aplicada International* 17: 21-33.
5. Kurtzman, R. H., Jr. 2010. Ventilation for mushroom cultivation: the importance of the needs of mushrooms and of the gas laws. *Micologia Aplicada International* 22: 63-78.
6. Martínez-Carrera, D., A. Aguilar, W. Martínez, P. Morales, M. Sobal, M. Bonilla and A. Larqué-Saavedra. 1998. A sustainable model for rural production of edible mushrooms in Mexico. *Micología Neotropical Aplicada* 11: 77-96.
7. Pimentel, D., J. Houser, E. Preiss, O. White, H. Fang, L. Mesnick, T. Barsky, S. Tariche, J. Schreck and S. Alpert, 1997. Water resources: agriculture, the environment and society. *Bioscience* 47: 97-106.