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Reply - water conservation

Water is the most important ingredient in all life, so it is important that we conserve it as much as possible. Unfortunately, Dr. Kalberer seems to have missed or misunderstood that the theme of my remarks was water conservation and that the calculations were theoretical[8]. However, I must admit that I should have given references to the theories. Unfortunately, the individual who reviewed my remarks, did not suggest that I needed those references. One of my faults is that too often I expect people to know all of the basics of all related science. So, I do not reference textbooks, when I write. Sometimes, as in this case, such references are appropriate.

One very important theory of ecology is the trophic, productivity, or biomass pyramid. It can be found in textbooks on ecology, but in retrospect I should have cited a book in my first remarks. However, Wikipedia is an easy source: When energy is transferred to the next trophic level, typically only 10% of it is used to build new biomass, becoming stored energy (the rest going to metabolic processes). As such, in a *pyramid of productivity* each step will be 10% the size of the previous step (100, 10, 1, 0.1, 0.01)[10]. However, the ecological theory is not the only reason for my use of 10%. Rather a biological efficiency (B.E.) of approximately 100% with approximately 10% dry matter has been a common measure of success for oyster mushroom cultivation. Somewhat greater B.E. percentages have been recorded, but I am not aware of any cases where the dry weight of all of the mushrooms produced was recorded[2]. The biomass pyramid is not hard and fast, but even if it were, with 7.5% dry weight, 133% B.E. would represent the prediction of the biomass pyramid. Because water is always a variable, B.E. is of some economic value, but it is of questionable value scientifically. Dry weights for oyster mushrooms, in the literature vary from 7.5 to 13.3% or by a factor of 1.8. I chose a dry weight of 10%, because it is reasonable and easy to work with.

One might question how the trophic pyramid applies to mushrooms. Plant biomass is the lowest level, next herbivores. At the top are the ultimate carnivores. It seems reasonable to treat mushrooms as herbivores. However, the primary reason that the pyramid shows that herbivores consume ten times their weight, is that they need food for maintenance. Animals move about in search of food, mushrooms do not. However, mushroom mycelium ramifies in the substrate[4]. That takes a great amount of energy and is the bulk of the biomass. When we harvest mushrooms it is only a small portion of their total biomass. Suddenly, I am pointing out an apparent error in my own remarks. It would mean that for mushrooms, much of what appears to be remaining substrate is actually mushroom mycelium. However, in the end, if we obtain 100+% B.E., apparently, much of the mycelium is resorbed, converted to mushrooms and the substrate is almost mineralized. That, of course, means that my calculations for the first two breaks, by themselves, are not what should be expected in the real world. However, I was trying to express an overall idea piece by piece. Consider the visible life of *Armillaria*; when you find an infected living tree, with honey colored mushrooms around it. Usually, on close examination, you will see ropy rhizomorphs, under the broken bark and those will weigh no less than the mushrooms. If you return several years later and the mushrooms have been eaten, but the tree has not been disturbed otherwise, you will find almost nothing remaining. There will be little or no wood and little or no rhizomorphs. The rhizomorphs were a large part of the ramifying mycelium, they were resorbed after there was little wood left. That means that my calculation require that we start with *only* the dry matter in the substrate, no mushroom mycelium may be included in initial dry weight. At the end of an acceptable experiment, essentially all of the substrate must be catabolized. Then none of Kalberer's citations meet the minimum requirements. I and others have done experiments with *Pleurotus* that do meet the minimum requirements, but at the time I did it, I only thought of it as "bragging rights," so I did not publish. It appears that Bernabé-González's laboratory must have done it many times[2].

The scientific weakness of B.E. becomes apparent when we look closely at the work of Zhang *et al.*[11]: 158.6/173.9 x 100 =91.2% B.E. That would seem to approach the requirement of 100% B.E., so why did their substrate lose so little dry weight? Remember, their mushroom dry matter was 7.5%. My calculations are based on mushrooms with 10% dry matter, so 91.2 x 7.5/10 = 68.4% B.E. equivalent and so is actually far from meeting the minimum requirements. Then 68.4% is really a poor yield for *Pleurotus* growing on rice or wheat straw. We are left wondering what they did wrong – contamination? Poor growing conditions?

Flegg[3] was interested in added water. He started with compost that was ready to be cased, thus, the *Agaricus* spawn had run and had already consumed some of the compost. Yet, Flegg said, and as Kalberer noted, that 16% of the substrate, dry weight was catabolized, (after spawn-run) although his fresh mushroom yield (B.E.) was 25%. I calculated for 100% yield and showed 54% metabolic water Flegg's 16% would be the equivalent of 64% (16 x 4) dry weight loss for 100% B.E. He also used 10% dry weight for his mushrooms. Then, equivalent metabolic water would be (64 - 6.4) x 18/30 = 34.6% for 100% B.E. While I calculated 54% for 100% B.E., I was starting from dry, fresh substrate, not substrate that already had been used to establish the massive mycelium, required to support mushrooms. Also, unlike the mineralized *Pleurotus* substrate, his *Agaricus* substrate would be expected to still contain the mass of the mycelium. I can only conclude, to the degree that we can compare, Flegg's data appears to agree with me. I hope Kalberer is not confusing metabolic water with water that becomes excess. That is, more than 65% of the weight of the substrate, due to catabolic loss of substrate dry matter. Notice that percent metabolic water is based on percent of CH_2O dry weight, but the 65% is the percentage of wet substrate weight, so Flegg's excess water is 64/0.35 x 0.65 = 113.4 g as a result of the loss of 64 g of substrate dry weight. Yet, when we consider the yield that Flegg reported, even metabolic water is higher than I would predict.

I am most confused by Kalberer's own papers[5,6]. I can find no data on loss of substrate dry weight in it. Without information on dry weight changes, I do not understand how it could bears on my theoretical calculations. I certainly agree that modern *Agaricus* cultivation uses/loses much more water than modern *Pleurotus* cultivation. I have done studies on casing[7]. My studies, also do not bear on water released by substrate consumption.

Kalberer is correct about some things. I did not write anything about transpiration. Mushrooms are fungi. Transpiration is a plant function, it requires a cuticle layer, vascular system and especially stomata[1,9]. Mushrooms have none of the required anatomy. Stomata and cuticle protect plants from rapid water loss, so evaporation from mushrooms is much faster than the loss of water by transpiration, under similar atmospheric conditions. Evaporation from mushrooms differs from evaporation from substrate, only to the degree it is effected by water supply and osmotic pressure. However, he states that I wrote nothing about evaporation. My last two paragraphs were devoted to evaporation and things related to it. It appears that Kalberer is unaware that modern *Pleurotus* cultivation is done in plastic bags or plastic bag tubing and that evaporation is restricted to the extent that growers do not add water after the substrate is spawned (**Fig. 1**). That practice, alone suggests some legitimacy to my calculations.

Finally, Kalberer is also correct that I seldom read horticultural journals. I make no claims of being a horticulturalist. I do read mycological journals. *The International Journal of Mushroom Sciences* and its progeny, *MICOLOGIA APLICADA INTERNATIONAL* were established in the hopes that mushrooms researchers and other applied mycological researchers might find a common peer reviewed journal for publication.

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LITERATURE CITED

1. *American Heritage Dictionary*. 1991. Houghton Mifflin Co., Boston. 1568 pp.
2. Bernabé-González, T and M. Cayetano-Catarino. 2010. Investigación y producción de hongos comestibles en Guerrero, México. Pp. 141-150. *In: Hacia un Desarrollo Sostenible del Sistema de Producción-Consumo de los Hongos Comestibles y Medicinales en Latinoamérica: Avances y Perspectivas en el Siglo XXI.* Eds. D. Martínez-Carrera, N. Curvetto, M. Sobal, P. Morales and V. M. Mora. Red Latinoamericana de Hongos Comestibles y Medicinales-COLPOS-UNS-CONACYT-AMC-UAEM-UPAEP-IMINAP, Puebla.
3. Flegg, P. B. 1974. The water requirement of the mushroom crop. *Scientia Horticulturae* 2: 237-247.
4. Groves, J. W. 1979. *Edible and Poisonous Mushrooms of Canada*. Agriculture Canada, Ottawa. 326 pp.
5. Kalberer, P. P. 1990. Water relations of the mushroom culture *Agaricus bisporus*: Study of a single break. *Scientia Horticulturae* 41: 277-283.
6. Kalberer, P. P. 1991. Water relations of the mushroom culture (*Agaricus bisporus*): Influence on the crop yield and on the dry matter content of the fruit bodies. *Mushroom Science* 13: 269-274.
7. Kurtzman, R. H., Jr. 1996. *Agaricus bisporus* casing layer V: Water-holding increased by adding gels to clay chips. *Mushroom Biology and Mushroom Products* 2: 259-264.
8. Kurtzman, R. H., Jr. 2012. Mushrooms equal water conservation. *Micologia Aplicada International* 24(1): 27-29.
9. *Webster's New World Dictionary*. 1988. Simon & Schuster, Inc., New York. 1574 pp.

10. Wikipedia <http://en.wikipedia.org/wiki/Ecological_ pyramid> See also, http://earth.rice.edu/mtpe/ bio/biosphere/topics/energy/40_biomass.html

11. Zhang R., X. Li and J. G. Fadel. 2002. Oyster mushroom cultivation with rice and wheat straw. *Bioresource Technology* 82: 277-284.

Fig. 1. Modern oyster mushroom growing room with plastic tubing containers. Trimming plastic to accommodate growing pins.