References

Braun, U. & Cook, T.A. (2012). *Taxonomic Manual of the Erysiphales (Powdery Mildews)*. Utrecht: CBS-KNAW Fungal Biodiversity Centre.

Chater, A.O., Woods, R.G., Stringer, R.N., Evans, D.B. & Smith, P.A. (2021). *White Moulds, Ramularia and Phacellium Anamorphs, in Wales and Britain: A Guide and Welsh Census Catalogue*. Chater.

Chupp, C. (1953). *A Monograph of the Fungus Genus Cercospora*. New York, Ithaca: Chupp.

Culpeper, N. (1794). *Culpeper's English physician; and complete herbal*. London: Printed for the author.

Darbyshire, S.J., Eden, F.A., Bromfield, S.P. & Mechanda, S. (2022). The Biology of Canadian Weeds: 158. *Galega officinalis* L. *Canadian Journal of Plant Science* 102: 160–185.

Farr, D.F., & Rossman, A.Y. *Fungal Databases, U.S. National Fungus Collections, ARS, USDA*. https://nt.ars-grin.gov/fungaldatabases/

Gerard, J. (1597). *The Herball or Generall Historie of Plantes*. London: John Norton.

Hadden, D.R. (2005). Goat's rue – French lilac – Italian fitch – Spanish sainfoin: *Galega officinalis* and Metformin: the Edinburgh connection. *Journal of the Royal College of Physicians Edinburgh* 35: 258–260.

Ing, B. (2021). Checklist of British *Erysiphaceae*. *Field Mycology* 22: 123 – 129.

Jones, D.P. & Baker, R.H.A. (2007). Introductions of non-native plant pathogens into Great Britain, 1970–2004. *Plant Pathology* 56: 891–910.

Kyrylenko, L.V. & Patryk, V.P. (2016). Fungoid Diseases of *Galega orientalis*. *Agricultural Microbiology* 24: 52–58.

Legon, N. & Henrici, A. (2005). *Checklist of the British and Irish Basidiomycetes*. Kew, Royal Botanic Gardens.

Online Atlas of the British and Irish Flora. https://plantatlas.brc.ac.uk/

Spooner, B. M. (2003). New British records 233: *Ramularia galegae* Sacc. *Mycologist* 17(2): 102–103.

Świderska-Burek, U. (2015). Cercosporoid Fungi from Poland. *Monographiae Botanici* 105: 1–166.

The use of human senses in the identification of mushrooms III – taste

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As individuals, our behaviour is an integral part of our interactions with the environment and is mainly determined by the interaction of our senses (Kapralos *et al*., 2017). One part of these sensory interactions is directly linked to one of our main biological functions, feeding. Have you ever wondered why we can taste? This question may seem basic, but the underlying biological and evolutionary mechanisms deserve our attention (see Breslin, 2013 for evolutionary insights into human taste). Tasting the environment has allowed our ancestors to survive and pass on their genes (McLaughlin & Margolskee, 1994). This is crucial information for our organism and is enabled by a complex set of chemoreceptors that allow us to evaluate what we eat (Yarmolinsky *et al*., 2009). Apart from being an essential element for our survival, the sense of taste has been shown to be linked to the neural system of memory and pleasure (Veldhuizen *et al*., 2010). Thus, taste is used to enjoy certain foods, surpassing its primary role of providing energy to our organism. In mycology this behaviour is mainly employed by mycophagous people to appreciate the fruit of their mushroom hunting. However, the sense of taste has not only a physiological and psychological role; it can also be used in field taxonomic identification.

Before going into more detail about the taxonomic value of taste, I must point out that I will not be dealing with edibility or use in the social sphere (e.g., hallucinogenic mushrooms.) All field mycologists must remain cautious about tasting mushrooms. As far as we know, no currently known mushroom is deadly or a health hazard when we merely taste it, i.e., in contact with the mouth. To be so, mycotoxins must be ingested and absorbed by our gastrointestinal tract through our bloodstream. This is because of the high liposolubility of most mycotoxins (Kiroska & Velickova, 2021). It is therefore

highly recommended to immediately spit out the pieces of mushrooms or rinse your mouth several times if needed. In addition, taste is not a good indication of edibility: *Amanita virosa* is nice-tasting, with a meringue-like texture, but is poisonous, easily killing an individual if ingested. This field behaviour used by some mycologists should not be used under any circumstances for the field identification of plants. A simple contact of certain parts of some plants with the mouth can cause severe skin reactions, burns or mouth sores. Finally, I encourage the use of taste only in situations or fungal groups where it is of real taxonomic value and discourage the systematic use of taste where this does not apply. Often knowing the taste will not be a determining factor in the diagnosis, except in certain cases where the taste allows one to confirm and reinforce a taxonomic hypothesis. For these few cases, take only a very small piece of the mushroom to appreciate it and do not hesitate to clean, if necessary, the part which is going to be chewed. It is also judicious to remove the coating of the mushroom because of the risk of contracting echinococcosis conveyed by the excrement of wild animals. Numerous pieces of evidence have proven that many mushrooms are great bio-accumulators, especially of heavy metals (Dowlati *et al*., 2021; Priyadarshini *et al*., 2021; Ediriweera *et al*., 2022). This should make mycologists prudent about tasting mushrooms growing on roadsides or near polluted areas.

A useful but controversial taxonomic criterion

It is true that tasting mushrooms in the field is a controversial subject. The sense of taste is used more often at mycophagous meals than for field taxonomic purposes. Adding to the fear in the collective mind of getting sick by tasting a mushroom is the fact that taste may provide little taxonomic information compared to other human senses. Nevertheless, taste remains an underestimated and underused taxonomic tool in mycological field identification.

Our sense of taste cannot differentiate between many categories apart from salty, sweet, bitter, sour, peppery and a few other flavours. Without getting into non-essential subtleties, our sense of taste generally allows us to differentiate between broad categories such as sweet, pleasant, unpleasant or without any specific flavour. Some specific tastes like radish or flour come up quite often. Species descriptions focus particularly on the flavour of the flesh. Different groups of *Russula* can be distinguished according to whether the flesh is sweet (or mildly pungent) (e.g., *R. cyanoxantha*, *R. decolorans*) or strongly acrid (e.g., *R. ochroleuca*, *R. sanguinea*). However, other parts of the carpophore may be tasted such as the cap surface (e.g., *Russula amara* has a bitter-tasting cap surface) or the latex from *Lactarius* s.l. (e.g., the milk from *Lactifluus vellereus* is highly astringent).

Taste perception is highly susceptible to individual variations and may lead to misinterpretation. Some individuals will easily recognize all the subtleties of a given mushroom while others will affirm that "it tastes like mushrooms". To maximise the chance of catching the real taste, a small sample must be chewed in order to elicit the different tastes. Moreover, tastes we can recognize are biased by our own personal experience and sensorial background and above all, our ability to perceive through our mouth receptors. A taste we cannot identify or bridge with an already known one is generally described as 'indescribable' or 'singular taste'. As with other senses, the taste may vary depending on if it is dry or fresh. A great example can be found with *Bondarzewia mesenterica*, presenting a spicy taste when fresh and a bitter taste when dry. I won't go into more details about the limits and issues of the use of taste in the identification of mushrooms since Hallock (2007) has already given interesting and complete thoughts about that matter.

One facet of human-fungus interactions and ecological implications

Despite its limited taxonomic usefulness, taste allows us to understand many facets of the interactions between humans and fungi. One of the remarkable sensations one can experience is astringency resulting from the binding between salivary proteins and tannic acids in the mouth (Mese & Matsuo, 2007). Some mushrooms are even easily identifiable by this characteristic, such as the bitter iodine polypore (*Jahnoporus hirtus*) or the latex of some milkcap species. These fungal cells accumulate a pressurised liquid containing terpenes that serve as protection against mycophagy (Taskirawati & Tuno, 2016). The extreme bitterness of *Gymnopilus*

penetrans, one of the most common macromycetes species in European forests, also acts as chemical protection. Small released tannins during the white-rotting process are integrated into the cells and are at the origin of the bitter taste. *Calocera viscosa* contains many tannins (polyphenolic compounds) that are indigestible in the human digestive tract and have been used as a natural vermifuge for laxative purposes. *Russula* spp. produce highly burning and peppery terpenoid compounds. These sensations that we perceive during field taxonomic investigations are the expressions of physiological mechanisms fulfilling different ecological roles.

Mushrooms naturally accumulate toxins, but they are not primarily directed toward humans since we do not exert much predatory pressure on them (i.e., we are a facultative mycophagous species). This toxicity is a trait that was selected as it is used to give protection against all other mycophagous species (e.g., rodents, reptiles, slugs, insects, etc; see Elliott *et al*., 2019, 2022 and Santamaria *et al*. 2023 for vertebrate and invertebrate mycophagy) that may live in the same ecosystem. Despite these protections, some mycophagous species are thus adapted, and their lifecycle may be partially or entirely dependent on mushroom hosts, such as strictly mycophagous larvae of *Mycetophilidae* flies. Protecting carpophores while spores are being produced is a major issue for the dispersion and survival of the species (Varga *et al*., 2022). Toxicity against humans is undoubtedly an 'accident' of recent evolutionary history of humans and fungi, mainly due to our genetic proximity to the other encountered mycophagous organisms.

Conclusion

The sense of taste is only of limited taxonomic use and suffers from negative human perception. Among those cases where tasting a mushroom can add relevant clues to the diagnosis, every field mycologist must be aware of its limits and potential danger. Mushroom taste gives interesting insights into the ecology of macromycetes and is intimately linked to smell, which is a much more important and useful human sense in field mycology.

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References

Breslin, P.A. (2013). An evolutionary perspective on food and human taste. *Current Biology*, 23 (9): R409–R418.

Dowlati, M., Sobhi, H.R., Esrafili, A., FarzadKia, M., & Yeganeh, M. (2021). Heavy metals content in edible mushrooms: A systematic review, meta-analysis and health risk assessment. *Trends in Food Science & Technology*, 109: 527–535.

Ediriweera, A.N., Karunarathna, S.C., Yapa, P.N., Schaefer, D.A., Ranasinghe, A.K., Suwannarach, N., & Xu, J. (2022). Ectomycorrhizal Mushrooms as a Natural Bio-Indicator for Assessment of Heavy Metal Pollution. *Agronomy*, 12 (5): 1041.

Elliott, T.F., Bower, D.S. & Vernes, K. (2019). Reptilian mycophagy: a global review of mutually beneficial associations between reptiles and macrofungi. *Mycosphere* 10: 776–797.

Elliott, T.F., Truong, C., Jackson, S.M., Z˙Òiga, C.L., Trappe, J.M., & Vernes, K. (2022). Mammalian mycophagy: a global review of ecosystem interactions between mammals and fungi. *Fungal Systematics and Evolution*, 9 (1): 99–159.

Hallock, R.M. (2007). The taste of mushrooms. *McIlvanea*, 17: 33–41.

Kapralos, B., Collins, K., & Uribe-Quevedo, A. (2017). The senses and virtual environments. *The Senses and Society*, 12 (1): 69–75.

Kiroska, I., & Velickova, N. (2021). The Importance of Qualitative and Quantitative Biological Methods for Evaluation and Screening of Mycotoxins. *Albanian Journal of Medical and Health Sciences*, 55: 1–6.

McLaughlin, S., & Margolskee, R.F. (1994). The sense of taste. *American Scientist*, 82 (6), 538–545.

Mese, H., & Matsuo, R. (2007). Salivary secretion, taste and hyposalivation. *Journal of oral rehabilitation*, 34 (10): 711–723.

Priyadarshini, E., Priyadarshini, S.S., Cousins, B.G., & Pradhan, N. (2021). Metal-Fungus interaction: Review on cellular processes underlying heavy metal detoxification and synthesis of metal nanoparticles. *Chemosphere*, 274: 129976.

Santamaria, B., Verbeken, A. & Haelewaters, D. (2023). Mycophagy: A global review of interactions between invertebrates and fungi. Joutnal of fungi 9(2): 163

Taskirawati, I., & Tuno, N. (2016). Fungal defense against mycophagy in milk caps. *Sci. Rep. Kanazawa Univ*, 60: 1–10.

Varga, T., F˙ldi, C., Bense, V., & Nagy, L.G. (2022). Radiation of mushroom-forming fungi correlates with novel modes of protecting sexual fruiting bodies. *Fungal Biology*, 126 (9): 556–565.

Veldhuizen, M. G., Rudenga, K. J., & Small, D. M. (2010). The pleasure of taste, flavor, and food In Kringelbach, M. L. & Berridge, K. C. (Eds), *Pleasures of the brain*. Oxford University Press, Oxford, 146–168.

Yarmolinsky, D.A., Zuker, C.S., & Ryba, N.J. (2009). Common sense about taste: from mammals to insects. *Cell*, 139 (2): 234–244.