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All-clear for gourmets: truffles not radioactive

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Abstract. Although ranging among the most expensive gourmet foods, it remains unclear whether Burgundy truffles (*Tuber aestivum*) accumulate radioactivity at a harmful level comparable to other fungal species. Here, we measure the ^{137}Cs in 82 *T. aestivum* fruit bodies from Switzerland, Germany, France, Italy, and Hungary. All tested specimens reveal insignificant radiocaesium concentrations, thus providing an all-clear for many truffle hunters and cultivators in large parts of Europe as well as the subsequent chain of dealers and customers from around the world. Our results are particularly relevant in the light of ongoing efforts to cultivate Burgundy truffles, as well as the fact that several forest ecosystems are still highly contaminated with ^{137}Cs, for which mushrooms are one of the main pathways to human diets.

1 Introduction

Extensive cultivation efforts of the Burgundy truffle (*Tuber aestivum* Vittad.) far beyond its traditional homeland in France aim at supplementing wildlife harvests of this species for the growing demand of a globalized gourmet market (Hall et al., 2003; Büntgen et al., 2012). Despite the rapidly increasing economic interest in this ectomycorrhizal ascomycete, much of the hypogeous life cycle is, however, not yet fully understood (Stobbe et al., 2012, 2013). Together with a general lack of biological and ecological insight, it is still unknown whether belowground truffle fruit bodies are accumulating radioactivity at a harmful level comparable to other fungal species and subsequent components of the trophic food web (Dighton et al., 2008; Hohmann and Huckschlag, 2005; Strebl and Tataruch, 2007; Steiner and Fielitz, 2009; Mietelski et al., 2010).

Since the Chernobyl accident in late April 1986 ($\sim 51°23'$ N and $\sim 30°05'$ E), large parts of Europe's topsoil have been radioactively contaminated (De Cort et al., 1998; Evangeliou et al., 2013), with high radionuclide levels implying concerns for ecotoxicology and human health. Some ectomycorrhizal and saprotrophic fungi appear particularly prone to mediating and incorporating radiocaesium-137 (^{137}Cs) (Dighton et al., 2008), with different melanin contents and mycelium depths contributing to species-specific rates of radio-resistance and ^{137}Cs accumulation (Mietelski et al., 2010). In regions where the aerosol fallout after Chernobyl was most intense, not only mushrooms but also later components in the food chain, including game meat of red deer, roe deer, and wild boar, still exceed the ^{137}Cs tolerance value of 600 Bq kg^{-1} (Hohmann and Huckschlag, 2005; Strebl and Tataruch, 2007; Steiner and Fielitz, 2009).

2 Data, methods and results

Here, we measure the ^{137}Cs activity concentration of 82 *T. aestivum* fruit bodies, which were harvested by trained dogs between 2010 and 2014 in natural habitats and plantations across Switzerland, Germany, France, Italy, and Hungary (Fig. 1a). Individual truffles of at least 50 g were gently cleaned at their surface, carefully ground, and immediately frozen until their final assessment in the gamma spectrome-

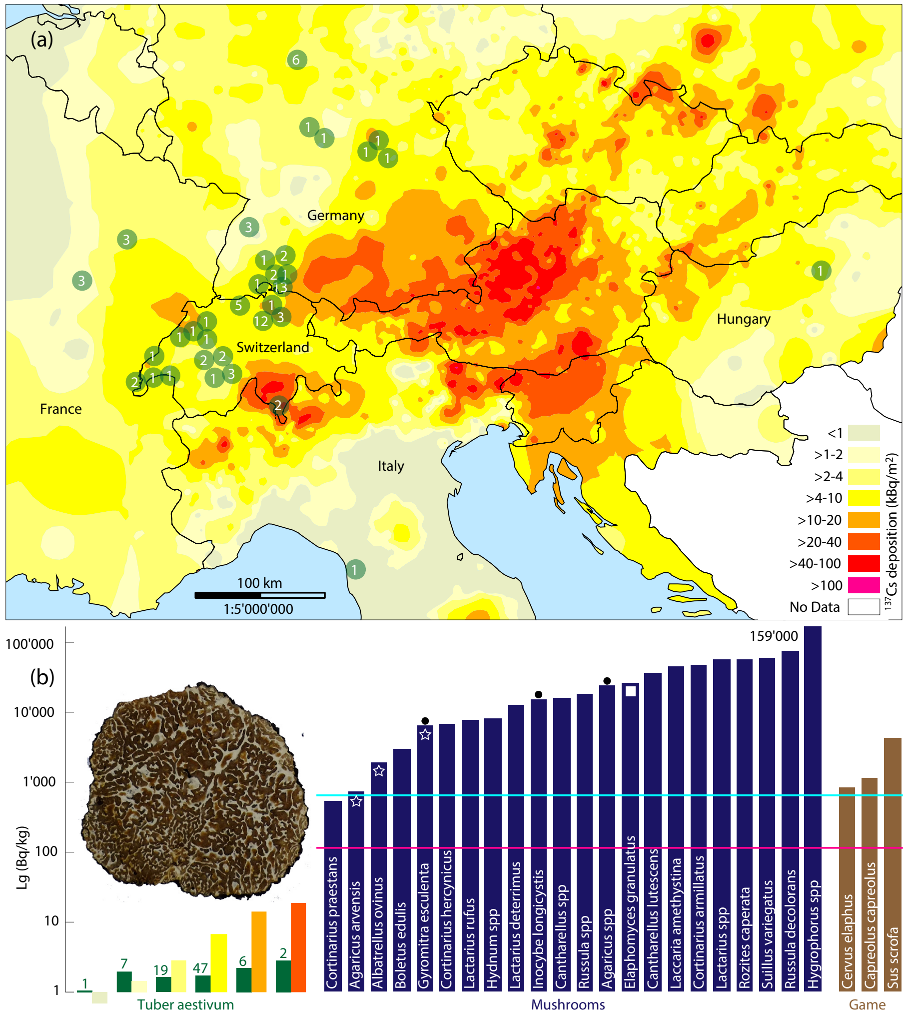

Figure 1. Truffle location and ^{137}Cs topsoil contamination. **(a)** Distribution of 82 Burgundy truffle sites (green spots) superimposed on ^{137}Cs surface deposition after Chernobyl (De Cort et al., 1998). **(b)** Mass-specific mean ^{137}Cs detection limit (after $\sim$20 h) of *T. aestivum* fruit bodies ($\sim$45–50 g) classified after local deposition levels (numbers refer to the amount of samples per deposition level), together with published ^{137}Cs contamination values of edible and toxic (black dot) mycorrhizal and saprotrophic (white star) above- and belowground (white square) mushrooms (Dighton et al., 2008; Steiner and Fielitz, 2009; Mascanzoni, 2001), as well as game meat (Strebl and Tataruch, 2007). Horizontal lines are tolerance values for food (100 Bq kg^{-1}) and fungi/game (600 Bq kg^{-1}).

ter, an instrument that measures the activity of γ-emitting radionuclides. After correction for the decay rate, all specimens reveal insignificant ^{137}Cs values below the detection limit of 2 Bq kg^{-1} (determined by the background noise, counting efficiency, processing time and sample weight). This result suggests an all-clear for many Burgundy truffle hunters and cultivators across large parts of Europe, as well as for the complex follow-up chain of dealers and customers from around the world.

3 Discussion and conclusions

Our findings, in agreement with local-scale evidence from Italy (Lorenzelli et al., 1996), are surprising as mycorrhizal mushrooms play a key role in the radioecology of natural ecosystems (Fig. 1b). Hypogeous deer truffles (*Elaphomyces granulatus*), for instance, range amongst the most contaminated fungi (Hohmann and Huckschlag, 2005; Strebl and Tataruch, 2007; Steiner and Fielitz, 2009). Reasons for non-radioactive *T. aestivum* possibly involve species-specific requirements for soil structure and chemistry, together with mycelium depth, melanin content, and/or the lack of ^{137}Cs-binding pigments. It has also been argued that calcium carbonate reduces the soil–plant/fungi transfer of ^{137}Cs, while its availability for organisms is elevated in nutrient-poor organic soil horizons (Mascanzoni, 2001, 2009).

Truffles generally fruit near the surface of calcareous substrate (Stobbe et al., 2012, 2013). Nevertheless, more insight is needed into the chemical composition of truffle fruit bodies and their symbiotic interaction with host plants (Büntgen and Egli, 2014; Büntgen et al., 2015), considering potential effects on the cycling of ambient ^{137}Cs from both Chernobyl and atmospheric nuclear testing in the 1950s and 1960s. These and associated tasks surrounding the hidden world of truffles appear timely in the light of recent cultivation efforts (Hall et al., 2003; Stobbe et al., 2013), as well as the fact that forest ecosystems still provide ample ^{137}Cs for uptake, with mushrooms representing one of the main pathways to human diets (Mascanzoni, 2009). Further relevance emerges from the environmental contamination and subsequent distribution of the Fukushima Daiichi accident in March 2011 (Yasunari et al., 2011; Murakami et al., 2014), as well as from the anticipated effects of global warming on the transfer rate of radionuclides (Dowdall et al., 2008), for instance.

In conclusion, we hope that our study will stimulate interdisciplinary research within the timely arena of radioecology. Among others, pending truffle-related projects should include the collection and examination of many more fruit bodies from differently contaminated areas and different species in tandem with nearby soil samples, the consideration and investigation of other isotopic elements, as well as a comprehensive assessment of mycelium biochemistry.

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