Phylogenetically conservative isotope fractionation and milk effect in mammals, revealed from feeding-controlled experiments of stable carbon isotopes for paleontology

Yuri Kimura[1,2], Thure E. Cerling[3], Keita Yamada[4], Azusa Seki[5], Isaac Casanovas-Vilar[2], Lawrence J. Flynn[6], Louis L. Jacobs[7]*

[1] Department of Geology and Paleontology, National Museum of Nature and Science, Tsukuba, Japan
[2] Institut Català de Paleontologia Miquel Crusafont (ICP-CERCA), Universitat Autònoma de Barcelona, Barcelona, Spain, elona, Barcelona, Spain
[3] Department of Geology and Geophysics, School of Biological Sciences, University of Utah, Salt Lake City, UT, United States,
[4] Department of Environmental Chemistry and Engineering, Institute of Science Tokyo, Yokohama, Japan,
[5] Fukushima Medical Device Development Support Centre, United States,
[6] Department of Earth Sciences, Southern Methodist University, Dallas, TX, United States,
[7] Department of Human Evolutionary Biology, Harvard University, Cambridge, MA, United States
*Presenting Author Email: ykimura@kahaku.go.jp

Stable carbon isotope analysis has proven invaluable for understanding dietary ecology and migration patterns in mammals, both in the past and present. The stable carbon isotopic composition of tooth enamel reflects the weighted contribution of C3 and C4 plants in animal diet, generally linking to the overlying vegetation in their habitats. The general application of carbon isotopes to this research requires prior understanding of the isotope fractionation between diet and bioapatite (bones and tooth enamel). The enrichment of 14 permil from diet to tooth enamel has been widely applied to extinct large ungulates of various sizes; however, some later experiments suggested a value between 12 and 14 permil for medium-sized ungulates and for non-ungulates. Due to physiological uncertainties regarding the variation in the enrichment value and to the problems of sampling very small teeth, the study of stable isotope ecology of small mammals has been limited.

To understand the isotope enrichment from diet to tooth enamel of extinct small mammals and understand the physiological factors controlling these values, we set up feeding-controlled experiment examining four rodent species. We raised these rodents on diets with known carbon isotopic compositions and monitored the isotopic values of their breath and tooth enamel.

Our results demonstrate that cubs consistently displayed lower carbon isotope values than their mothers, suggesting a significant isotopic signature related to milk consumption. As the cubs transitioned to solid food, their breath carbon isotope values shifted towards the isotopic composition of their diet, indicating a gradual decrease in the influence of milk on their progressively changing diet. Based on our findings, we propose that the baseline value of isotope enrichment from diet to tooth enamel is approximately 12 permil for mammals with both differential digestion and methanogenesis as factors that may increase the enrichment factor by another 1 to 4 permil. This study contributes to the development of robust paleoecological models for extinct mammals, especially micromammals which exhibit little or no methane production or differential digestion.

Funding acknowledgement:
21K15176,PID2020-117289GB-I00 (MCIN/AEI), GenCat/CERCA Programme, AGAUR (2021 SGR 00620).