European Mineralogical Conference
Vol. 1, EMC2012-545, 2012
European Mineralogical Conference 2012

Calcium isotope fractionation in vertebrates

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During the past years the application of Ca isotopes has spread into the field of life sciences and biomedicine. Currently, the urinary Ca isotopic composition is under investigation as a proxy for Ca metabolism related diseases in the human body. A proper knowledge of the transport processes of Ca isotopes in the body and the occurring isotope fractionation during transport is of fundamental importance.

In order to verify and refine the current Ca isotope transport model in vertebrates we analyzed the Ca isotopic composition of diet, feces, blood, bones and urine from 18 Göttingen minipigs. The pigs were part of a bioassay conducted by the Federal Research Center for Nutrition and Food, Kiel, Germany. Samples from three different groups from the bioassay were investigated: control group, glucocorticosteroid (GC)-treated group and calcium deficient food group.

While $\delta^{44/40}Ca_{diet}$ values are in average +0.42‰ and only vary by about 0.1‰ the observed Ca isotope variations in feces, bones, blood and urine are much higher. The overall range of $\delta^{44/40}$Ca values is about 3.2‰ ranging from –0.54‰ (feces) up to +2.74‰ (urine).

The Ca isotopic composition of urine shows an enrichment in the heavy Ca isotopes ($\delta^{44/40}Ca_{urine}$ from +1.61‰ to +2.74‰. This enrichment is consistent with previous studies and has been explained by preferential transport of light Ca isotopes during reabsorption of Ca from the primary urine. This leads to enrichment of heavy Ca isotopes in secondary urine which is collected in the bladder and finally is excreted.

The difference between $\delta^{44/40}Ca_{blood}$ and $\delta^{44/40}Ca_{bone}$analyzed in this study is in average 0.66‰This value is a by factor of 2 lower than the previously reported fractionation between soft tissue (including blood) and mineralized tissue.

Calcium in feces represents the unabsorbed fraction of dietary Ca and thus $\delta^{44/40}$Ca of feces can be used to determine if Ca isotopes are fractionated during intestinal absorption. As the absorption of Ca in the intestine is a transcellular transport favouring the light Ca isotopes, it is expected that $\delta^{44/40}Ca_{feces}$ should be higher than $\delta^{44/40}Ca_{diet}$. $\delta^{44/40}Ca_{feces}$ from the control and GC treatment group are not very different from $\delta^{44/40}Ca_{diet}$ suggesting that intestinal Ca isotope fractionation is very small. In contrast, $\delta^{44/40}Ca_{feces}$ values from the Ca deficient food group are lower than $\delta^{44/40}Ca_{diet}$ suggesting a preferential absorption of heavy Ca isotopes. Alternatively, low $\delta^{44/40}Ca_{feces}$ could result from additional isotopically light Ca entering the intestine by intestinal fluids. In consequence, the $\delta^{44/40}Ca_{feces}$ of the control and GC treated group require a fractionation during intestinal Ca absorption balancing the additional Ca from the intestinal fluids.

Our findings show the need of refining the currently used Ca isotope transport model. The soft tissue compartment (including blood) needs be split into two compartments (blood and soft tissue) and an additional intestinal fluid compartment combined with a Ca isotope fractionation during intestinal Ca absorption is needed.