

Metabolism of Radiocarbon and Tritium in the Human Body

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Abstract

In the radiation safety assessment for nuclear facilities including the first commercial spent nuclear fuel reprocessing plant in Rokkasho, Japan, the internal doses of the public due to ingested ^{14}C and tritium have been estimated using the dose conversion factors based on the simple ICRP metabolic models in the human body. Although the biological half-life of tritium water (HTO) in the human body was examined in several cases, actual data on the metabolism of organic ^{14}C and organically bound tritium (OBT) in diet are quite limited. The objectives of this research program are to establish experimentally the metabolic models of organic ^{14}C and OBT in the human body for more realistic dose estimation. To obtain metabolic parameter values of ^{14}C , which are also utilized for OBT, we used the stable isotope of ^{13}C to label organic molecules on oral administration experiments as a substitute for ^{14}C .

Until FY 2016, various ^{13}C -labeled nutrients were administered to volunteers, followed by measuring the ^{13}C concentration in their breath and hair as representatives of inorganic and organic excreta, respectively. In FY2017, hair samples from volunteers administered with ^{13}C -labeled oleic acid or glycine were measured, and ^{13}C -labeled phenylalanine and glucose were also administered to volunteers, followed by collecting breath and hair samples. The breath samples were measured for ^{13}C , and the hair samples will be analyzed in FY2018. All processes of the experiment were approved by the IES Review Board for Human Subject Experiments, and written informed consents were obtained from all volunteers.

The recovery of ^{13}C of administered nutrients was 83-97% so far excluding unsaturated fatty acids for which recovery was 59-60%. Although the undetected proportion of ~10% may be attributed to a non-absorbing fraction in the gastrointestinal tract, the large undetected proportion of unsaturated fatty acids was hard to explain by only a non-absorbing fraction in the tract. We assumed that the undetected fraction was accumulated in adipose tissue, which is reported to have a long mean residence time of carbon based on analyzing ^{14}C that originated from nuclear weapon testing. A tentative metabolism model was constructed based on our results and the reported mean residence time. The 50-year cumulative body burden for ^{14}C , as an index of the committed dose of the radioisotope ^{14}C , in unsaturated fatty acids was estimated to be larger than that of the other nutrients by the model.

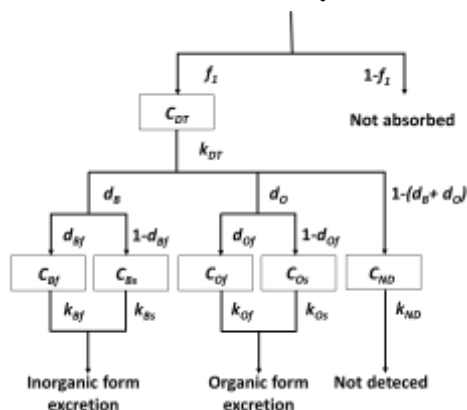


Fig.1 Structure of the metabolic model for ingested ^{13}C .

Compartments of ^{13}C : C_{DT} , digestive tract; C_{Bf} and C_{Bs} , fast and slow compartments for inorganic excretion, respectively; C_{Of} and C_{Os} , fast and slow compartments for organic excretion, respectively; C_{ND} , compartment for not detected component of administered ^{13}C . d is distribution factor and k is elimination rate constant.

Table 1 Parameters for carbon in fatty acids

Parameter	Oleic acid	Linoleic acid*	Palmitic acid*
k_{DT}	11 ± 4	3.8 ± 1.1	2.6 ± 0.3
d_B	0.61 ± 0.04	0.61 ± 0.07	0.90 ± 0.05
d_{Bf}	0.57 ± 0.07	0.48 ± 0.07	0.56 ± 0.08
k_{Bf}	3.2 ± 0.7	20 ± 3	3.2 ± 0.3
k_{Bs}	0.11 ± 0.03	0.081 ± 0.015	0.096 ± 0.029
d_O	0.018 ± 0.001	0.019 ± 0.005	0.034 ± 0.008
d_{Of}	0.53 ± 0.17	0.41 ± 0.05	0.66 ± 0.20
k_{Of}	0.52 ± 0.09	2.1 ± 1.7	0.44 ± 0.13
k_{Os}	0.022 ± 0.016	0.043 ± 0.017	0.044 ± 0.002

Mean value \pm standard deviation. *, Determined using data from previous research.

Table 2 Parameters for carbon in amino acids

Parameter	Glycine	Glutamic acid*	Leucine*
k_{DT}	14 ± 3	25 ± 8	7.5 ± 1.1
d_B	0.75 ± 0.02	0.84 ± 0.03	0.57 ± 0.05
d_{Bf}	0.37 ± 0.03	0.73 ± 0.02	0.52 ± 0.05
k_{Bf}	28 ± 6	36 ± 12	14 ± 3
k_{Bs}	0.18 ± 0.01	0.21 ± 0.03	0.13 ± 0.06
d_O	0.23 ± 0.01	0.061 ± 0.014	0.37 ± 0.04
d_{Of}	0.48 ± 0.02	0.39 ± 0.08	0.33 ± 0.02
k_{Of}	0.22 ± 0.02	0.39 ± 0.05	0.29 ± 0.01
k_{Os}	0.011 ± 0.001	0.017 ± 0.008	0.013 ± 0.000

Mean value \pm standard deviation. *, Determined using data from previous research.

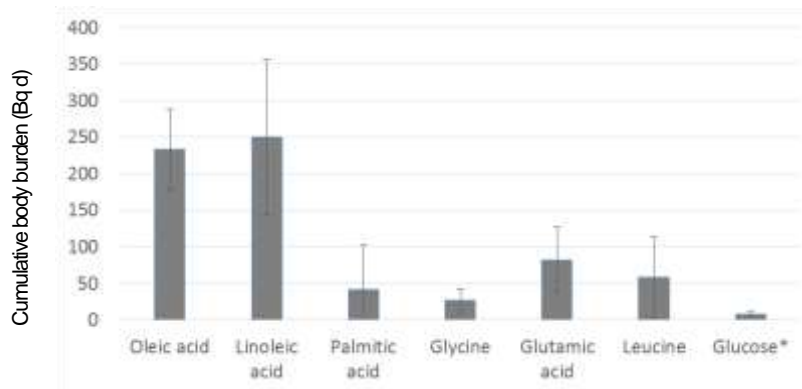


Fig.2 Cumulative body burden for 50 years after an ingestion of 1 Bq of ¹⁴C in nutrients.

*, Determined using data from previous research.