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Differences in natural carbon isotope ratios of milk and hair from cattle grazing tropical and temperate pastures

ABOUT 99% of all carbon is the ^{12}C isotope while 1% is ^{13}C. The precise ratio of the isotopes will vary depending on the material analysed. In plants, fractionation of carbon is brought about primarily by carbon dioxide assimilation in photosynthesis and is due to preferential utilisation of ^{12}C and exclusion of ^{13}C. Curiously enough, it has been found recently[1,2] that higher plants which fix carbon dioxide by way of the Calvin C_3 cycle pathway differ in $^{13}C/^{12}C$ ratios from plants which fix carbon dioxide through the C_4-dicarboxylic acid pathway. Temperate pasture species fix carbon by way of the Calvin pathway and have $^{13}C/^{12}C$ ratios of approximately −28‰ (ref. 3 and M.M.L., J.H.T., and R. J. Jones, unpublished), whereas tropical pasture grasses fix carbon through the C_4-dicarboxylic acid pathway[4] and have $^{13}C/^{12}C$ ratios of approximately −12‰ (ref. 2 and M.M.L., J.H.T., and R.J.J., unpublished). $^{13}C/^{12}C$ ratios are expressed relative to a carbonate standard[5].

Smith and Epstein[5] suggested that isotope ratios of marine animal tissues reflect the ratio in their presumed diet, but there seem to have been no direct comparisons of the isotope ratios of higher animal tissue with those of the food eaten. Our aim, therefore, was to compare the carbon ratios of tissues from animals grazing pasture with contrasting $^{13}C/^{12}C$ ratios. The tissues sampled were hair and milk, representing the products of long and short term absorption of nutrients respectively, whereas the pastures grazed were composed of either temperate C_3 species or tropical C_4 grasses, each grazed at two locations (Table 1). Pasture was the only source of carbon except at Wollongbar where 2–3% of the predominantly C_4 diet consisted of bran/oaten chaff (C_3). The isotope measurements of pasture, hair and milk samples were made with a ratio mass spectrometer[6]. Differences between single replicates are usually less than 1‰.

The carbon ratios of the pasture samples (Table 1) reflected their botanical composition with values close to those previously reported for temperate and tropical pastures (ref. 3 and M.M.L., J.H.T., and R.J.J., unpublished). There were also large differences between the ratios for milk and hair produced from C_3 and C_4 pastures, although the mean difference was reduced from −14.0‰ with pasture to −9.8‰ for the tissues. This narrowing of the ratio may be due to differences in discrimination against ^{13}C during transformations by the rumen microorganisms or within the tissues of the animal. Alternatively, the animals grazing C_4 pastures may have selectively grazed a small amount of C_3 weeds which would increase the carbon ratio relative to that of the feed sample. Similarly, selection of C_4 weeds in C_3 pastures would reduce the ratio below that expected. Values for milk and hair were identical at three of the four locations, indicating that differences in the carbon ratios of the feeds are reflected in both long term and short term animal products. The cause of the difference in ratios for milk and hair at Swan's Lagoon is unknown. Since the carbon ratio of milk and hair are similar, it is likely that the ratios for other animal tissues, including muscle and fat, will show similar differences between feeds.

These results show that the carbon ratios of animals reflect the carbon ratio of the feed being eaten, and that these ratios can be used as a naturally occurring marker of carbon. This finding could have important implication for animal physiology, forensic science and studies of animal evolution. It should be possible to calculate the proportion of carbon in milk coming from feed and body reserves or to determine the rate of exchange of body protein and fat. This would be achieved by feeding a completely C_4 diet to animals that had previously been given only C_3 feeds so that all their tissues had carbon ratios characteristic of C_3 species. In temperate zones C_4 diet could be based upon either the forage or grain of *Zea mays* or *Sorghum bicolor*. Alternatively, animals on a C_4 diet could be changed to one comprised of C_3 feeds. In forensic science this observation could prove valuable in determining the diet and hence the origin of animals or animal products. It should also be possible to determine the diets of ancient animals by measuring the carbon isotope ratios of their remains.

Table 1 $^{13}C/^{12}C$ ratios of pasture and of milk and hair of grazing cattle

Pasture location		Pasture species	Photosynthetic pathway	No. of cows	Time since calving (d)	$\delta^{13}C$ parts per ml Pasture	Milk	Hair
Swan's Lagoon, Qld	20°10′S, 147°15′E	*Heteropogon contortus*	C_4	3	45	−14.0	−15.5	−12.1
Wollongbar, NSW	28°50′S, 153°25′E	*Pennisetum clandestinum*	C_4	3	107	−12.4	−15.0	−15.1
Murray Bridge, SA	35°07′S, 139°16′E	**Lolium perenne*	C_3	1	120	−25.4	−22.5	−22.3
Werribee, Vic.	37°54′S, 144°39′E	**Lolium perenne*	C_3	1	210	−28.9	−26.0	−26.2

*Also *Trifolium repens* and other temperate species.

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