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Worldwide stable carbon and nitrogen isotopes of *Big Mac*® patties: An example of a truly "glocal" food

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ABSTRACT

The *Big Mac*®, McDonald's® signature burger, is a global food served in over 100 countries. We measured carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) stable isotope ratios of *Big Macs*® from twenty-six countries. The $\delta^{13}C$ values varied from −25.4‰ to −11.1‰, representing cattle-rearing systems based exclusively on C_3 plants, exclusively on C_4 plants, or both C_3 and C_4 plants. Median $\delta^{15}N$ value was 6.6‰; the 25th and 75th percentile were 5.9‰ and 7.3‰, respectively. Calculated percentages of imported beef were consistent with the $\delta^{13}C$ values of purchased *Big Macs*®. Japanese patties had higher $\delta^{13}C$ values than expected based on that country's C_3 agriculture, however Japan imports beef from Australia, where C_4 plants are prevalent. Lower latitude countries generally had higher $\delta^{13}C$ values than higher latitude countries, reflecting the larger distribution of C_4 plants in warm regions. Although *Big Macs*® are a global food, we conclude they also contain local components.

1. Introduction

The signature sandwich of the McDonald's® fast-food restaurant chain is the *Big Mac*®, which was created in 1967 by Jim Delligatti in Pittsburgh and was added to the national (US) menu in 1968. Today, a *Big Mac*® is a double-decker hamburger (100% beef) with special "Mac" sauce, iceberg lettuce, cheese, pickles, and onions and contains 480–600 kcal, depending upon country. For the first time in human history, consumers can buy and receive – generally in a few minutes (Pollan, 2006; Roberts, 2008) – the same *Big Mac*® meal from over 32,000 locations in approximately 120 countries, 365 days a year. Consequently, McDonald's® and its *Big Mac*® are almost instantly connected with globalisation (Turner, 2003). This is best exemplified by the "*Big Mac Index*" created by *The Economist* to compare currencies of different countries by determining the price of a *Big Mac*® in each of them (The Economist – http://www.economist.com/markets/bigmac/about.cfm, 2009).

There are several examples of local societies influencing McDonald's® restaurant outlets causing them to change and adapt products according to local tastes (Illouz & John, 2003). For example, in India patrons can enjoy the vegetarian *McAloo Tikki*®, while Japanese diners can purchase the *Ebi Filet-O*®, a shrimp burger. Many McDonald's® international outlets are therefore hybrids of the pure McDonald's® concept conceived in the US in the early 50's (Pollan, 2006), blending with local culture in a process called "glocalisation" (Turner, 2003).

Based on the concept of *rationalisation* described by Weber (1921), Ritzer (2000) coined the term *McDonaldisation* to describe how contemporary fast-food restaurant chains such as McDonald's® are driven by efficiency, predictability, calculability and control. Morris and Reed (2007) have proposed: "to extend the *McDonaldisation* thesis into the rural and, by extension, into the natural by simply tracking the burger-food chain to the place where the raw materials are produced." According to Roberts (2008), ground beef for burgers, like the *Big Mac*® sandwich, is prepared in batches encompassing a multitude of steer carcasses purchased from several suppliers. Hamburger patties could therefore be useful integrators of beef characteristics available in a large geographic region.

Here, we tested the proposal of Morris and Reed (2007) by attempting to trace the incorporation of local components into a globally-available food (the *Big Mac*®) via stable isotope analysis. We used stable carbon isotope ratio (expressed as $\delta^{13}C$) analysis because plants with the C_3 photosynthetic pathway have lower $\delta^{13}C$ values compared to plants with the C_4 photosynthetic pathway. Most plants, such as wheat, temperate grasses and trees

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have C_3 photosynthesis and the δ^{13}C values of these plants vary in a range from −30‰ to −24‰. Although fewer plant species worldwide use the C_4 photosynthetic pathway, there are two key C_4 plants that are important in human and animal nutrition: maize (corn) and tropical grasses. These plants have C_4 photosynthesis and their δ^{13}C values vary from −14‰ to −11‰. Cattle can eat both C_3 and C_4 plants depending upon the local geographic and economic conditions. Since the δ^{13}C values of animal tissues are nearly identical to that of their food sources, the carbon isotope ratio of beef will reflect the proportion of C_3 and C_4 plants ingested by cattle in their geographic range (Heaton, Kelly, Hoogewerff, & Woolfe, 2008). We expect that *Big Mac*® patties, analysed in this study, range from approximately −11‰ (cattle fed exclusively on maize or tropical grasses) to approximately −25‰ (cattle fed exclusively on C_3 plants such as hay or soybeans). Any intermediate values between these extremes would indicate that the cattle ingested proportions of both C_4 and C_3 plants.

The interpretation of stable nitrogen isotope ratios (expressed as δ^{15}N) of animal meats is not as straightforward as carbon isotope ratios (C_3 *vs.* C_4) because the nitrogen isotope ratios of the plants depend not only on the nitrogen source (soil *vs.* atmosphere; nitrate *vs.* ammonium), but also on the internal nitrogen balance of the plant since, for instance, nitrogen, can be lost via foliar volatilisation, altering the nitrogen isotopic composition of the plant (Högberg, 1997). In general, however, the δ^{15}N values of natural plants used as beef cattle fodder may indicate the characteristics of climate, since tropical plants tend to have higher δ^{15}N values than temperate plants (Martinelli et al., 1999). The measured δ^{15}N values of beef may also reveal the type of fertiliser used to grow plants ingested by the animals, since plants that receive organic fertilisers tend to have higher δ^{15}N values than plants that received mineral fertilisers (Choi, Lee, Ro, Kim, & Yoo, 2002; Choi, Ro, & Hobbie, 2003; Kriszan, Wulf Amelung, Schellberg, Gebbing, & Kühbauch, 2009).

We hypothesised it would be possible to track *McDonaldisation* (Morris & Reed, 2007) by using stable carbon isotope ratio analysis to calculate the proportion of C_3 and C_4 plants in *Big Mac*® ground beef patties collected from 26 countries around the world. Specifically, we hypothesised that the carbon isotope ratios of *Big Mac*® ground beef patties should vary geographically and reflect C_3/C_4 food sources of the region. In addition, we expected that the nitrogen isotope ratios of *Big Mac*® ground beef patties should also vary geographically and reflect known patterns of nitrogen isotope differences among grass sources in tropical and temperate regions. To test these expectations, we collected hamburger (beef) patties from McDonald's® outlets around the world. We first present the results of our restaurant survey comparing our hamburger data to other published beef datasets. We next relate the geographic trends in measured δ^{13}C and δ^{15}N values observed in the collected *Big Macs*® to global plant distributions before finally comparing our beef patty data to published δ^{13}C and δ^{15}N values of human fingernails.

2. Material and methods

Samples of beef patties were collected from meals ordered from McDonald's® menus at multiple restaurant outlets in several countries (Table 1). All samples were immediately dried to prevent decomposition. In the laboratory, samples were loaded into cellulose thimbles and delipified on a Soxhlet apparatus for 48 h using a 2:1 mixture of chloroform and methanol. Delipified samples were ground, and then stored in glass vials. Dried lipid-extracted *Big Mac*® patties were weighed (1–2 mg) into tin capsules. Carbon and nitrogen isotope ratios of each sample were determined on a ThermoFinnigan Delta Plus isotope ratio mass spectrometer (Bremen, Germany). Stable isotope contents are reported in "delta" notation as δ values in parts per thousand (‰) where $\delta = (R_{sample}/R_{standard} - 1) \times 1000$, and *R* is the molar ratio of the rare to abundant isotopes in the sample and an international standard, respectively. The standard used for carbon is Pee Dee Belemnite (PDB); the standard for nitrogen is atmospheric air (AIR). To estimate the relative proportion of C_3 and C_4 plants in the beef patties we used a linear two end-member calculations:

Table 1
Median δ^{13}C and δ^{15}N values of *Big Mac*® patties and 25th and 75th percentiles. *N* is the number of patties collected from each country, and import (%) is the calculated percentage of imported beef in each country.

Country	δ^{13}C (‰)			δ^{15}N (‰)			*N*	Import (%)
	Median	25th	75th	Median	25th	75th		
Argentina	−17.2	−17.3	−17.1	7.4	7.3	7.5	12	0
Australia	−19.4	−22.5	−14.0	7.6	7.4	7.7	12	0
Austria	−22.0	−22.4	−21.9	6.0	5.9	6.0	7	13
Brazil	−11.1	−11.8	−10.0	6.3	5.7	6.6	62	0
Canada	−21.6	−21.6	−21.4	5.8	5.5	6.0	7	12
China	−13.9	−15.7	−13.0	5.0	4.8	5.3	16	1
England	−25.4	−25.6	−25.4	6.7	6.6	6.7	5	23
France	−21.8	−22.0	−21.6	7.4	7.3	7.8	7	20
Germany	−21.7	−21.9	−21.3	6.3	5.9	6.5	3	21
Hungary	−22.0	−22.2	−21.7	5.7	5.6	5.9	6	27
Indonesia	−19.5	−23.2	−15.3	8.4	7.7	9.0	5	9
Israel	−20.4	−20.4	−20.3	7.6	7.6	7.7	6	38
Japan	−11.8	−12.5	−11.0	8.8	8.3	8.9	6	48
Malayasia	−21.5	−21.5	−21.6	7.5	7.4	7.6	8	81
Mexico	−13.9	−14.0	−13.7	6.8	6.6	7.2	7	15
Netherlands	−20.7	−21.2	−20.5	7.1	6.7	7.4	4	90
Paraguay	−12.1	–	–	5.5	–	–	1	0
Portugal	−20.7	−20.8	−20.3	5.9	5.9	6.0	9	51
Scotland	−25.2	−25.6	−25.2	6.9	6.8	7.6	8	23
Slovakia	−21.0	−21.2	−20.2	5.6	5.1	6.3	6	19
South Africa	−13.0	−16.2	−12.8	7.5	7.3	7.7	10	2
Spain	−21.1	–	–	6.8	–	–	2	18
Sweden	−23.2	−25.9	−23.2	6.6	6.6	6.7	5	34
Turkey	−20.5	–	–	5.5	–	–	1	0
USA	−14.5	−15.8	−12.8	6.3	6.2	6.5	11	7
Uruguay	−16.7	−17.3	−16.2	6.9	6.7	7.0	20	1

$$\%C_4 = (\delta^{13}C_{\text{beef patty}} - {}^{13}C_{\text{English beef patty}}) / (\delta^{13}C_{\text{Brazilian beef patty}} - \delta^{13}C_{\text{English beef patty}})$$

where % C_4 is the relative proportion of C_4 plants in the cattle diet, $\delta^{13}C_{\text{beef patty}}$ is the average isotopic composition of the beef patties from a specific country, the averaged $\delta^{13}C_{\text{English beef patty}}$ value was defined as −25.4‰, and the $\delta^{13}C_{\text{Brazilian beef patty}}$ value was defined as −11.1‰ (Table 1).

We estimated the proportion of imported meat using data from the United Nation's FAOSTAT database (http://www.faostat.org, 2010) and the following equations:

$$\text{Country available meat} = (\text{country production} - \text{exported meat}) + (\text{imported meat})$$

$$\%\ \text{imported meat} = 100 \times (\text{imported meat}/\text{country available meat}).$$

For beef trade we considered two items from the FAOSTAT database: "cattle meat" and "cattle boneless meat."

Data for the US McDonald's® hamburgers used in this study were derived from the results of a previous assessment (Chesson, Podlesak, Thompson, Cerling, & Ehleringer, 2008).

Country-level data were grouped by latitude in order to test our hypothesis that the climatic control on the geographical distribution of C_4 plants can be tracked using hamburger patties from different countries. Latitude ranges were based on the global distribution of C_4 plants modelled by Still, Berry, Collatz, and DeFries (2003). The first latitude zone encompassed the tropical/sub-tropical belt spanning from the equator to 20° latitude. The second zone encompassed latitudes 20°–40°. The third latitude zone spanned 40°–60°. For countries that extended beyond the latitude boundaries set in this study, we placed the country in the latitude range occupied by most of its territory. For example, Brazil was placed in the tropical/subtropical belt although the southern states of Brazil extend further south than 20°S. Australia was placed in the range 20°–40°S, although the northern portion of the country lies on the tropical/subtropical belt. Another notable exception was the US, which was placed in the range 20°–40°N although the northern portion of the country extends into higher latitudes.

To test for differences between stable isotope values across latitude zones, we first transformed $\delta^{13}C$ values by multiplying them by −1 and applying a Box–Cox transformation to obtain a normal distribution of the data. After normalisation we used a one-way analysis of variance (ANOVA) followed by a post-hoc Tukey's test for unequal variance using the STATISTICA 9.1 package. The $\delta^{15}N$ values of hamburger patties followed a normal distribution and were not transformed prior to statistical analyses. To test for differences between the $\delta^{13}C$ values of hamburgers patties sampled in different Australian cities we used a post-hoc Tukey's test for unequal variance.

3. Results

The *Big Mac*® $\delta^{13}C$ values ranged from −25.4‰ to −11.1‰ (Table 1 and Fig. 1). The overall median $\delta^{13}C$ value among all countries was −16.2‰ (25th percentile = −12.2‰; 75th percentile = −21.5‰; $n = 247$). The lowest $\delta^{13}C$ values were found in the United Kingdom (England and Scotland) and the highest in Brazil (Table 1). The highest intra-country variability was found in Australia. Here *Big Mac*® $\delta^{13}C$ values from Perth and Sydney averaged ¯14.0‰ ($n = 4$) and −19.6‰ ($n = 4$), respectively. These differences were statistically significant at the $p < 0.01$ level. A second batch of samples from a different McDonald's® outlet in Sydney averaged −22.7‰ ($n = 3$), which was statistically different from the other values ($p < 0.01$).

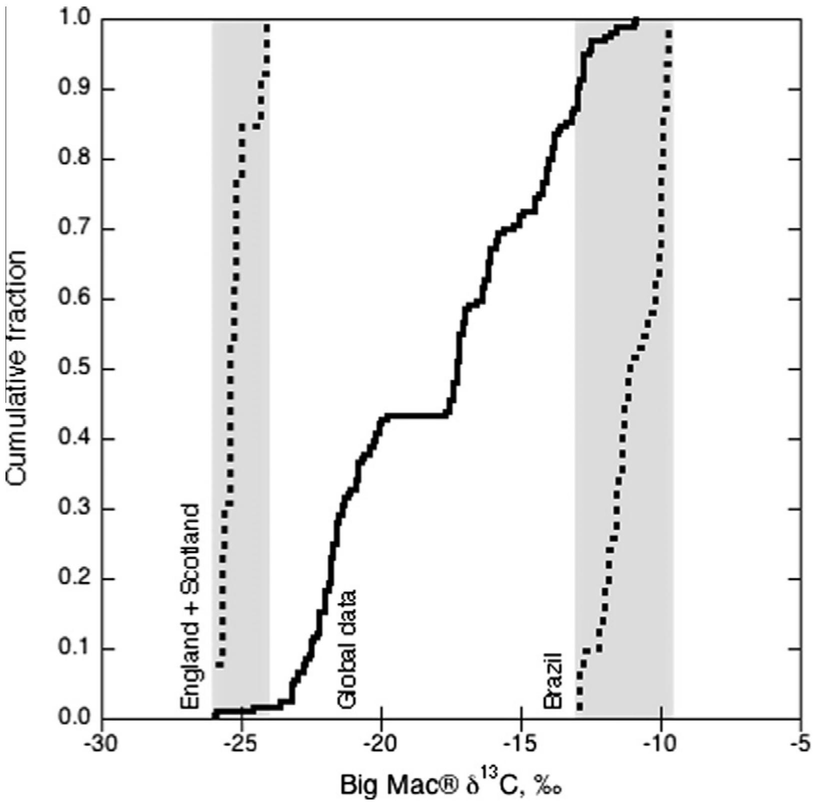

Fig. 1. Cumulative $\delta^{13}C$ values of *Big Macs*. The grey bars show the range of values found for UK and Brazil samples. The continuous black line is the values found in this study and was denominated global data.

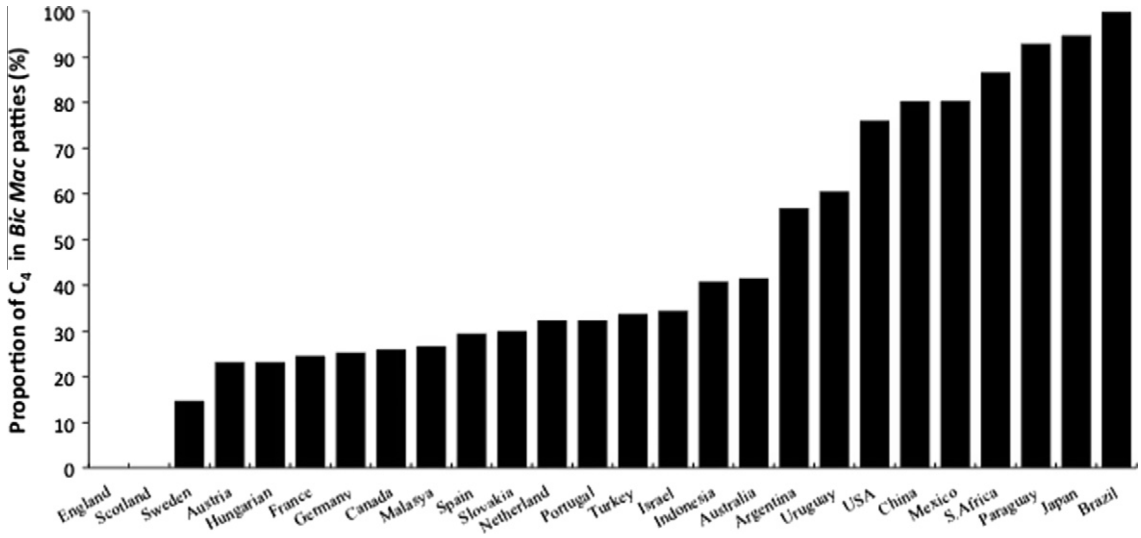

Fig. 2. Relative proportion of C_4 plants in patties of *Big Macs*® sampled in different countries. C_4 proportion estimated using Eq. (1). See text for details.

Table 2
Median $\delta^{13}C$ and $\delta^{15}N$ values followed by the 25th and 75th percentiles and number of patties (N) collected in each latitude range. C_4 (%) is the calculated percentage of C_4-plant carbon in the patties.

Latitude	$\delta^{13}C$ (‰)			C_4[a]	$\delta^{15}N$ (‰)			N
	Median	25th	75th	(%)	Median	25th	75th	
20°S–20°N	−11.4	−12.7	−10.0	100	6.5	5.9	6.8	76
20°–40°	−15.3	−17.1	−13.2	72	6.9	6.4	7.5	94
40°–60°	−21.8	−23.0	−21.1	25	6.4	5.9	6.9	69

[a] C_4 relative contribution estimated using Eq. (1).

We estimated the relative proportion of C_4 plants in *Big Mac*® patties sampled in different countries (Fig. 2). Because we used England and Brazil as end-members in our linear C_3/C_4 mixing line, we assumed that *Big Mac*® patties in England and Scotland contained no C_4 components (% C_4 = 0), while Brazilian *Big Macs*® were composed entirely of C_4 components (% C_4 = 100; Fig. 2). The C_3/C_4 dietary contributions to beef patties collected from other countries fell between these extremes. Most European and Asian countries had a proportion of C_4 plants that varied from 20% to 30%. *Big Mac*® patties from Israel, Australia, Argentina, and Uruguay had C_4 proportions of 40–60%. *Big Mac*® patties from the United States, China, South Africa, Mexico and Japan were composed of approximately 75–80% C_4 components (Fig. 2).

The $\delta^{15}N$ values of *Big Mac*® patties varied from 4.2‰ to 9.2‰, and the median value was equal to 6.6‰ (25th percentile = 5.9‰; 75th percentile = 7.3‰, n = 247). *Big Mac*® patties from Japan had the highest $\delta^{15}N$ values (median = 8.8‰) and those from China had the lowest (median = 4.8‰; Table 1). Similar to the $\delta^{13}C$ observations, *Big Mac*® patties from Australia exhibited the highest variability among individual patties, with $\delta^{15}N$ values ranging from 4.2‰ to 8.5‰.

There were no statistically significant differences in the $\delta^{15}N$ values of hamburger patties purchased in countries and grouped by latitude. However, there was a significant decrease in the median $\delta^{13}C$ value of hamburger patties collected in countries at higher latitudes when compared to those collected in countries at lower latitudes (F = 192.04; p = 0.00001; Table 2). These differences were confirmed with the post-hoc Tukey's test for unequal variance.

Based on FAO data, it appears that most countries in our study produced their beef locally, with the exceptions of (a) Sweden and Israel, which import 30–40% of their meat; (b) Portugal and Japan, which import approximately half of their meat; and (c) Malaysia and the Netherlands, which import most of their beef (Table 1).

4. Discussion

4.1. Comparison between isotopic values of Big Mac® patties in different countries

As expected, we observed large ranges in the $\delta^{13}C$ values of *Big Mac*® patties, including values indicative of 100% C_4-plant feed (Brazil) and 0% C_4-plant feed (England and Scotland; Table 1). Our results are consistent with other studies analysing beef samples from several parts of the world, which found high $\delta^{13}C$ values of Brazilian beef samples (Heaton et al., 2008; Nardoto et al., 2006; Schmidt et al., 2005). Previously published studies also found high $\delta^{13}C$ values (−14.3‰ to −9.5‰) for US beef samples (Bong et al., 2010; Heaton et al., 2008; Horacek & Min, 2010; Nakashita et al., 2008; Schmidt et al., 2005); and for patties from US fast-food chains (Chesson et al., 2008). The lower $\delta^{13}C$ values observed in *Big Mac*® patties from European countries were also observed in beef sampled from that continent (Heaton et al., 2008; Schmidt et al., 2005). The large variance we observed in the $\delta^{13}C$ values of *Big Mac*® patties from Australia (Table 1) was also observed in beef samples from this country (Bong et al., 2010; Heaton et al., 2008; Horacek & Min, 2010; Nakashita et al., 2008).

On the other hand, Boner and Förstel (2004) analysed a mix of traditional pasture-fed cows and organic beef samples and found large variability (−24‰ to −13‰) in German beef samples that was not captured in the *Big Mac*® patties analysed in this study nor in the study of Heaton et al. (2008). This may be the result of limited sample size from Germany (n = 3) in our study. In addition, the variation we observed in this survey for Chinese *Big Macs*® did not capture the variability of $\delta^{13}C$ values of Chinese beef collected from four Chinese provinces (Guo, Wei, Pan, & Li, 2010). The results in our study (median = 4.8‰) were more similar to the measured isotope ratios of beef collected in the Jinlin and Guizhou provinces of China [median = 4.7‰ and 5.5‰, respectively (Guo et al., 2010)].

We did not observe a large range in the $\delta^{15}N$ values of *Big Macs*® collected in this survey. Our results were similar to the $\delta^{15}N$ values of beef samples found in several other studies (Bong et al., 2010; Guo et al., 2010; Heaton et al., 2008; Horacek & Min, 2010; Nakashita et al., 2008; Schmidt et al., 2005). The median value of our *Big Mac*® patties was equal to 6.6‰, with a low variability around the median (25th percentile = 5.9‰; 75th percentile = 7.3‰, n = 247). The average δ^{15}N values of beef samples collected globally by Heaton et al. (2008) were similar (4.7–7.3‰) to the median value found in this study. This is somewhat surprising if we consider all the factors that influence the δ^{15}N values of plants (Högberg, 1997), as well as the agricultural systems in which plants are cultivated (Choi et al., 2002, 2003; Kriszan et al., 2009), their post-harvest handling (Bahar et al., 2008), and the isotopic fractionation between forage and beef (Vander Zanden & Rasmussen, 2001). On the other hand, the large-scale use of inorganic fertilisers, similar beef feeding strategies between countries and similar beef processing techniques may have contributed to the low variability found in δ^{15}N values of hamburgers patties in our sampling.

4.2. Does the global meat trade impact the isotopic composition of Big Mac® patties?

In order to clearly implicate *Big Mac®* patties in a globalisation process, it is crucial that the δ^{13}C values of patties be clearly linked to the actual meat trade in the countries included in this study. Specifically, it is important to identify whether the majority of cattle meat used in a country is produced locally or imported from another region and whether beef import would be expected to impact the δ^{13}C values of beef that is then used in *Big Mac®* patties available for sale in a given country. We used data from the Food and Agriculture Organisation (FAO) of the UN to estimate the proportion of imported *vs.* locally produced cattle meat in each country in 2005. As presented previously, most of the countries included in this study produced their beef locally, with the exception of six countries, presented in ascending order of beef import: Sweden, Israel, Portugal, Japan, Malaysia and the Netherlands (Table 1).

It is noteworthy that even the small percentage of cattle meat imported by European countries is mainly imported from other EU countries. For example, Brazil and the US, which have a high composition of C_4 plants in beef cattle meat, have a relatively low share of the European import market. As a consequence, Brazilian beef represents only 3–4% of the total cattle meat available in Portugal, Sweden, and the U.K. Conversely, Japan imports half of the cattle meat available in the country, and 90% of Japanese imports came from Australia, where cattle are both grass and grain fed (Bindon, 2001; Kondo, 2010). Meat produced in Japan is basically entirely grain fed and has δ^{13}C values varying between −20‰ to −17‰ (Nakashita et al., 2008). The high δ^{13}C values we observed in *Big Mac®* patties from Japan (median = −11.8‰, Table 1) suggest that beef from C_4 grass-fed Australian cattle was used in the collected *Big Mac®* sandwiches.

The Netherlands imports more than 90% of the cattle meat available for consumption in that country. The case of the Netherlands illustrates the complexity of the current global trade. In 2007, almost 400,000 tons of cattle meat was produced, but approximately 350,000 tons were exported, while another 300,000 tons were imported. From this import total, almost 20% was from Brazil; this is equivalent to 16% of the total available meat in the country. The remainder of Netherland's imports came from the EU. Therefore, the isotopically distinct cattle meat from Brazil (which we found to contain the highest proportion of C_4 plants) may have had some impact on the isotopic composition of the cattle meat in the Netherlands, and consequently *Big Mac®* patties, as seen by the intermediate δ^{13}C values of Netherlands samples (median = −20.7‰, Table 1).

4.3. How does the global distribution of C_3 and C_4 plants impact the isotopic composition of Big Mac® patties?

The C_3/C_4 plant distributions in the world depend on several factors (Still et al., 2003). The most relevant for this study are climatic factors and land use changes where original C_3 vegetation is replaced either by a C_4 pasture or a maize field. In terms of climate, it is well established that higher temperatures during the growing season favour C_4 plants in relation to C_3 plants (Collatz, Ball, Grivet, & Berry, 2001; Ehleringer, 1978; Ehleringer & Björkman, 1977). In terms of land use changes, economical and geopolitical drivers will determine turnover between C_3 and C_4 plants. For example, this is the case for the Amazon region. Together these economic and geopolitical drivers will determine the global distribution of C_3 and C_4 plants. Still et al. (2003) modelled the fraction of land covered by C_4 plants, including C_4 crops, at a global scale. There is a clear trend in the C_4 fraction of vegetation, which increases at low latitudes and reflects the preference of C_4 plants for warmer temperatures (Collatz, Ball, Grivet, & Berry, 2001; Ehleringer, 1978; Ehleringer & Björkman, 1977). As hypothesised, the proportion of C_4 plants in *Big Mac®* patties followed a similar trend when values were grouped by latitude (Table 2): in tropical/subtropical regions there was a clear dominance of C_4 plants in the patties. This proportion decreased to 75% in the latitude range 20°–40° and to only 25% in the range 40°–60° (Table 2).

As defined in our C_3/C_4 mixing model, Brazilian *Big Mac®* patties had the highest proportion of C_4 plants (Fig. 2); this is most likely because the most important feedstocks for cattle in that country are C_4 African grasses (*Brachiaria*). Bortolussi, McIvor, Hodgkinson, Coffey, and Holmes (2005) reported that C_3 and C_4 grasses are used as cattle fodder in Australia. This mix, of C_3 and C_4 grasses available as fodder, accounts for the intermediate δ^{13}C values of the Australian *Big Mac®* patties (Table 1). In contrast, in the US the main feedstock for cattle is maize, followed by soybean, which is a C_3 plant (Pollan, 2006; Roberts, 2008). The change in cattle diet away from grasses is due to the evolution of the American agricultural system in the last 50 years, with maize cultivation heavily subsidised by the government. With abundant inexpensive maize available, it has been more productive and efficient to raise cattle in "concentrated animal feeding operations" (Pollan, 2006; Roberts, 2008).

In Mexico, several C4 grasses, including those from the Cynodon and Panicum genera, are used as beef cattle fodder (Magana, Tewolde, Anderson, & Segura, 2006). Maize sillage (Arriága-Jordan, García-Martinez, Albarrán-Portillo, Espinoza-Ortega, & Castelán-Ortega, 2003) as well as some C3 plants (Sandoval-Castro, Anderson, & Leaver, 2000) are also used since approximately 20% of these types of plants are present in patties from Mexico (Fig. 2). China is an intriguing country, having a vast agricultural network that includes several plant fodder production systems (Guo et al., 2010; Hou et al., 2008). However, according to Li, Yuan, Wan, & He, 2008, cattle in China are raised under a system called "mixed farming," where cattle are fed with a mixture of farm and human food waste products, maize being the most commonly used plant for this purpose. These multiple production systems led to distinct δ^{13}C values of beef from different Chinese provinces (Guo et al., 2010). In our study, it appears Chinese *Big Mac®* patties included primarily C_4 plants (Fig. 2).

Big Mac® patties from England and Scotland had no C_4 components, as defined by our mixing line. Livestock production systems in these countries rely heavily on C_3 temperate grasslands (Evans & Gaskell, 2003; Fraser, 2007). The same is also true for the other European countries (Conner, Hamilton, Sheeby, Stuth, & Kreuter, 1998) considered in this study (Fig. 2). For instance, Spain has an agro-silvicultural system called *deseha*, which is equivalent to the *montados* (Gaspar, Mesías, Escribano, Rodriguez de Ledesma, & Pulido, 2007) in Portugal, where C_3 grasslands are combined with sparse trees. It appears that maize is the main C_4 plant available as cattle fodder in these countries and is used only in the winter months as silage.

Table 3
Median $\delta^{13}C$ and $\delta^{15}N$ values of Brazilians, Americans, and Europeans human fingernails and *Big Mac*® patties of these countries. Δ is the difference between carbon and nitrogen stable isotope values of fingernails and patties.

	N	$\delta^{13}C$ (‰)		$\Delta^{13}C$	$\delta^{15}N$ (‰)		$\Delta^{15}N$
		Fingernails	Patties	(‰)	Fingernails	Patties	(‰)
Brazil[a]	110	−15.3	−11.1	−4.2	10.3	6.3	4.0
USA[a]	117	−18.8	−14.5	−4.3	9.7	6.3	3.4
Europeans[b]	32	−20.4	−22.0	1.6	9.7	6.5	3.2

[a] Fingernails data from Nardoto et al. (2006).
[b] Nardoto, G. (non published data).

4.4. How does the isotopic composition of Big Mac® patties compare with the isotopic composition of fingernails in different countries?

We finally compared the stable isotopes values of *Big Mac*® patties with human fingernails of Brazilians, Americans and Europeans originally collected by Nardoto et al. (2006). The median $\delta^{13}C$ values of human fingernails tracked the $\delta^{13}C$ values of patties (Table 3). The $\delta^{13}C$ values of Brazilian fingernails and patties were the highest, while $\delta^{13}C$ values of Americans fingernails and patties were intermediate, and values of the Europeans fingernails and patties were the lowest (Table 3). The main difference among the three groups was that the $\delta^{13}C$ values of Brazilians and Americans fingernails were approximately 4‰ lower than the $\delta^{13}C$ values of patties collected in those countries (Table 3). This difference may indicate that Brazilians and Americans have a higher proportion of C_3 plants in their diets in relation to beef cattle used in hamburger patties. On the other hand, the $\delta^{13}C$ values of Europeans fingernails were approximately 1.5‰ higher than the values of patties, which could indicate that Europeans have a higher proportion of C_4 plants in their diets in comparison with the relative proportion of C_4 plants present in the *Big Mac* patties sampled in Europe (Table 3). There was no difference among $\delta^{15}N$ median values of patties sampled in Brazil, the US or European countries (Table 3). Likewise, there was also no difference between median $\delta^{15}N$ values of fingernails from these countries. However, we did observe the usual 3–4‰ ^{15}N enrichment along trophic levels (Vander Zanden & Rasmussen, 2001). As a consequence, the median $\delta^{15}N$ values of human fingernails were higher than the patties in all countries (Table 3).

4.5. The Big Mac® is a truly "glocal" food

Based on our worldwide sampling of *Big Mac*® patties, we conclude that although the burgers we collected were all made the same way, looked the same, and often even tasted much the same, they clearly had a local flavour as well. In this sense the *Big Mac*® is truly a "glocalised" food that contradicts the homogenising *McDonaldisation* paradigm (Turner, 2003). *Big Mac*® patties can contain carbon produced locally in small household farming systems in China, in cornfields of Iowa, in range lands of Australia, in temperate grasslands of northern Europe, in *dehesa* and *montado* systems of Spain and Portugal, as well as in *pastagens* (pastures) of the Amazon and the Cerrado regions.

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