Tracking the Origins of Animal Management in a Neotropical Foraging-to-Farming Population using Carbon Stable Isotope Analysis of Lysine

Nadia C. Neff[1,3], Keith M. Prufer[1,3], Erin E. Ray[1,3], Geraldine Busquets-Vass[2,3,4], Seth D. Newsome[2,3]

[1]Department of Anthropology, University of New Mexico, [2]Department of Biology, University of New Mexico,
[3]Center for Stable Isotopes, University of New Mexico, [4]Centro de Investigación Científica y Educación Superior de Ensenada, Unidad La Paz

Introduction and background

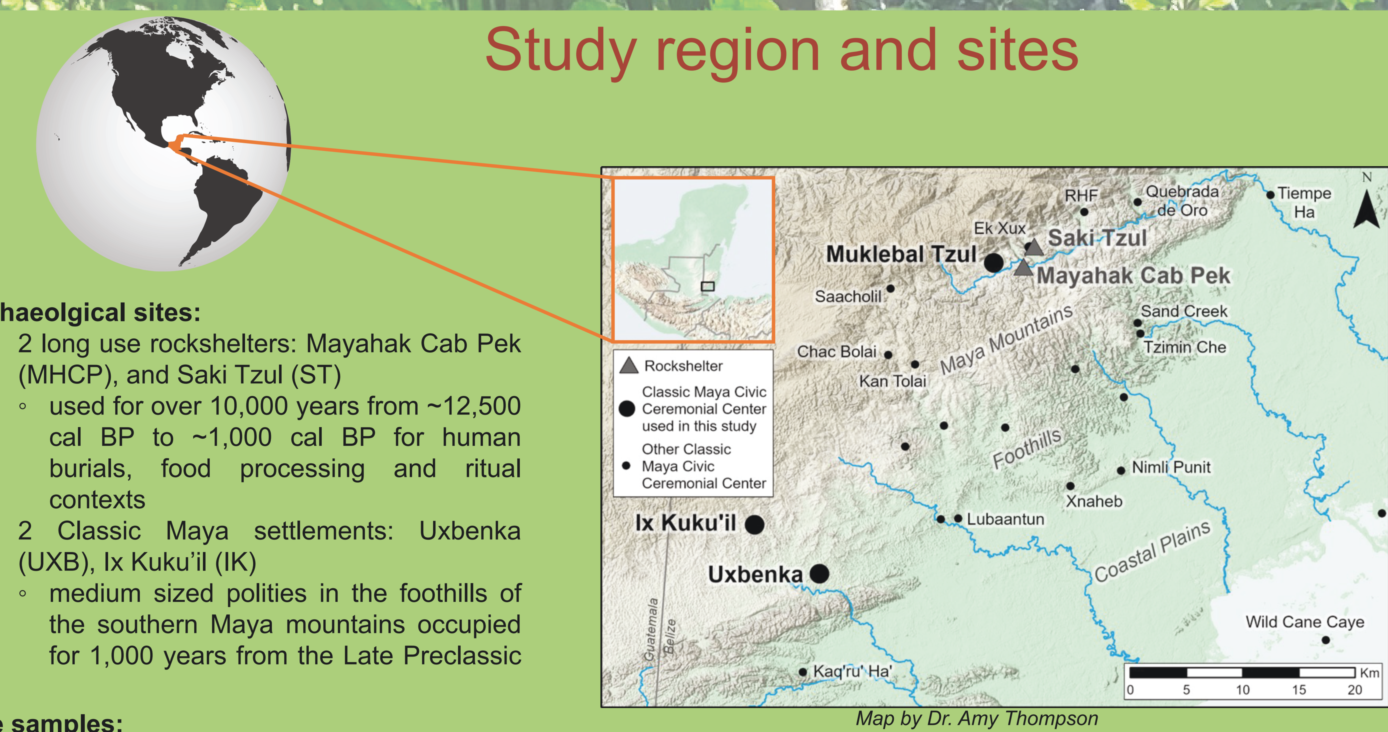
The premise

The middle-late Holocene in Southern Belize saw shifts in subsistence strategies including the introduction of managed plants and animals. Botanical and stable isotopic data have been used to track the introduction of agricultural products into diet with maize first consumed before 7,000 cal. BP. However, the timing of the introduction of managed animals (e.g. turkey, as a proxy) is less understood because early faunal assemblages are rare in the neotropics. We present the results of carbon Compound Specific Isotope Analysis of Amino Acids (CSIA-AA) of directly dated human skeletons from two rockshelters spanning the transition to agriculture and two Classic Maya settlements to determine the latest date for the incorportion of C_4 consuming managed animals into human diets using the C_4 signal of maize in the essential amino acid lysine as a proxy. We propose that human $\delta^{13}C_{lysine}$ values can be used to track the incorporation of managed (but not necessarily domesticated) animals into neotropical diets during the transition to agriculture.

Project goals

- **Calculate how much maize product (raw maize or nixtamal), or maize fed animal meat (proxy = modern turkeys) each archaeolgoical individual would have needed to eat a day to account for their respective proprotion of C_4 derived lysine**
- **Compare these results to the mean food mass an adult eats per day (3-5lbs) to determine which individuals needed to consume C_4 animal meat to satisfy their daily lysine requirements**
- **Determine the latest possible date for the introduction of C_4 animal protein into the diet of early neotropical populations**

Study region and sites



Map by Dr. Amy Thompson

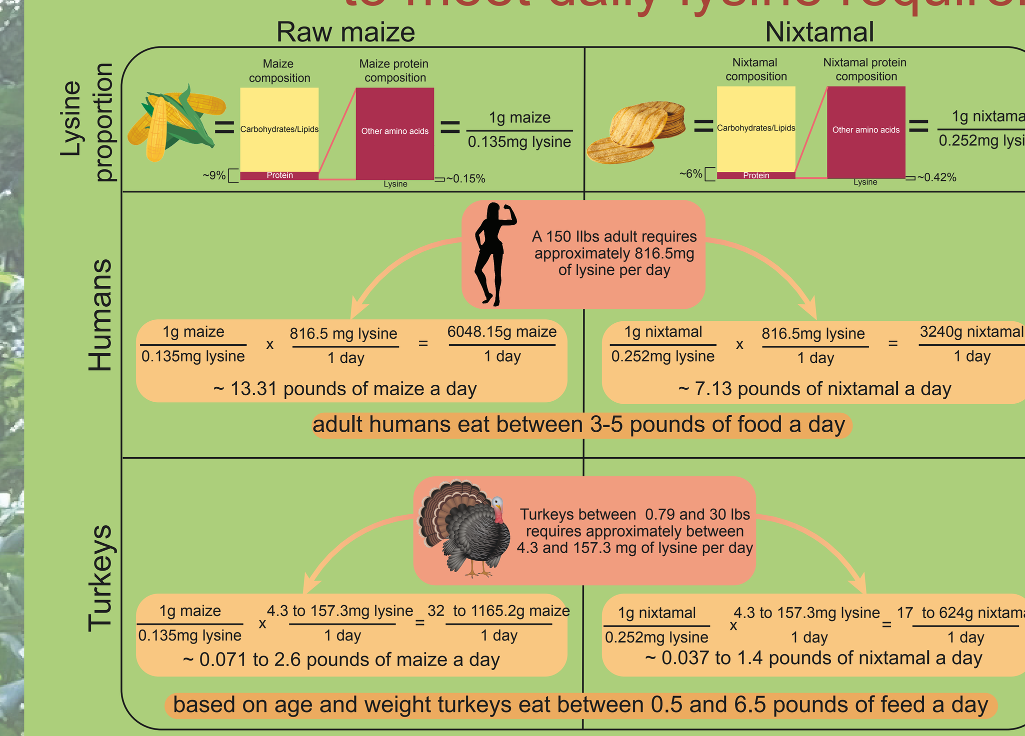
Archaeolgical sites:

- 2 long use rockshelters: Mayahak Cab Pek (MHCP), and Saki Tzul (ST)
  - used for over 10,000 years from ~12,500 cal BP to ~1,000 cal BP for human burials, food processing and ritual contexts
- 2 Classic Maya settlements: Uxbenka (UXB), Ix Kuku'il (IK)
  - medium sized polities in the foothills of the southern Maya mountains occupied for 1,000 years from the Late Preclassic

The samples:

- 39 archaeological individuals (33 adults, 6 juveniles) spanning the transition to maize-based agriculture
- 8 modern free-ranging, maize-fed turkeys from near UXB
- 40 modern plants collected in the Maya Mountains and foothills

How much maize or nixtamal do you have to eat a day to meet daily lysine requirements?



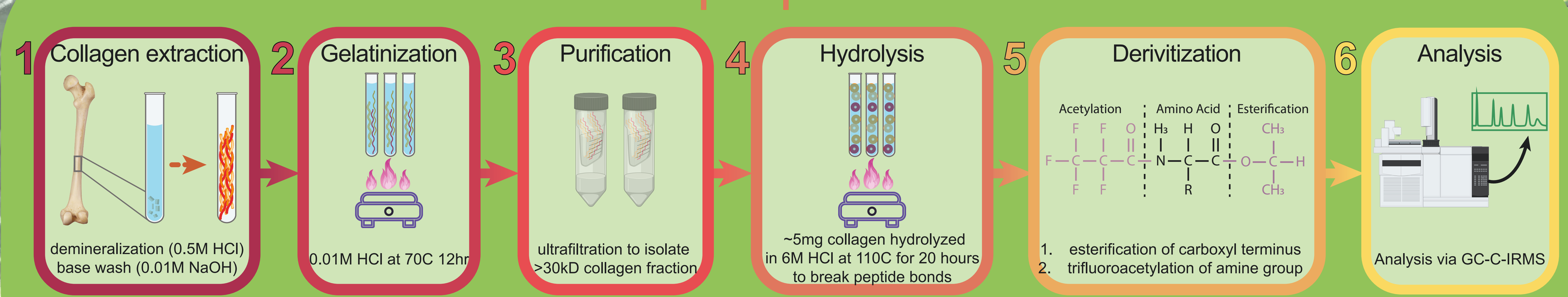
Lysine is an essential amino acid that we need to maintain normal body functioning. Not consuming enough lysine can lead to multiple health consequences (FAO). As an essential amino acid, humans and animals cannot make lysine but instead must route it either directly by eating the primary producers (like plants) that synthesize it *de novo* or indirectly and often in greater abundance by eating other consumers that ate plants that synthesized lysine *de novo*. **Due to the extremely low concentration of lysine in maize, it is impossible for humans to source enough lysine from eating maize alone.** Therefore we can look to another source to account for daily lysine requirement: maize consuming animals such as the turkey.

Chemical, analytical, and statistical methods

Methods overview

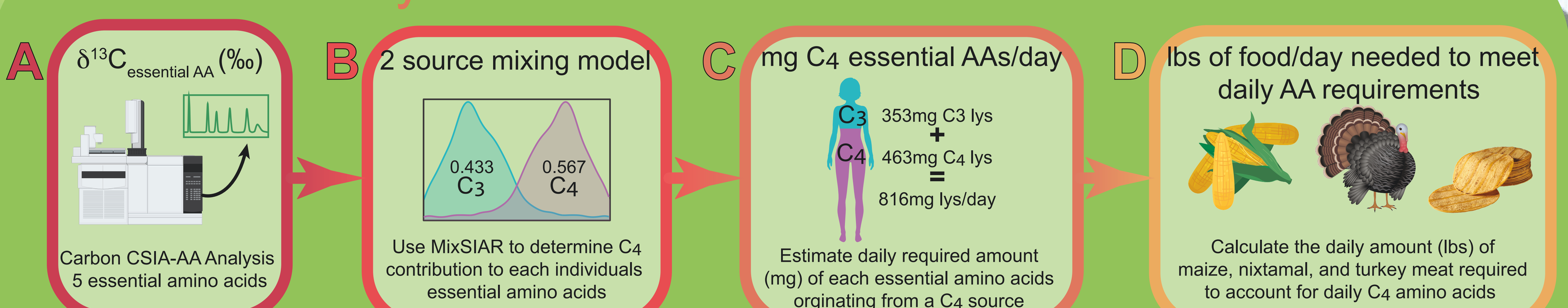
Carbon ($\delta^{13}C$) compound specific isotope analysis of amino acids (CSIA-AA) is used to generate $\delta^{13}C$ values for the individual amino acids that make up bulk protein like collagen. This method allows researchers to track the different biochemical origins of individual amino acids into consumer tissues. CSIA-AA data can be used to create concentration dependent models based on essential amino acid abundances in plants such as maize. By using single amino acid Bayesian mixing models in conjunction with lysine concentrations in different food sources, we can calculate the minimum amounts of maize products and maize eating animals necessary to consume to account for individual $\delta^{13}C_{lysine}$ values to meet daily lysine requirements.

Chemical preparation methods



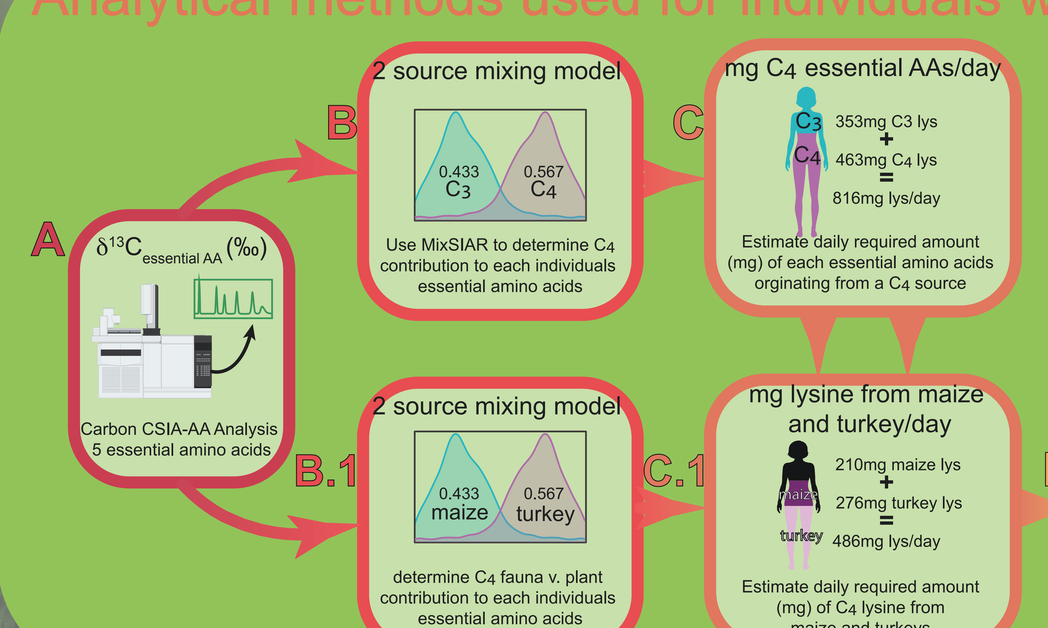
Sample preparation and analyses were performed by the lead author at the Univeristy of New Mexico's Center for Stable Isotopes in accordance with standard methods. Plant samples were homogenzied and then treated the same as collagen samples beginning in step 4, with the addition of a filtration step before derivitization. All modern samples were corrected for the Suess Effect post analysis.

Analytical methods used for all individuals



After calculating the $\delta^{13}C_{lysine}$ values for each individual, plant, and modern turkey, we performed a 2 source mixing model using the MixSIAR package in R to calculate the proportion of lysine coming from a C_4 source for each individual and modern turkey. We then used these proportions to calculate the daily amount (mg) of lysine originating from maize based on daily lysine requirements per lb of body weight using an average body weight based on age group. Then using the concentration of lysine in maize products and turkey meat (at different C_4 lysine proportions) we calculated the amount of each food type an individual would have had to eat to meet daily C_4 lysine requirements.

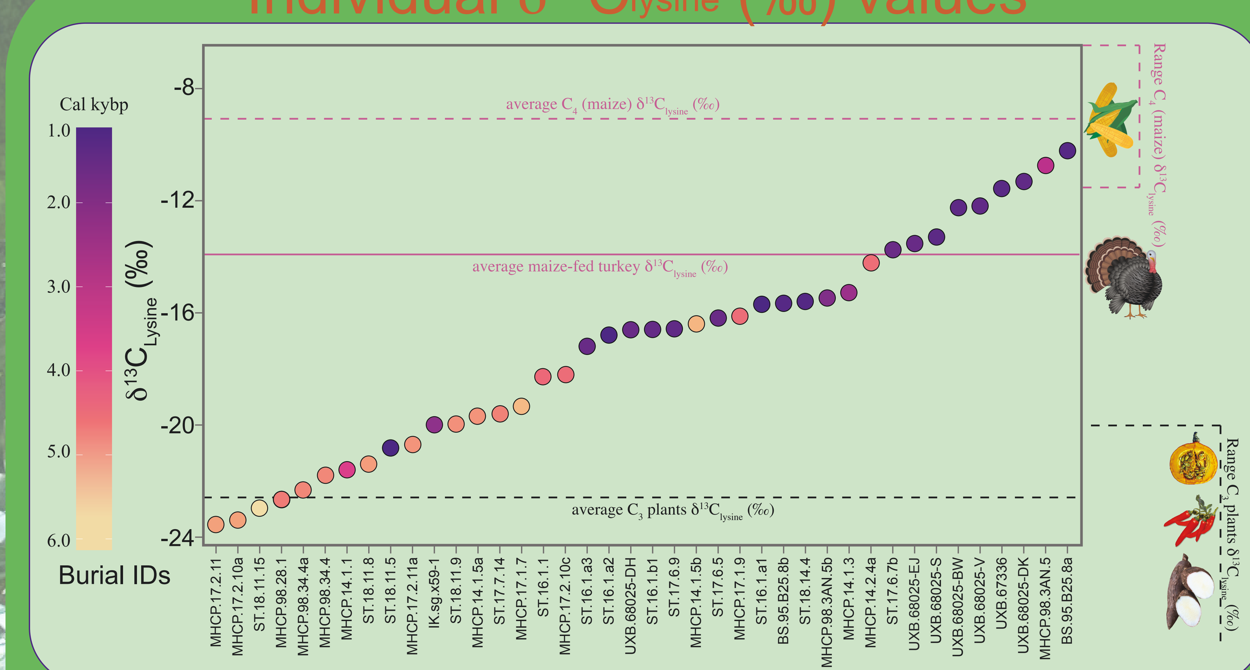
Analytical methods used for individuals with high $\delta^{13}C_{lysine}$ values



Individuals with higher $\delta^{13}C_{lysine}$ values than maize-fed turkeys were treated differently. To obtain the higher values a combination of turkey (as a proxy) and maize products would have been necessary, unless ancient turkeys were fed greater amounts of maize than modern turkeys.

Results, discussion, and conclusion

Individual $\delta^{13}C_{lysine}$ (‰) values

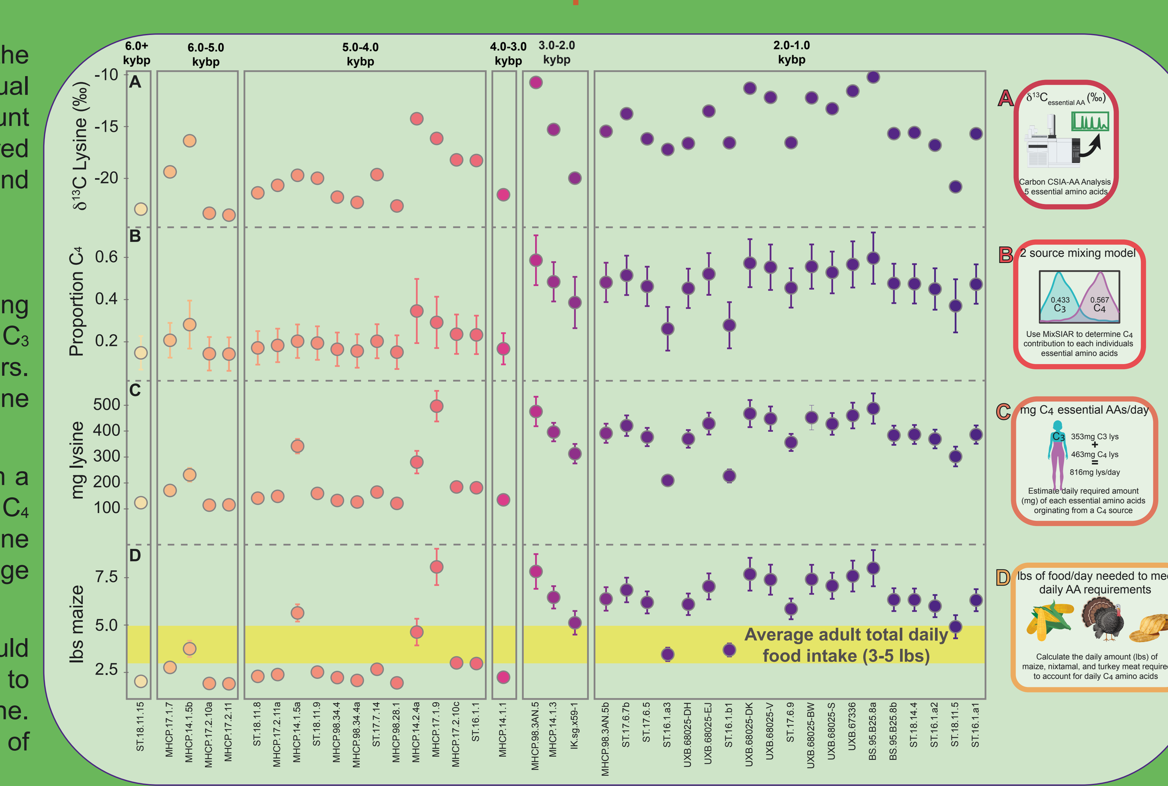


This plot shows the $\delta^{13}C_{lysine}$ ranges of the C_3 and C_4 plants used in the mixing models and the average $\delta^{13}C_{lysine}$ value of modern maize-fed turkeys. Despite the low abundance of lysine in maize, our results still show a trend of increasing $\delta^{13}C_{lysine}$ values through time, indicating that by the classic period over 50% of lysine was sourced from maize. Some of these individuals even had higher $\delta^{13}C_{lysine}$ values than modern maize-fed turkeys.

Individual calculation steps

The 4 steps used to calculate the amount (lbs) of maize each individual would have needed to eat to account for their $\delta^{13}C_{lysine}$ values. Plot is ordered by calibrated radiocarbon age and binned into 1,000 year increments.

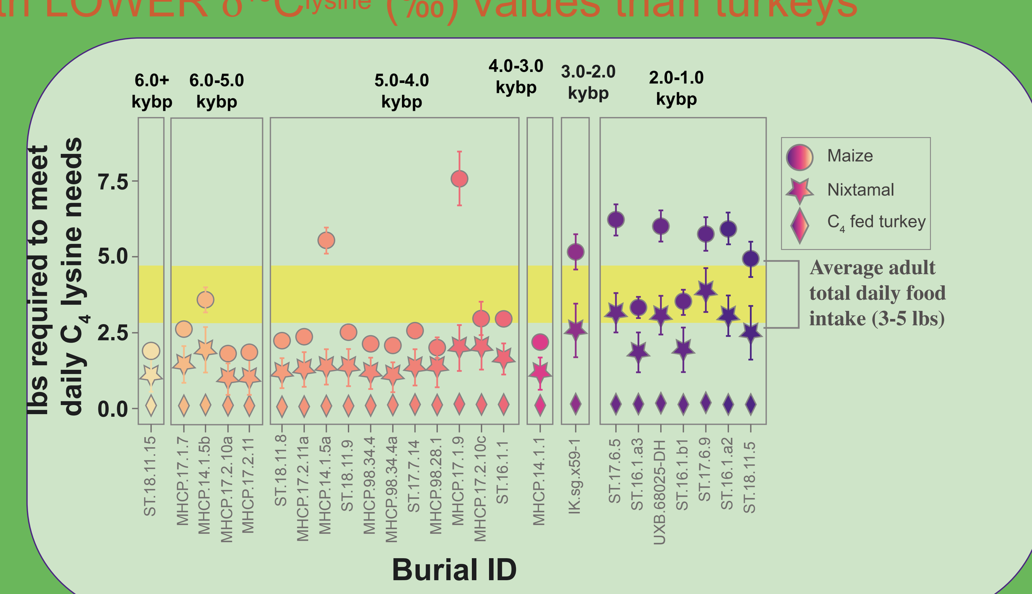
- **A:** individual $\delta^{13}C_{lysine}$ values
- **B:** results of individual mixing models using $\delta^{13}C_{lysine}$ values of C_3 and C_4 plants as end members. Value is the proportion C_4 with one standard deviation reported.
- **C:** daily mg of lysine derived from a C_4 source. Individual proportion C_4 multiplied by the average daily lysine requirements based on age category.
- **D:** lbs of maize each individual would have needed to eat each day to obtain enough C_4 derived lysine. Yellow bar is the average amount of total food an adult eats a day.



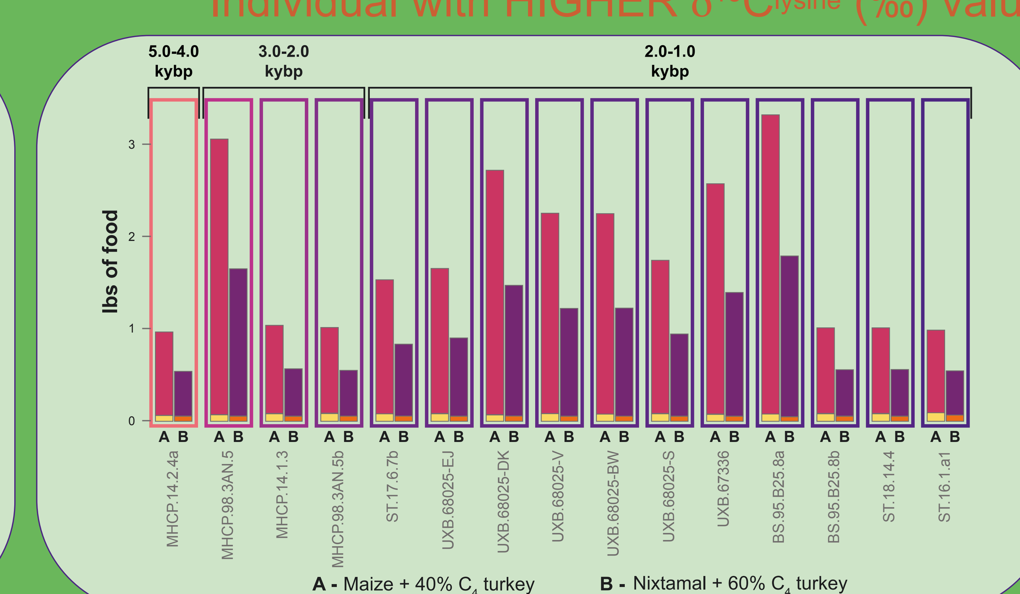
Individuals with LOWER $\delta^{13}C_{lysine}$ (‰) values than turkeys

For the individuals with $\delta^{13}C_{lysine}$ values lower than modern maize-fed turkeys, we calculated the amount of three different food types (maize, nixtamal, and C_4-fed turkey meat) they would have had to eat to account for daily C_4 derived lysine requirements.

Although possible, it is still unlikely that even the earliest individual would have obtained their lysine from consuming maize or possibly nixtamal alone.



Individual with HIGHER $\delta^{13}C_{lysine}$ (‰) values than turkeys



For the individuals with $d^{13}C_{lysine}$ values higher than turkeys, we used a series of mixing models determine the combinations of maize or nixtamal and turkey meat needed to account for daily C_4-derived lysine requirements (see methods figure for individuals with high $d^{13}C_{lysine}$ values).

The bars represent 2 potential diet combinations for each individual. Turkey C_4-derived lysine percents are the high and low proprotions obtained through 2-source mixing models.

Conclusions

- **Our results show a trend of increasing $\delta^{13}C_{lysine}$ values indicating high proportions of lysine originating from a C_4 source in individuals by 6000 cal. BP.**
- **Based on the low abundance of lysine in maize and daily lysine requirements in humans, these results are only possible through trophic concentration of C_4-derived lysine, obtained by consuming maize-eating animals.**
- **These results indicate that people were consuming maize-eating animals by at least 6,000 cal. BP if not before. This leads to the question of whether maize domestication was centered around direct consumtion or if it was related to animal management. Our results indicate that the latter is very likely.**

Acknowledgements

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