

Study puts the Neotropics on the map of the world's food production centers in antiquity

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Dental caries on the teeth of buried skeletons (oral pathology of individual MO59 (female, YA). (a) Left maxilla: A, dental wear; B, ante-mortem tooth loss; C, occlusal-dentin caries and pit caries; D, occlusal-pulp caries. (b) Mandible, occlusal view. (c) Mandible, lingual view on right side: E, M2: occlusal caries and related abscess and cervical caries; F, M3: gross-gross caries and related abscess. (d) Mandible, buccal view on left side: G, M1: occlusal pulp caries, abscess, and alveolar resorption/ image: Luis Nicanor Pezo-Lanfranco) Credit: Luis Nicanor Pezo-Lanfranco

Shell middens are archaeological features consisting mainly of the remains of marine animals thrown away near settlements over hundreds

or thousands of years. They are the debris of human activity. In Brazil, they are known by the Tupi word sambaqui.

The sambaquis were left by people who lived between 8,000 and 1,000 years ago in coastal Atlantic Forest areas, traditionally considered peripheral to South America's first food production centers in the Andes and the Amazon.

A new study, however, presents strong evidence that sambaqui societies were not ordinary hunter-gatherers. Analysis of their middens shows that they cultivated or at least managed [edible plants](#) and had a [rich diet](#) with a substantial proportion of carbohydrates. Fapesp—São Paulo Research Foundation- FAPESP has supported the study.

Findings from the study have recently been published in *Royal Society Open Science*. It was conducted by researchers from Brazil and the United Kingdom using data collected at the Morro do Ouro and Rio Comprido sambaquis in Babitonga Bay near Joinville, Santa Catarina State.

"The significant levels of consumption of high-carbohydrate foods evidenced by these two sambaquis suggests the communities had a mixed subsistence economy that combined fishing and the collection of seafood with some form of plant cultivation," said Luis Nicanor Pezo-Lanfranco, a bioarcheologist at the University of São Paulo's Bioscience Institute (IB-USP), first author of the article and a FAPESP grantee.

Pezo-Lanfranco conducted the study at IB-USP's Biological Anthropology Laboratory, led by Professor Sabine Eggers, in partnership with archeologists at the University of York (UK) and Joinville's Sambaqui Museum.

According to the traditional archeological view of prehistory in South

America, the hunter-gatherers who left the shell middens maintained themselves mainly by foraging marine resources. This idea began to be contested in the 1980s when evidence was found that the sambaqui societies had a far more diversified economy.

The high frequency of sambaquis on the southern coast of what is now Brazil and the large volume of some of these shell middens, which also contain hundreds of human burials, are considered evidence of high population density, monumental architecture, and social complexity during the Middle to Late Holocene.

Dental caries on the teeth of buried skeletons, interpreted as evidence of a high-carbohydrate diet, are among the reasons for concluding that these communities had a more diversified economy and diet than previously believed.

Moreover, archeological digs have identified remains of plants that may evidence incipient cultivation of food crops, including tubers (yam and sweet potato), corn, palm trees, soursops and sweetsops (Annonaceae).

The new study was based on oral pathology and stable isotope analyses performed directly on the skeletons. The analyses revealed unexpectedly high consumption of plant resources, i.e., carbohydrates, by the Morro do Ouro sambaqui people on the northern coast of Santa Catarina in the Middle Holocene (8,000-4,000 years ago).

The northern coast of Santa Catarina has the largest number of sambaquis in Brazil. Hundreds of shell mounds are scattered around Babitonga Bay.

"We analyzed the [oral health](#) and stable isotopes of human remains buried in the Morro do Ouro and Rio Comprido sambaquis to investigate the dietary habits of these communities during the Middle and Late

Holocene," Pezo-Lanfranco said.

Finds made at Morro do Ouro have contributed significantly to the discussion of population density, health and disease, and cultural and dietary variability in Atlantic Forest coastal communities during the Middle Holocene.

Archeological digs conducted there in the 1980s brought to light large amounts of remains of terrestrial and marine animals, artifacts, domestic structures, and human burials.

The animal remains were from several species of mollusk (clams, mussels, oysters), fish (mullet, croaker, seabass, pufferfish, catfish) and terrestrial mammals (lowland paca, white-lipped peccary). Polished stone tools and charred coconut remains have also been found.

According to Pezo-Lanfranco, 116 burials were excavated by several archeological expeditions between 1960 and 1984. Carbon dating of bone collagen for this study showed that the site was occupied between 4,800 and 4,100 years ago. An analysis of minute dental calculus traces from the site performed in 2010 by Verônica Wesolowski, a researcher at the University of São Paulo's Museum of Archeology and Ethnology (MAE-USP), had already identified grains of starch compatible with sweet potato, yam, and coconut.

At nearby Rio Comprido, archeologists found polished stone knives and axes as well as 67 burials in the 1970s. The site was occupied in two phases: Rio Comprido 1 (RC1) between 5,600 and 4,300 years ago (Middle Holocene) and Rio Comprido 2 (RC2) between 4,000 and 3,400 years ago (Late Holocene).

Morphological analysis performed for the study included the determination of sex and age as well as oral pathologies in 70

individuals, 42 from Morro do Ouro (MO) and 28 from Rio Comprido (16 RC1 and 12 RC2). Stable carbon and nitrogen isotopes from 36 individuals were analyzed, 20 from MO and 16 from RC (nine RC1 and seven RC2).

Using 11 oral health markers, a total of 1,826 alveoli and 1,345 teeth from these 70 individuals were examined. Most of the skeletons analyzed were found to be male and aged 20-49 on average at the time of death.

"The frequency of [dental caries](#) ranged from 7.6 percent to 13.2 percent of the samples. This was more than expected for groups of hunter-gatherer-fishers and more compatible with the pattern found for the first farmers of the Late Holocene in other regions, such as the Andes," Pezo-Lanfranco said.

Analysis of teeth from Late Holocene hunter-gatherers found in Patagonia, for example, showed caries frequencies ranging from 3.3 percent to 5.19 percent, while samples from more recent sedentary populations in Patagonia displayed a frequency of 10.17 percent.

Caries types varied considerably across the two sambaqui sites, but statistically significant differences were observed only in cervical (extraocclusal) lesions.

The frequency of occlusal caries was generally high in all groups, ranging from 53.7 percent (MO) to 70 percent (RC1) of the individuals analyzed. The highest frequency of enamel caries was recorded for RC1, whereas MO had the highest frequency of extraocclusal caries.

Carious lesions have been associated with diets rich in fermentable carbohydrates and sugar. The frequency of extraocclusal caries and cavities on smooth tooth surfaces increases when diets are rich in

cariogenic foods.

"It's probable, therefore, that the Morro do Ouro people had a more cariogenic and refined diet than the Rio Comprido 2 people, quite possibly because they cooked their food, for example," Pezo-Lanfranco said.

Processed carbohydrates

Dietary estimates based on stable isotopes from teeth and bone showed that the main protein source was fish, ranging from a low of 33 percent in people from MO to 87 percent-90 percent in RC2.

Plants accounted for the largest share of calorie intake in MO (48 percent), followed by fish (44 percent) and hunted terrestrial mammals (8 percent).

Bone collagen data from RC1 showed fish to be the main source of calories (48 percent), followed by plants (44 percent) and terrestrial mammals (7 percent).

Pezo-Lanfranco found similar proportions for RC2: fish (48 percent), plants (42 percent) and terrestrial mammals (10 percent). All percentages are averages, with individual values varying considerably.

The main protein source was fish for individuals from MO (58 percent-84 percent), RC1 (66 percent-85 percent) and RC2 (74 percent-83 percent). These levels are slightly higher than the values found for prehistoric and contemporary hunter-gatherers.

"The high proportion of chronic or static caries among individuals from RC1 suggests a less cariogenic diet than among individuals from RC2 and MO. This may be associated with the phosphate and calcium present

in diets of marine origin, as you would expect for fisher communities," Pezo-Lanfranco said.

"On the other hand, the higher frequency of deep and extraocclusal caries in RC2, and particularly in MO, points to widespread consumption of cariogenic and processed carbohydrate from roasted or boiled plants. The evidence from RC and MO suggests the existence of some kind of plant cultivation, albeit incipient."

Cervical caries, the most frequent type of extraocclusal caries in individuals from MO (29 percent), are associated with the frequent consumption of sucrose and solid fermentable starch, high levels of salivary lactobacilli, and the deposition of cervical calculus with gingival recession (receding gums).

"Cervical caries frequencies of around 16 percent have been reported for Pleistocene hunter-gatherers in northern Africa and interpreted as the first signs of the systematic harvesting and storing of high-carbohydrate wild plant food," Pezo-Lanfranco said.

In Andean agriculturalists, cervical caries are attributed to the consumption of fermented beverages made from cassava, corn, and other starchy foods. Previous studies have shown that sucrose, starch with sucrose, fructose and dextrose in descending order stimulate the production of smooth-surface and cervical caries, while high amounts of maltose and starch tend to lead more to cervical caries.

"So the MO diet was probably richer in cariogenic carbohydrate than the RC diet, and comparable to the diets of some agricultural peoples in antiquity," Pezo-Lanfranco said.

The dental wear index in MO and RC was lower than for several sambaqui communities studied elsewhere. The RC2 diet seems to have

been more abrasive than the MO diet. Stone vessels and grindstones found at MO may have been used to make flour. Microscope analysis of these implements is pending.

"This study puts the Neotropics on the map of the world's food production centers in antiquity. The Atlantic Forest coast has mostly been peripheral to this narrative despite its unique biodiversity and the archeological records of dense human occupation since the Middle Holocene. The new study challenges this traditional view," Pezo-Lanfranco said. "We assembled strongly convincing evidence for high-carbohydrate dietary habits among hunter-gatherers in the Joinville region some 4,500 years ago. Confirmation that they had cultivar production systems and how far they had progressed with domestication of the plant species concerned awaits further research."

More information: Luis Pezo-Lanfranco et al, Middle Holocene plant cultivation on the Atlantic Forest coast of Brazil?, *Royal Society Open Science* (2018). [DOI: 10.1098/rsos.180432](https://doi.org/10.1098/rsos.180432)

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