Journal of Archaeological Science: Reports 7 (2016) 189–194

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Stable carbon isotope values ($\delta^{13}C$) of purslane (*Portulaca oleracea*) and their archaeological significance

Kenneth Barnett Tankersley [a,b,*], Denis G. Conover [c], David L. Lentz [c]

[a] Department of Anthropology, University of Cincinnati, Cincinnati, OH 45221, USA
[b] Department of Geology, University of Cincinnati, Cincinnati, OH 45221, USA
[c] Department of Biology, University of Cincinnati, Cincinnati, OH 45221, USA

ARTICLE INFO

Article history:
Received 18 January 2016
Received in revised form 12 April 2016
Accepted 19 April 2016
Available online xxxx

Keywords:
Stable carbon isotope value
Photosynthesis
Archaeobotany
Paleobotany
Paleodiet
Common purslane (*Portulaca oleracea*)
Maize (*Zea mays*)
Eastern North America
Late Holocene
Bioarchaeology

ABSTRACT

Elemental Analyzer Isotope Ratio Mass Spectrometry was used to determine the $\delta^{13}C$ values of common purslane (Portulaca oleracea), a highly edible and nutritious annual succulent and member of the Portulacaceae family, which uses both C4 fixation and Crassulacean acid metabolism (CAM) photosynthesis. The $\delta^{13}C$ values for the plant range between −11.2‰ and −20.5‰ (C4 −11.2‰ to −13.9‰, CAM −17.6‰ to −20.5‰), which overlaps with $\delta^{13}C$ values for maize (Zea mays) −9.1‰ to −17.3‰. Both plants occur on late Holocene archaeological sites in eastern North America and likely contributed to the $\delta^{13}C$ ratios reported for ancient human collagen and hydroxyapatite. Taphonomically, *P. oleracea* has a lower archaeological visibility because it is completely edible and the seeds are tiny (0.02 to 0.76 mm) in comparison to maize kernels and cobs. Therefore, we can no longer assume that maize was the only significant plant food in the late Holocene diet of eastern North America, which elevated $\delta^{13}C$ ratios in ancient human tissues.

1. Introduction

The photosynthetic pathways of plants vary in their biochemical processes to fix carbon. C3 plants may be hydrophytic, mesophytic, or xerophytic and are common in temperate environments. They have a normal leaf anatomy with photoactive stomata, a high rate of photorespiration, and a single CO_2 fixation with a CO_2 compensation point between 30 and 70 ppm (Govindjee et al., 2006).

C4 plants are mesophytic and are common in warm weather tropical environments. The C4 pathway occurs in several thousand species of tropical and subtropical plants, including the economically important crops of corn, sugarcane, and sorghum. By avoiding photorespiration the C4 pathway ensures a more efficient delivery of CO_2 for fixation and greater photosynthetic rates than C3 plants under conditions of high light intensity, high temperature, and low CO_2 concentrations (Levetin and McMahon, 2016). C4 plants typically have a Kranz leaf anatomy with photoactive stomata, a much lower rate of photorespiration, and a double CO_2 fixation with a CO_2 compensation point at 10 ppm (Govindjee et al., 2006).

CAM (Crassulacean acid metabolism) plants include xerophytic plants such as cacti and are common in dry lands and semiarid and arid climates. CAM plants typically have a xeromorphic leaf anatomy with scotoactive stomata, a reduced rate of photorespiration, and a double CO_2 fixation with a CO_2 compensation point at 5 ppm (Govindjee et al., 2006). By opening their stomata at night instead of the daytime, CAM plants avoid the higher evaporative demand of the atmosphere that occurs during the daytime. Purslane, *Portulaca oleracea*, uses C4 photosynthesis under well-watered conditions, but has the unusual ability to switch to the CAM pathway under drought conditions (Koch and Kennedy, 1980, 1982).

It has been long presumed that the consumption of the C4 cultigen maize (*Zea mays*) was the sole source of ^{13}C enrichment in late Holocene age human collagen and hydroxyapatite (i.e., bone, hair, teeth) obtained from archaeological sites in eastern North America. Late Holocene archaeobotanical records for this region are dominated by C3 silvicultural masts and herbaceous plant foods, which were gathered or cultivated (Table 1). Additionally, there is also a correlation between an increase in $\delta^{13}C$ values in human collagen and hydroxyapatite and the increase in the size and quantity and of maize recovered from late Holocene archaeological sites (van der Merwe, 1982; Vogel and van der Merwe, 1977; van der Merwe and Vogel, 1978). Consequently, $\delta^{13}C$ values have been used as an isotopic fingerprint for the

* Corresponding author at: Department of Anthropology, PO Box 210380, 481 Braunstein Hall, University of Cincinnati, Cincinnati, OH 45221-0380, USA.
E-mail address: tankerkh@uc.edu (K.B. Tankersley).

http://dx.doi.org/10.1016/j.jasrep.2016.04.009
2352-409X/

consumption of maize (Beehr and Ambrose, 2007; Dong et al., 2010; Emerson et al., 2005; Hedman, 2006; Hedman and Emerson, 2008; Hedman et al., 2002; Rose, 2008; Schoeninger, 2008; Tykot, 2006).

Because human paleodietary reconstructions for the late Holocene of eastern North America have focused exclusively maize in the interpretation of $\delta^{13}C$ values for human collagen and hydroxyapatite, other C4 and CAM wild plant foods such *P. oleracea* have been ignored. The aim of the present study is to ascertain the photosynthetic nature of *P. oleracea*, obtain $\delta^{13}C$ values for the plant, and discuss the implications for archaeological interpretations of late Holocene diets in eastern North America (i.e., east of the Mississippi River).

2. Purslane

Common purslane (*P. oleracea*), colloquially known as duckweed, fatweed, pigweed, little red root, moss rose, pursley, and pussley, is an annual succulent and a member of the Portulacaceae family of flowering plants. While several species of terrestrial plants that have the ability to switch between C3 and Crassulacean Acid Metabolism (CAM) photosynthesis, *P. oleracea* is one of the few species with the ability to switch between C4 and CAM (Kluge and Ting, 1978; Koch and Kennedy, 1980, 1982; Lara et al., 2004). Physiologically, the shift from C4 to CAM results from stress after an increase in CO_2 uptake, a decrease in water, or both (Cushman, 2001; Taiz and Zeiger, 2006).

Cross-culturally, *P. oleracea* is consumed as a delicious and nutritious food (Mohamed and Hussein, 1994). Leaves and stems can be harvested before the plant comes into flower, eaten raw or cooked, and they can be stored (Yanovsky, 1936). The leaves and stems provide an important nutritional wild pant food that is rich in heart-healthy omega-3 fatty acids. They also provide about 271 cal, 49 g of carbohydrate, 26 g of protein, 12 g of fiber, 4 g of fat, 1813 mg of potassium, 1488 mg of calcium, 547 mg of phosphorus, 251 mg of ascorbic acid, 55 mg sodium, 29 mg of iron, 6 mg of niacin, 1 mg of riboflavin, 0.36 mg thiamine, and 15,280 μg of β-carotene per 100 g (Mohamed and Hussein, 1994).

While the plant can be harvested and consumed prior to seeding, the seeds may also be consumed and also have a high degree of nutritional value. *P. oleracea* seeds are extremely small (0.20 to 0.76 mm) (Fig. 1), a single plant can yield upwards of 240,000 of them, which can always be eaten raw or ground and cooked as bread, flat-cake, or as gruel (Yanovsky, 1936). There are approximately 2765 purslane seeds per gram, which contain about 21 g of protein and 19 g of lipids, including behenic, linoleic, linolenic, oleic, palmitic, and stearic, fatty acids (Mohamed and Hussein, 1994).

P. oleracea is also an important medicinal plant. The leaves and stems are used as an antibacterial, antiscorbutic, anti-inflammatory, antibiotic, demulcent depurative, diuretic, and febrifuge. It is used in the treatment of burns, caterpillar stings, coughs, earaches, headaches, insect stings, skin diseases, and stomach aches. The seeds are also used for dyspepsia and opacities of the cornea (Mohamed and Hussein, 1994).

2.1. Origin of P. oleracea in eastern North America

In 1672, the British Massachusetts's colony recognized *P. oleracea* in eastern North America, but they assumed that an earlier European population had introduced the species to the region. However, *P. oleracea* has been documented from late Holocene archaeological contexts across eastern North America dating as early as 2500 and 3000 years ago (Byrne and McAndrews, 1975; Chapman and Stewart, 1974). The presence of *P. oleracea* at Archaic, Woodland, Fort Ancient, and Mississippian sites in Eastern North America as well as Mesoamerica (e.g., Byrne and McAndrews, 1975; Chapman and Stewart, 1974; Drooker, 1997; Lentz et al., 2014; Lopinot, 1997; Slotten, 2015) sites suggest that it is an indigenous species.

The widespread geographic distribution of *P. oleracea* in the late Holocene is likely anthropogenic. An increase in the number and size of disturbed habitation areas in warm and moist environmental settings resulting from plant domestication and a semi-sedentary livelihood would have created ideal growing conditions. *P. oleracea* was likely an invasive species in late Holocene garden plots growing alongside chenopod (*Chenopodium berlandieri*), gourd (*Lagenaria siceraria*), sumpweed (*Iva annua*), squash (*Cucurbita pepo*), sunflower (*Helianthus annuus*), and more recently in the agricultural fields of maize and beans (*Phaseolus vulgaris*) of more complex polities (Chapman and Stewart, 1974).

Given the pleasant taste and exceptionally nutritious and medicinal value of *P. oleracea*, it was likely consumed as an uncultivated food throughout the late Holocene but has largely gone unnoticed because the entire plant could be consumed. *P. oleracea* has a very low archaeological visibility when compared to cultigens with larger seeds such as squash, gourds, beans, and maize. Therefore, it is not surprising that

Table 1
C3 plant foods identified in the late Holocene archaeobotanical records of Eastern North America (Fritz, 2000, 2014; Lentz, 2000; Munson, 1984; Smith, 1986; Watson, 1974, 2001).

Common name	Species	Plant food
American chestnut	*Castanea dentata*	Silvicultural mast
Beans	*Phaseolus vulgaris*	Cultivated domesticate
Bitternut hickory	*Carya cordiformis*	Silvicultural mast
Black walnut	*Juglans nigra*	Silvicultural mast
Bottle gourd	*Lagenaria siceraria*	Cultivated domesticate
Butternut	*Juglans cinenea*	Silvicultural mast
Chenopod	*Chenopodium berlandieri*	Cultivated domesticate
Cushaw squash	*Cucurbita argyrosperma*	Cultivated domesticate
Erect knotweed	*Polygonum erectum*	Herbaceous
Giant ragweed	*Ambrosia trifida*	Herbaceous
Gourd-like squash	*Cucurbita pepo*	Cultivated domesticate
Little barley	*Hordeum pusillum*	Herbaceous
Maygrass	*Phalaris caroliniana*	Herbaceous
Mockernut hickory	*Carya tomentosa*	Silvicultural mast
Pignut hickory	*Carya glabra*	Silvicultural mast
Shagbark hickory	*Carya ovate*	Silvicultural mast
Shellbark hickory	*Carya laciniosa*	Silvicultural mast
Sumpweed	*Iva annua*	Cultivated domesticate
Sunflower	*Helianthus annuus*	Cultivated domesticate
White oak	*Quercus alba*	Silvicultural mast

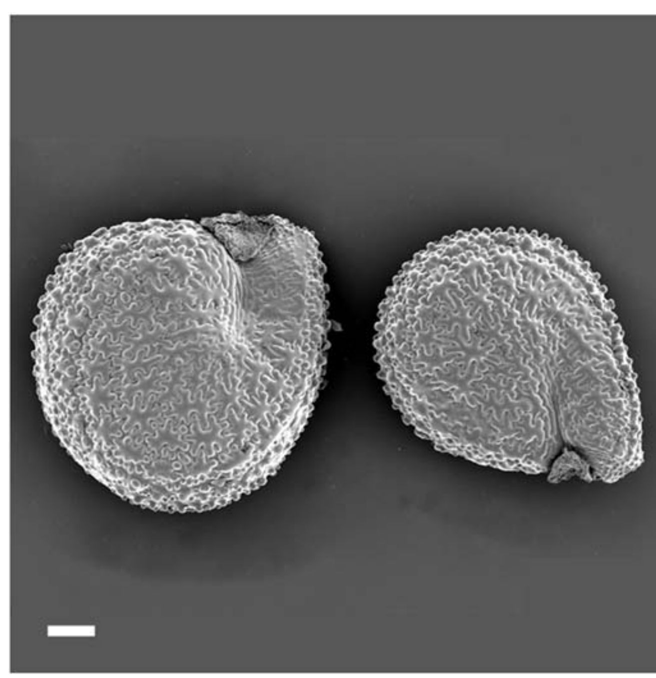

Fig. 1. ESEM of a purslane seed.