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Reviving the Arid American Diet in the Face of Climate Change: Assessing its Composition, Links to the Mesomerican Diet and Potential to Advance Indigenous Health and Diabetes Prevention

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Abstract: Climate change is aggravating diseases of oxidative stress for desert dwellers in México and the USA. This public health crisis has prompted scientists to reconsider the valueofIndigenousdiets of both Mesoamerica and Arid America. While these two gastronomies share many features, Mesomerican diets are more diverse. However, a higher percentage ofplants inArid American diets have adapted to water scarcity, heat and damaging radiation. The phytochemical and physiological adaptations of these plants to abiotic stresses in arid environments incidentally buffer their consumers from certain diseases of oxidative stress. By comparing plant genera comprising Mesoamerican and Arid American diets, we detected a higher ratio of CAM succulents in the wild and domesticated food plant species in Arid American diets. We then determined which plant genera in in both gastronomic traditions have the resilience to enhance food security as climate change advances. We surveyed these same genera for known hypoglycemic and antioxidant properties that may prevent or treat diabetes and other diseases. Finally, we elucidate which Indigenous culinary preparation techniques enhance the value of prepared foods and beverages compared to their raw ingredients. Diets based on these probiotic, chemoprotective foods may have adaptive value in a hotter, dried world.

Key words: Arid America · Climate Change · Diabetes · Food processing · Indigenous Diets · Mesoamerica · Nutrition · Oxidative Stress

INTRODUCTION

There is the smell of danger in the dry air: Thecurrent rates of global climate change are predicted to dramatically impact food security and increase health risks in North America, even as climate catastrophes and carbon emissions have already generated more than $820 billion/yr in additional physical and mental health care costs in the U.S.A.(Crimmins *et al*. 2016; DeAlwis and Limye 2021; and Ebi and Hess 2020).

Nevertheless, many think of the health impacts of climate change to be maladies such as severe dehydration, heat exhaustion, heat stroke and rhabdonmyolosis, or injuries from wildfires and floods. Less recognized are the rising costs treating those who suffer from a variety of nutritional and microbial diseases, particularly for farmers, foragers and farmworkers exposed daily to climatic stresses.

In particular, suchstressorsare also affectingmillions of North Americans in Canada, the U.S.A. and México who are already suffering from adult-onset, non-insulin dependent diabetes (Zibbermint 2020) and other "diseases of oxidative stress" (Nabhan *et al*. 2020). The term *oxidative stress* indicates a metabolic imbalance between oxidants and antioxidants that can be triggered by any number of factors, including exposure to UV radiation, heat, dehydration, chemical pollutants and biogenic volatile organic compounds(BVOCs);these can contribute to the pathogenesis of a suite of chronic diseases such as cardiovascular diseases, diabetes, neurodegenerative diseases and cancer (Sharifi-Rad *et al*. 2020).

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Recent evidence suggests that many of these maladies can be grouped as metabolic syndrome of “diseases of oxidative stress” that will undoubtedly be further aggravated by climate change (Birben *et al*. 2012; Nabhan *et al*. 2020).

Yet even today, the consequences of oxidative stresses in the environment haveworsened the epidemic ofadult-onset diabetes, which itself is a generator of oxidative stress. It is estimated that this syndromeaffectsaround 13 million adults in Mexico (Barquera *et al.* 2013; IDF Diabetes Atlas 2019) and at least 31 million residents in the U.S.A(American Diabetes Association 2013; IDF Diabetes Atlas 2019; Zimmermint 2020), with a prevalence around 15% and 13% in each country respectively. The meteoric rise in the incidence and prevalence of these and other nutrition-related “diseases of Western civilization” has taken a disproportionate toll on individuals with Indigenousor Native Americanancestry –those of the First Nations of the North American continent (Baschetti 1998; Kuhnlein *et al*. 1996).

More broadly, there is ample documentation thatclimate-triggered health risks are reaching epidemic proportions, devastating ruralIndigenous communities in arid and semi-arid, subtropical areas of the U.S.A and México (Shaw *et al*. 2010).

At the same time, the therapeutic use of food and medicinal plants as “nutriceuticals” with exceptional antioxidant properties are already being exploited for their ability to treat or prevent several human pathologies in which oxidative stress seems to be one of the causes (Sharifi-Rad 2020). The possibility that Indigenous cultures’ own ethnobotanical resources can be used to deal with this health crisis has prompted México’s activist-scholars to initiate thoughtful, thorough and far-reaching efforts to reviveto the original structure and composition of the Mesoamerican diet in all their dimensions (eg., Calvo and Rueda-Esquibel 2015; Legaspi 2019; Zizumbo-Villarreal*et al*. 2016).

Similarly, Indigenous populations in the Desert Southwestof the U.S.A.are employing their “native foods” to help manage the seven-decade rise in rates of obesity, diabetes and related diseases (Edaakie and Enote 1999; Kavena 1980; Patchell and Edwards 2013; Tohono O’odham Community Action 2010; and Wolfe *et al*. 1985). These native foods revival efforts began within Indigenous communities well before climate change was recognized as a stressor. Even then, it was clear that dietary interventions were cost-effective in dealing with this culturally devastating and economically burdensome issue (Kuhnlein *et al*., 1996; Minnis 2021).

Our objectives for this reappraisal and revival of healthful, plant-baseddiets prior to Spanish invasionin México and the Southwestern U.S.A. are a) thatthey can reduce the number of people suffering from climate- and nutrition-related diseases while b) that they may help restore food sovereignty to Indigenous communitiesin ways that reinforce their cultural identity abnd assure thgeir continuity.

To date, few applied dietary interventions in response to nutrition-related diseaseshave gained access to in-depth reconstructions of the food plant diversity in Mesoamerican diets once prevalent in the Neotropical heartland of Mexico, or in Aridamerican dietsonce prevalent in the deserts and dry subtropics of the U.S.A/México borderlands.Unfortunately, many of the unacquainted simply assume that Mesomerica is equivalent to México as if it is merely a synonym for the entire Republic of México. To the contrary, much of México’s populations now dwells in hot, dry climates, with arid and semi-arid food-producing landscapesdominating 60% of the national territory. We therefore wish to compare, contrast and revive elements of what we call the Mesoamerican and Arid American diets traditionally consumed in México and the adjacent Southwestern U.S.A. Our ultimate goal is to detail how the composition of the food plants in these two diets, when interacting with Indigenous culinary processing techniques, can help reduce the health impacts of climate change. We hypothesize that lessons learned from both gastronomic traditions have the capacity to help desert dwellers manage diabetes and other diseases of oxidative stress now being aggravated by climate change.

Geographic Context, Materials and Methods: For the purposes of the exercise, we will modify the map and definition of the culture areas known as Mesoamerica and Aridoamerica as Paul Kirchhoff (2009) and other geographers have done for the last half century (see Figure 1).

In addition, we have integrated Kirchoff’s OasisAmerica—with its nucleated set of irrigated agricultural communities-- into the larger matrix of “seasonally dry-farmed’ (*de temporal)* communities of the cultural area which he called Aridamerica. To distinguish our older inter-digitation of Kirchhoff’s OasisAmerica and Aridoamerica with our newly defined region, we call this new (agri-)cultural area “Arid America.”Our new geographic delineations of these two regions were elaborated by our colleagues in México and the U.S.A who contributed to an agroecological research article complementary to this one (Nabhan et al 2020), using

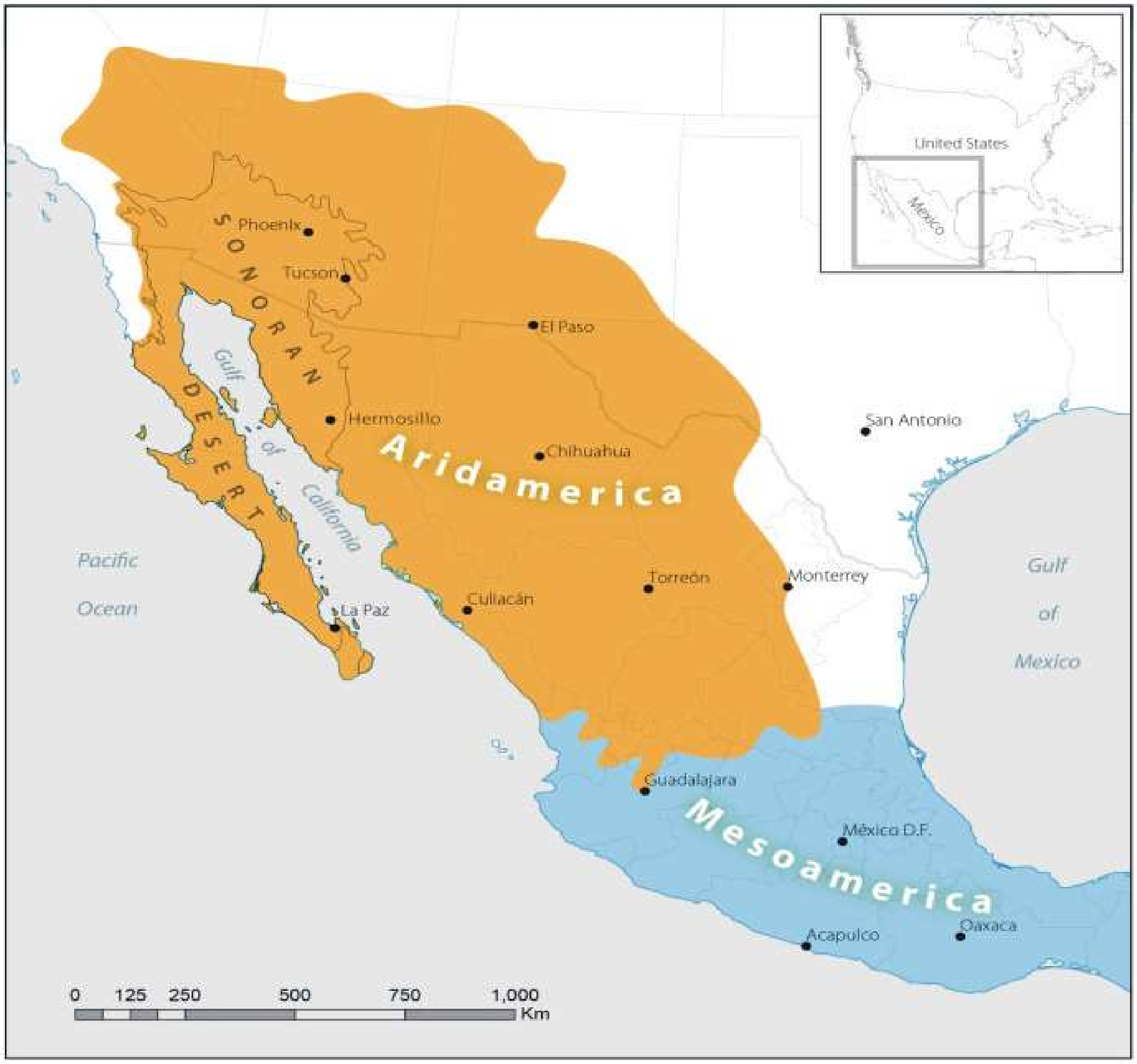

Fig. 1: **Caption Missing**

floristic, vegetational, agroecological, ethnobotanical, anthropological and linguistic factors first elaborated by Hernández-Xolocotzi (2013) to find the most parsimonious fit of the boundaries of each region (Figure 1).

As defined here, both Mesoamerica and Arid America fall primarily within the larger Neotropical phytogeographic region which biogeographer Rzedowski considered to be "MegaMéxico" that extended into the Desert Southwest of the U.S.A (Rzedowski 1978). Hence, the Aridamerican region or center spans the Sonoran Desert (including Baja California's deserts) as well as the higher elevation Chihuahuan Desert (including the Zacatecas-Potosí Desert) to the east. It can be taken as a biocultural region with both great floristic and cultural diversity)Luque ey al 2016).

While these two true deserts form the core of Aridamerica, it also includes arid subtropical thornscrub, as well as semi-arid grasslands, savannas, oak woodlands and coniferous forests interdigitating with the northern extent of drought-vulnerable reaches of Mesoamerica. When considering the eastern boundary, we included the Zacatecas-Potosí Desert as an important cultural-agricultural feature, for it is part of the cradle of prickly pear *'nopalera'* and agave '*magueyal*" agriculture of perennial succulents in México This is a region where both natural hybridization and cultural manipulkation or selections from hybrid swarms influenced the domestication of multiple *Agave* and *Opuntia* species (Colunga-García-Marín *et al*. 2007; Gentry 1982; Griffith 2004).

Table 1: Domesticated Plants Associated with the Arid American Center of Crop Diversity (Revised from Nabhan 1985; full citations for references are in Supplemental Materials)

Species	Common Names	Probable Domes-tication in Arid America	Probable Domes-tication in Mesoamerica	Registered in pre-Invasion Arid America	Registered in post-Invasion Arid America	Reference
Agave americana	arroqueño, maguey de pulque	X	X	X	X	Colunga-García-Marín *et al.* 2007& 2017; Gentry 1982
Agave angustifolia	bacanora, espadín	X	X		X	Colunga-García-Marín *et al.* 2007& 2017; Gentry 1982
Agave delameteri	Tonto Basin agave	X			X	Hodgson 2012
Agave mapisaga	pulquero, listocillo, tarimbaro		X		X	Colunga-García-Marín *et al.* 2007& 2017; Gentry 1982
Agave murpheyi	Hohokam agave	X		X	X	Hodgson 2012
Agave philIipsiana	Grand Canyon century plant	X		X		Hodgson 2012
Agale rhodacantha	mexicano, yocogihua	X	X		X	Colunga-García-Marín *et al.* 2007& 2017; Gentry 1982
Agave salmiana	maguey de pulque, maguey verde	X	X	X	X	Colunga-García-Marín *et al.* 2007& 2017; Gentry 1982
Agave sanpedroensis	San Pedro agave	X		X		Hodgson et al. 2018
Agave verdensis	Sacred Mountain agave	X		X		Hodgson & Salywon 2013
Agave yavapaiensis	Page Springs agave	X		X		Hodgson & Salywon 2013
Agave weberi	maguey de mezcal	X			X	Colunga-García-Marín *et al.* 2007; Gentry 1982
Amaranthus cruentus	alegria, grain amaranth, huatle	X		X	X	Burns et al. 2000
Amaranthus hypochon-driacus	alegria, grain amaranth, huatle		X	X	X	Burns et al. 2000; Ford 1981
Canavalia ensiformis	jack bean	X		X	X	Ford 1981
Capsicum annuum	Chile		X		X	Burns et al. 2000
Chenopodium berlandieri	Huazontle		X	X	X	Ford 1981
Cucurbita argyrosperma	calabaza de las aguas, green stripedcushaw		X	X	X	Burns et al. 2000;Ford 1991
Cucurbita moschata	Segualca		X	X	X	Ford 1981
Cucurbita pepo	calabaza, pumpkin		X	X	X	Ford 1981
Distichlis palmeri	nypa, Palmer's saltgrass	X			X	Yensen 2008
Dysphania ambrosioides	Epazote		X			Blanck-aert et al. 2012
Gossypium hirsutum	algodón, cotton		X?	X	X	Ford 1981
Helianthus annuus	girasol, sunflower	?	?		X	Ford 1981
Hyptis suaveolens	cham, chia grande, conivari		X		X	Burns et al. 2000
Hordeum pusillum	little barley	X?		X	?	Graham et al. 2017; Ford 1981, Louder-back& Pavlik 2018
Jaltomata procumbens	Jaltomato	X	X		X	Burns et al. 2000
Lagenaria siceraria	bottlegourd, bule		X	X	X	Ford 1981
Myrtillocactus geometrizans	garambullo, blue myrtle cactus		X		X	Hernández- et al. 1991
Opuntia durangensis	xoconostle chivo	X			X	Griffith 2004
Opuntia leucotricha	nopal duraznillo	X?	X		X	Griffith 2004
Opuntia megacantha	large-thorned prickly pear, orange fruit prickly pear, nopal blanco, nopal picochulo	X?	X		X	Griffith 2004
Opuntia robusta	tuna tapón, tuna Castillana	X?	X		X	Griffith 2004
Opuntia streptacantha complex (incl. *O. ficus-indica*)	nopal de Castilla, nopal cardón, white-spined prickly pear	X?	X		X	Griffith 2004
Panicum sonorum	sagui, Sonoran panicgrass	X		X	X	Burns et al. 2000
Phaseolus acutifolius	tepari, tepary bean	X	X?	X	X	Ford 1981
Phaseolus coccineus	ayocote, runner bean		X	X	X	Ford 1981
Phaseolus lunatus	alubia, lima bean, sieva		X?	X	X	Ford 1981
Phaseolus vulgaris	common bean, frijol comun		X	X	X	Ford 1981
Proboscidea parviflora	devil's claw, torito, uña de gato	X			X	Ford 1981
Physalis philadelphica	miltomate, tomatillo	X?	X	X	X	Solís-Montero et al. 2021
Salvia hispanica	chia		X		X	Cahill & Provance 2002
Salvia tiliifolia	Raramuri chia	X			X	Burns et al. 2000
Solanum jamesii	Four Corners potato	X		X	X	Kinder et al. 2017
Solanum cf. nigrescens	chichi-quelite, yerba mora	X?	X			Burns et al. 2000
Stenocereus griseus	Pitayo		X		X	Casas et al. 2002
Stenocereus marginatus	Organo		X		X	Casas et al. 2002
Stenocereus pruinosus	cuapatla, pitayo de mayo, xoconostle					Casas et al. 2002; Parra et al. 2012
Stenocereus stellatus	jonocostle, pitaya de augusto					Casas et al. 1999; Casas et al. 2002
Zea mays	maíz		X		X	Ford 1981

To developafull characterization of the Arid American diet and its health benefits, we have built on an earlier paper in this journal which established Arid America as a secondary center of plant domestication and diversification complementary to but distinct from that of Mesomerica (Nabhan 1985). However, we have amplified and corrected this initial inventory of domesticated crop plants of Arid America to use as a point of departure for a fresh investigation of the entire regional dietary traditions (Table 1).

First, we will ask what annual and perennial crops dominated the diets in both regions prior to the Invasion by the Spanish and other European countries trying to establish hegemony over Indigenous Nations. Next, we will document which wild native plant species preceded and complemented or underpinned this domesticated crop inventory from the late pre-Invasionera, throughhistoric "colonial" eras, rounding out the diets of"Indigenous" or "Native American" communities of Arid America.

To do so, we have drawn upon two ethnographic ethnobotanies from each of three subregions: Baja California (Aschmann 1959 for the Cochimí of the Central Desert and Wilken-Robertson (2018) for the Kumeyaay of the semi-arid foothills); the mainland's Sonoran Desert, including Rea (1987) for the Upper Pima of the Arizona Uplands and Felger and Moser (1985) for the hyper-Arid Gulf Coast of Sonora; and the Chihuahuan Desert, including Latorre and Latorre (1965) for the Kickapoo of Coahuila and Texas, as well as Solano-Picazo and Blancos (2015) for the Wirikuta (Huichol) of San Luis Potosí). These have been supplemented by regional classics such as Hodgson's (2001) *Food Plants of the Sonoran Desert* and Hernández-Sandoval *et al.* (1991) *Plantas Utiles de Tamaulipas*. These six references give us a somewhat comprehensive view of the wild or semi-cultivated food plants whose presence in these regions predate Spanish Invasion, with a focus on nutritionally significant genera that continue to be consumed by two or more Indigenous cultures across the entire Arid American region.

Next, we analyze which of these wild food plants were crop relatives or congeners of the domesticated species listed in the Table 1 inventory. Our hypothesis is that well before fully domesticated plants entered their traditional cuisines, Indigenous communities were already familiar with and gastronomically utilized several crop wild relatives in their diets (Contreras *et al*. 2018; Riordan and Nabhan 2019).

To compare the relative richness of wild crop relatives in a local flora of Western Mesoamerica with one from western Arid America, we have selected the flora of the Sierra de Manantlán Biosphere Reserve on the Jalisco-Colima border (Vásquez G. *et al*. 1999) and the flora of Cañon de Nacapule in the Sierra de Aguaje, part of the Cajón del Diablo Biosphere Reserve in coastal Sonora, México (Felger *et al*. 2017).

To further refine our retrodiction of Indigenouspre-Invasion diets, we give particular attention to those documented in among cultures of Arizona, Baja California and Sonora to represent the AridAmerican diet and those of Jalisco and Colimato represent the Western Mesoamerican diet. To do so, we draw upon the series of ethnographic cookbooks *'recetarios'*compiled, edited and published by México's Dirección de Culturas Populares, Indigenas y Urbanas in its *Cocina Indígena y Popular* series (eg.s, Moraga Campuzano 2016; Yocupicio Buimea 2000), by the Centro de Investigación y Desarollo (eg., Luque-Agraz2012), as well as Indigenous cookbooks of comparable quality from the Southwestern U.S.A.(Tohono O'odham Community Action 2010).

Because the cookbooks typically lack scientific names for the wild plants included in them, we cross-referenced their regional and Indigenous folk nameswith updated scientific nomenclature fromAvitia-García and Castillo-González (2002), Hodgson (2001), Inés-Olaya, 1991; Martínez(1979), Moerman (1998) and Vela (2013).We will also include domesticated foods recordedin compendia such asBurns *et al*. (2000); Zizumbo-Villarreal and Colunga-García Marín (2010); and those in the new Table 1 derived from Nabhan (1985).

For lack of equally detailed dietary documentation of various cultures' food preparation techniques across both regions, we will sample the best-documented traditional diets and their historic food systems where these two culture areas occur west of the continental divide. We have chosen to reflect upon a classic dietary study fromwestern Mesoamerica (Jalisco, Colima), where Zizumbo-Villarreal, Colunga-GarcíaMarín and Flores-Silva (2016) have analyzed food and beverage preparations in historic Nahuatl-speaking communities. We have directly compared its Mesoamerican food preparation techniques with those of the Hopi of Aridamerica, who are also in the Uto-Nahua language family (Kuhnlein and Calloway 1977; Kavena 1980; Nabhan *et al*. 1985; and The Hopi Dictionary Project 1998).

We also selected two case studies from the Sonoran Desert of Arid America (Sonora and Arizona), where several teams have analyzed food and beverage preparations ofO'odham and Comcaac communities (Felger and Moser 1982;Nabhan *et al*. 1985; Brand-Miller at al. 1990; Hernández-Santana and Narchi 2018; Narchi*et al*. 2020).These communities live just north of the Yoéme (Yaqui) and Mayo (Yoreme) communities of southern Sonora, whose recetarios reflect similar desert plant preparation trends. We are particularly interested in recipes that retain remnants of pre-Invasion food and probiotic beveragepreparation techniques that predate mechanical milling, cooking on gas or electric stoves and industrialized fermentation and distillation (Olivera-Linares *et al*. 2021.)

Table 2: Annual or annualized food crops in Western Mesoamerica and Arid America (Full citations for references are in Supplemental Materials)

Neotropical Crop Species	Common Hispanicized Nahuatl or Spanish Name	Presence in Western Mesoamerica	Common American English Name	Presence in Western Aridoamerica
Amaranthus cruentus	alegría	*X*	red grain amaranth	*X*
Amaranthus hypochondriacus	huautli	*X*	grain amaranth	*X*
Canavalia ensiformis	haba blanca		jack bean	*X*
Capsicum annuum	chile	*X*	chile pepper	*X*
Chenopodium berlandieri nutalliae	huazontle	*X*	lambsquarters	*X*
Cucurbita argyrosperma	calabaza de las aguas, pipiani	*X*	cushaw squash	*X*
Cucurbita ficifolia	chilacayote	*X*	figleaf gourd	*X*
Cucurbia moschata	segualca	*X*	big cheese pumpkin	*X*
Cucurbita pepo	calabaza	*X*	acorn squash	*X*
Dysphania ambrosioides	epazote	*X*	epazote	*X*
Helianthus annuus	girasol	*X*	sunflower	*X*
Hordeum pusillum	cebada chica		little barley	*X*
Hyptis suaveolens	chan, chia grande, combari,	*X*	big chia, conivari	*X*
Jaltomata procumbens	jaltomato	*X*	creeping false holly	*X*
*Panicum hirticaule (*incl. *P. sonorum)*	sagui		Sonoran panicgrass, Sonoran millet	*X*
Phaseolus acutifolius	tepari	*X*	tepary bean	*X*
Phaseolus coccineus	ayocote	*X*	runner bean	*X*
Phaseolus lunatus	tatashete	*X*	lima bean	*X*
Phaseolus vulgaris	Frijol	*X*	common bean	*X*
Physalis philadelphica	tomate, miltomate	*X*	tomatillo	*X*
Porophyllum ruderale	papalo, papoloquelite, quilquiña	*X*	odoro	
Porophyllum tagetoides	pipicha	*X*	odoro	
Portulaca oleracea	verdolagas	*X*	purslane	*X*
Salvia hispanica	Chia	*X*	chia	
Setaria parviflora	motilla, paitén, triguillo, zacate sedoso	*X*	bristly foxtail, cola de zoora, knotroot foxtail, marsh bristlegrass	
Solanum lycopersicon	jitomate	*X*	tomato	*X*
Solanum nigrescens (incl. douglasii)	chichiquelite	*X*	wonderberry	*X*
Tagetes ficifolia	cempaasúchil	*X*	marigold	
Zea mays	maíz	*X*	corn	*X*

Characterizing the Annual Food Crop Biodiversity of Arid America and Mesoamerica: Of some thirty species of annual or annualized perennials domesticated as crop before the Spanish Invasion, each of the two cultural regions harbors roughly the same number of these short cycle, warm season food staples (Table 2): 25 species for Mesomerica and 24 for Arid America. It is abundantly clear that during pre-Invasion eras, Mesoamerican cultures domesticated far more annual food crops plants than did Arid American cultures. The mix of plant families in these two sets of regional annual crops is much the same: composites, cucurbits, grasses, legumes, as well as pseudo-cereals from the amaranth family. But one critical difference between the two regions; crop repertoires is agroecological, not biosystematics.

Many of the Arid American cultivated plants were rigorously selected by both weather and culture to be short-cycle crops, maturing with dry seeds in as little as 36 to 55 days during the monsoon season of mid-summer to early fall, to "escape" drought rather than to endure it. These crops mimic summer "ephemeral" wildflowers in the Sonoran and Chihuahuan Deserts in that they quickly germinate, flower, set fruit and die before the late autumn drought period sets in. Since most of these crops utilize the C3 metabolic pathway, they require considerable soil moisture each week they are alive but reduce cumulative consumtive water use by matruring quickly. In contrast, most annual Mesoamerican crops are facultative perrenials, which persist in gardens and field for at least seven months during the warm season, whilecontinuing to set fruit in years with mild weather for twelve to fourteen months. Often, root fungi, other diseases and pests terminate their growth, not climatic constraints.

No fewer than 22 domesticated annual food crops were culturally dispersed from Mesoamerica into Arid America over the last four millennia (Burns *et al*. 2000; Dunmire 2004).Most of these require much more irrigation that the desert-adapted food crops like tepary beans, chia, little barley, and sagui or Sonoran panicgrass (Nabhan and de Wet 1984).

Nevertheless, Arid Americancultures obtained many of their staple foods from the south via group-to-group diffusion across a Uto-Nahualinguistic continuum (Merrill *et al*. 2009). Probably, the majority of domesticated annuals or annualized perennials grown for food in Arid Americaof the last several millennia began to diffuse into the more northern, arid region along the Western Mexican coastal trade routes beginning between 6000 and 5500 calibrated years before present (Merrill *et al*. 2009; Mabry, pers. comm). The Las Capas site in the western Tucson Basin has yielded three direct radiocarbon dates on maize remains between 5, 700 and 4, 500 calibrated years before present (Vint 2015, 2018). These are currently the oldest maize dates in the Southwest U.S./Northwest Mexico region, but archaeologists expect that more maize dates in this time range will eventually be reported as new investigations are conducted in the region.

In a few cases, we can posit that because all Mesoamerican food crop adapted to the wet Neotropics did not grow well in the hot, dry lowlands of Arid America, another, more desert-adapted set of congeners of similar utility was recruited. For example, the domestication of tepary beans in Arid America appeared well after common, lima and runner beans were domesticated in Mesoamerica. We might hypothesize similar processes of "relay domestication" into more northerly, arid climes with *Cucurbita, Solanum, Physalis, Jaltomata,* among other annual crop genera were recruited to play a similar role in diets as their tropical counterparts (see Rodriguez and Spooner, 1997 and Louderback and Pavlki 2018). The climatic differences between the two cultural regions also influenced the prevailing plant chemical defenses in the sets of annual dominating each of the two cultural regions, a topic which we will address in a later section on bioactive compounds.

These New World domestical annuals have remained among the most important warm season food crops in both cultural regions, but recent severe heat waves, prolonged drought and water scarcity associated with climate change are now impacting them in several ways, such as extrememely high summer temperatures causing abortion of flowers and fruits (Nabhan 2013a). This is disconcerting, since they have provided much of the calories and complex carbohydrates to their Indigenous communities for the last three millennia. In many ways, they have provided a now imperiled the structural matrix or "backbone" of the gastronomies of most (but not all) cultures in Mesoamerica and Arid America up until the last several decades.

Characterizing the Perennial Food Crop Biodiversity of Arid America and Mesoamerica: The domestication of some perennial food plants was once more difficult to discern that that of annual crops, but recent methodological advances have revealed many more domesticated perennials in North America than previously recognized (Casas *et al*. 1999, 2002, Hernández-Xolocotzi 1993).Of forty perennial food crop species one found between the two cultural regions since pre-Invasion eras, thirty-two of these perennial crop species continue to be found in Mesoamerica, while just twenty-five perennial crop species continue to be found in Arid America (Table 3). A semi-cultivated perennial, Palmer's saltgrass *(Distichlis palmeri)* of the Colorado River delta, fell out of management in Arid America but has since been revived (Yensen 2008), while another cereal, foxtail millet (*Setaria parviflora,)* has apparently disappeared altogether as a crop from both cultural regions (Austin 2006; Callen 1997).

Often ignored by early archaeologists seeking out the origins of domesticated crops, these plants do not exhibit morphological divergence from their wild ancestors as dramatically as annual domesticatres do (Casas *et al*. 2002; Louderback and Pavlki 2018). However, these resilient sets of perennial crops in Arid Amrerica and Mesoamerica survive drought and heat by deep roots tapping into deep soil moisture, by sloughing off branches during drought, or by extended dormancy. They also sequester far more carbon in the soils of milpas and agroforestry orchards that do annual crops originating in either region.

In contrast to the diverse perennial agricultural assemblage associated with Mesoamerican *milpa* fields and *solar/huerta* (dooryard garden) agroecosystems, only the southernmost edge of Arid Americaretains much diversity of perennial food crops. North of the Rio Soto La Marina, Rio Conchos, Rio Mayo and Rio Yaqui (Burns *et al*. 2000), there were very few tree cropsat all until Spanish introduction of Old-World fruits and nuts (Burns *et al*. 2000; Dunmire 2004).

Because of the biotic and abiotic stresses on fruit trees historically posed by highly variable, scarce rainfall as well as challenging heat, transpiration rates and pests, Arid American perennial crops were largely limited to succulent plants utilizing the Crassulacean Acid Metabolism (CAM) pathway, such as agaves and cacti.Importantly, 76% Arid American perennial crops utilize the CAM pathway, while only 66% ofWestern Mesomerican crops use the CAM pathway. The fruit

Table 3: Perennial Food Crops of Western Mesoamerica and Arid America(Full citations for references are in Supplemental Materials)

Scientific Name *=CAM plant	Common Names in Western Mesoamerica	Presence in Western Meso-America	Common Names in Aridamerica	Presence in Arid America
*Agave americana**	teometl, mescal serrano	X	Maguey	X
Agave angustifolia (incl. *A. tequilana)**	maguey espadín, espadilla, zapupe	X	Bacanora	X
*Agave delamateri**			Tonto Basin agave	X
*Agave hookeri**	mezcal	X		
*Agave inaequidens**	maguey bruto, hocimetl, raicilla	X	Agave	X
*Agave karwinksii**	barrial, cirial, popoloca	X		
*Agave mapisaga**	maguey de pulque	X	pulque agave	
*Agave murpheyi**			Hohokam agave	X
*Agave phillipsiana**	mezcal		Phillip's agave	X
*Agave rhodacantha**	maguey de monte, quixe	X	montane agave	X
*Agave salmiana**	maguey de pulque, maguey pulquero cimmarrón	X	pulque agave	X
*Agave sanpedroensis**			San Pedro century plant	X
*Agave verdensis**			Sacred Mountain agave	X
*Agave yavapaiensis**			Page Springs agave	X
*Ananas comosus**	ananá, abacaxi, piña	X	piña, pineapple	
Annona reticulata	anona corazón, corazón de buey, mamón	X	bullock's heart, custard apple, soursop	
Brosimum alicastrum	ramón	X	Breadnut	
Casimiroa edulis	matasano, zapote blanco	X	white sapote, zapote blanco	X
Crataegus pubescens	tejocote	X	Mexican hawthorn, tejocote	
Cyrtocarpa procera	chupandilla	X		
Dioscorea remotiflora	barbasco		camote, yam	
Diospyros digyna	zapote negro, zapote prieto	X	black sapote, ebony, zapote negro	
Distichlis palmeri			nypa, Palmer's saltgrass	X
*Hylocereus undulata**	pitahaya	X	dragonfruit, pitaya	
Leucaena leucocephala	guaje	X	leucaena, guaje	X
Manilkara zapota	chicozapote, chico sapotilla	X	chicle, sapodilla	
Myrtillocactus geometrizans*	garambullo, padre nuestro	X	Garambullo, Mexican fencepost cactus	X
*Nopalea cochinillifera**	nopal chamacuero, nopal de la cochinilla	X	cochineal cactus, nopal de la cochinilla	
*Nopalea karwinksiana**	nopal lengua de vaca	X	cow-tongue prickly pear, lengua de vaca	X
*Opuntia atropes**	nopal blanco	X	nopal blanco, white prickly pear	
*Opuntia durangensis**	xoconostle chivo	X	Prickly pear cactus, xoconostle	X
*Opuntia leucotricha**	nopal duraznillo	X	Nopal duraznillo	X
*Opuntia megacantha (incl. O. albicarpa)**	nopal amarillo, nopal espinudo, nopal manzo	X	nopal amarillo, yellow Eprickly pear cactus	X
*Opuntia robusta**	nopal camueso, tuna tapón	X	Nopal, prickly pear cactus	X
Opuntia streptacantha/ficus-indica complex*	nopal cardona, nopal de Castilla	X	Nopal cardona, nopal de Castilla, prickly pear cactus	X
*Pachycereus hollianus**	acompés, baboso, compés	X	baboso, drooler cactus	
Pachyrhizus erosus	jicama	X	Jicama, Mexican turnip, Mexican yam bean	X
Parmentiera edulis	cauchilote, cuajilote	X	cow okra, food candlenut, cuajilote, Mexican calabash tree	
Setaria parviflora	motilla, paitén, triguillo, zacate sedoso	X	Bristly foxtail, cola de zoora, knotroot foxtail, marsh bristlegrass	X
Solanum jamesii & S. cardiopyllum ssp. *ehrenbergii*	papita gueras	X	wild potatoes	X
*Stenocereus quereteroensis**	pitayo de Queretero	XX	Pitayo, organpipe of Queretero	X

crops of both trees and vines using the C3 pathwayare far more vulnerable to drought stress and crop failure, unless frequently irrigated.

The water conserving Crassulacean Acid Metabolism of cacti and succulents such as agaves allowed them to produce more edible biomass on less moisture than needed by C3 and C4 crop species from the tropics, including maize (Nobel 2009). We predict that climate change will increasing constrain yields of fruit and nut trees that use the C3 photosynthetic pathway and thereby suffer high transpiration rates. In our view, many fruit tree orchards in arid and semi-arid/subtropical landscapes will need to be replaced with CAM succulents such as agaves, prickly pears and columnar cacti if their farmers are to economically weather climate change.

In short, cultivators in the Arid American food system once relied on a relatively greater species richness of domesticated succulent crops (as opposed to trees and woody vines) in their cultivation of perennial food plants than did cultivators in the wetter Mesoamerican food system.As we shall see, there are both agroecological and human health reasons for reviving and extending the cultivation of these CAM succulent crops in dry lands (Leach and Sobolik 2010).

First, the water-conserving Crassulacean Acid Metabolism of cacti and succulents such as agaves allowed them to produce equal tonnages of edible biomass using just half to one-sixth of the moisture needed to provide the same yields by C3 and C4 crop species from the tropics, including maize (Nobel 2009).

Second, these cacti and succulents likely have provided an abundance of antioxidants, inulins and mucilaginous polysaccharides to prehistoric Arid American diets that are may be directly hypoglycemic and/or probiotic, thereby preventing the onset of diabetes (Rheinhard *et al*. 2012, Santos-Zea *et al*. 2012). The very same secondary compounds and mucilaginous complex carbohydrates that protect plants from water loss are also chemo-preventive when placed into human diets (Nabhan 2013b).

When analyzing the ratios of plants that use different metabolic pathways found in the Chihuahuan Desert, Leach and Sobolik (2010) confirmed that agaves and sotol were among the dominant components of pre-Invasion diets there, enabling desert dwellers to consume one of the highest concentrations of inulins from digesting agaves of any diet so far analyzed from any region on the planet. These desert dwelling men were consuming roughly 135 grams of agave inulins on an average day, while women in the same era were consuming 108 grams (Leach and Sobolik 2010). That is about five times the prebiotic dietary fiber than most contemporary Americans are gaining from all of their nutritional sources.

These inulin prebiotics stimulate the growth and development of beneficial gut bacteria while suppressing the growth of less desirable micro-organisms, creating an overall gut substrate that was conducive to promoting positive prehistoric health and well-being. Inulins and polyphenols of agaves are hypoglycemic, possibly preventing diabetes in those genetically predisposed to it (Santos-Zea *et al*. 2012).

Several agaves were independently brought into cultivation on well over 200, 000 hectares innorthwestern Arid America, on the edges of the Sonoran Desert (Fish *et al*. 1985; Hodgson 2012; Hodgson and Salywon 2013; Hodgson *et al*. 2018). They included *Agave delameteri, A. murpheyi, A. phillipsiana*, *A. sanpedroensis, A. verdensis* and *A. yavapaiensis* (Hodgson 2013; Hodgson, Salywon and Doelle 2020), while cultivation of a seventh species remains debated (Nabhan, Olmedo and Pailes 2019).

Toward the southeastern edges of Arid America where several *maguey pulquero* species went through the initial p hases of their domestication process (E. Ezcurra, pers. Com) *magueyales* arecultivated for *pulque* productionon hundreds of thousands if not millions of acres. These *magueyales* included *A. americana, A. angustifolia, A. mapisiga, A. lophantha*and *A. salmiana* which have long been cultivated and culturally dispersed in the Chihuahuan Desert-Altiplano ecotone as much as in Mesoamerica itself (Gentry 1982).

The same may be true with the prickly pear species and varieties that dominate the extensively managed*nopaleras* in the Chihuahuan Desert-AltipIano ecotone, which appear to include clones derived from multiple lineages, including *Opuntia leucotricha, O. megacantha, O. streptacantha* and *O. tomentosa* (Griffith 2004). In addition to this baffling array of cultivars that historically were all lumped into *Opuntia ficus-indica,* there may additional domesticated prickly pears that were historically domesticated in Arid America, such as *Opuntia durangensis* and possibly *Opuntia robusta.*

To summarize, cultivators in the Arid American food system relied on a greater percentage of succulent crops rich in hypoglycemic inulins in their total assemblage of perennials than did cultivators in the wetter Mesoamerican food system (Leach and Sobolik 2010). They may need to do so again.

Characterizing Thewild Food Plant Biodiversity of Arid America and Mesoamerica: In addition to domesticated crop plants from both Arid America and Mesoamerica, Indigenous communities in Arid America have continued to use as significant food and beverage sources over 235 wild plant species from at least 125 genera and 60 families on monocots and dicots. While it is beyond oure current capabilities to make a similar estimate of widely used food and berage plants from Mesomerica, we are relatively certain that the ethnographically documented inventory is much higher for this tropical region than for Arid America. If only for its greater surface area and floristic diversity, Mesoamerica likely has far more species, genera and families of food and beverage plants. Even so, Table 4 is clearly an under-estimate of the total number of the characteristic food and beverage plants of Arid America, for we have not include all microendemics or famine foods, only one known by two or more cultures in the region (Hernández-Sandoval *et al*. 1991; Hodgson 2001; Minnis 2021). It is likely that few additional families or genera would be identified in a complete inventory of the region, but we guess that at least 100 to 150 more species could be added to this regional inventory of gastronomic diversity (mapes and Basurto 2016).

While 225 food and beverage plants are certainly enough do draw upon through local harvesting and intra-region trade, there are some remarkable patterns evident

Table 4: Food plant species with nutritionally-significant roles in Arid American diets consumed by Indigenous cultures of Sonoran and Chihuahuan deserts, as well as those in adjacent semi-arid uplands from eastern Baja California to western Tamaulipas and Texas. Common names are provided in Norteño (northern Mexican) Spanish and Western (Southwestern U.S.A) English.(Full citations for references are in Supplemental Materials)

Family	Taxon	Part Used	Norteño Spanish Common Names†	Western English Common Names†	Metabolic Path way	Reference
Acanthaceae	*Ruellia californica*	flower (nectar)	tronador		C3	Felger & Moser 1985
Adoxaceae	*Sambucus nigra*	flower, fruit	sauco, tapiro	elderberry	C3	Hodgson 2001; Nabhan 2008; Wilken-Robertson 2018
Aizoaceae	*Trianthema portulacastrum*	leaf, seed	verdolaga de cochi	horse-purslane	C3	Felger & Moser 1985; Hodgson 2001
Amaranthaceae	*Allenrolfea occidentalis*	seed	deditos, herba de burro	iodinebush, pickleweed	C3	Felger & Moser 1985
	Amaranthus blitoides	leaves	bledo	mat amaranth	C4	Solano-Picazo & Blancos 2015
	Amaranthus fimbriatus	leaf	quelites	fringed amaranth	C4	Aschmann 1967; Estrada-Castillón 2014; Felger & Moser 1985; León de la Luz *et al*. 2008; Nabhan pers. obs.; Pinkava 1984
	Amaranthus palmeri	leaf, seed	bledo, quelite	carelessweed, pigweed	C4	Aschmann 1967; Estrada-Castillón 2014; León de la Luz *et al*. 2008
	Amaranthus watsonii	leaf	bledo, quelites	amaranth	C4	Aschmann 1967; Felger & Moser 1985; Hodgson 2001
	Atriplex canescens	seed	costilla de vaca	four-winged saltbush		Hernández-Sandoval *et al*. 1991
	Atriplex elegans	leaf	chamisa ceniza	wheel-scale saltbush	C3	Hodgson 2001
	Atriplex lentiformis	seed	chamiso , saladiillo	lens-scale saltbush, quailbush	C3	Hodgson 2001
	Atriplex nuttallii	stem	chamiso	saltbush	C3	Rea 1997
	Atriplex polycarpa	stem	chamiso	saltbush	C3	Hodgson 2001
	Atriplex wrightii	leaf	chamiso	saltbush	C3	Hodgson 2001; Nabhan 1982;
	Chenopodia-strum murale	seed	chual morado	net-leaf goosefoot	C3	Hodgson 2001
	Chenopodium berlandieri	flower (bud), leaf, seed	chual, huazontle, quelite, cenizo	lambs-quarters, pit-seed goosefoot	C3	Aschmann 1959; Hernández-Sandoval *et al*. 1991; Hodgson2001; Wilken-Robertson 2018
	Chenopodium fremontii	leaf	chual	goosefoot	C3	Hodgson 2001
	Dysphania ambrosioides	leaf	epazote	Mexican tea	C3	Hernández-Sandoval *et al*. 1991; Hodgson 2001
	Monolepis nuttalliana	leaf	cenizo del monte, patota	Indian spinach, poverty-weed	C3	Hodgson 2001; Rea 1997
Amaryllidaceae	*Allium drummondi*	bulb	cebollín	wild onion	C3	Hernández-Sandoval *et al*. 1991; Latorre & Latorre 1977
	Allium haematochiton	bulb	cobena	red-skin onion	C3	Hodgson 2001 Felger & Moser 1985; Hodgson 2001; Pinkava 1984
	Allium macroptalum	bulb, leaves	cebollín, cebollita	wild onion	C3	Hernández-Sandoval *et al*. 1991; Hodgson 2001
Anacardiaceae	*Pistacia mexicana*	fruit, seeds	lentisco		C3	Hernández-Sandoval *et al*. 1991
	Rhus microphylla	fruit	agrito, colorín, correosa, jarilla		C3	Hernández-Sandoval *et al*. 1991; Latorre & Latorre 1977; Solano-Picazo & Blancos 2015
Apocynaceae	*Marsdenia edulis*	fruit	batanene blanco, talayote, tonchi	netvine	C3	Felger & Moser 1985; Hodgson 2001
	Matelea cordifolia	fruit	talayote, piwal	Sonoran milkvine	C3?	Felger & Moser 1985; Hodgson 2001
	Matelea pringlei	fruit	tayalote	Milkvine	C3?	Felger & Moser 1985; Hodgson 2001
	Sarcostemma cynanchoides	stem	bejuco de leche, huirote	climbing milkweed	C3	Felger & Moser 1985; Hodgson 2001
	Vallesia glabra	fruit	citábaro, huevito, mahuira	pearlberry	C3?	Felger & Moser 1985; Hernández-Sandoval *et al*. 1991; Hodgson 2001
Arecaceae	*Brahia dulcis*	fruit, leaf "heart"	palma sombrero, soyote	sombrero palm	C3	Hernández-Sandoval *et al*. 1991
	Sabal uresana	fruit	babiso, palma del suelo, plametto	Ures fan palm	C3	Hodgson 2001; Felger & Moser 1985
	Washingtonia filifera	fruit	palma abanico, pamilla	California fan palm	C3	Aschmann 1967; Hodgson 2001
	Washingtonia robusta	fruit	palma abanico, palma coloada	skyduster fan palm	C3	Aschmann 1967; Felger & Moser 1985; Hodgson 2001
Aspargaceae (incl. Agavaceae)	*Agave americana*	leaf (leaf base), caudex, flower (nectar, stalk)	maguey cenizo		CAM	Hernández-Sandoval *et al*. 1991; Latorre & Latorre 1977
	Agave angustifolia	leaf (leaf base), caudex, flower (stalk)	maguey, bacanora	bacanora mescal	CAM	Felger & Moser 1985; Hodgson 2001

Table 4: Continued

	Agave cerulata	leaf (leaf base), caudex, flower (stalk)	maguey	century plant	CAM	Aschmann 1967; Felger & Moser 1985; Hodgson 2001
	Agave colorata (=fortiflora)	leaf (leaf base), caudex, flower (nectar, stalk)	mezcal ceniza	ashen century plant	CAM	Aschmann 1967; Felger & Moser 1985; Hodgson 2001
	Agave deserti	leaf (leaf base), caudex, flower (nectar, stalk)	maguey de la costa	coastal agave	CAM	Hodgson 2001;
Wilken-Robertson 2018	*Agave lechuguilla*	leaf (leaf base), caudex, flower (nectar, stalk)?	lechuguilla	lechuguilla	CAM	Hernández-Sandoval *et al*. 1991
	Agave palmeri	leaf (leaf base), caudex, flower (nectar, stalk)	lechuguilla	Palmer's agave, century plant	CAM	Aschmann 1967; Rea 1997; Hodgson 2001
	Agave pelona	leaf (leaf base), caudex, flower (stalk)	mezcal pelón	bald century plant	CAM	Aschmann 1967; Felger & Moser 1985, Hodgson 2001
	Agave shawii	leaf (leaf base), caudex, flower (nectar, stalk)		Shaw's agave	CAM	Aschmann 1967; Hodgson 2001; Wilken-Robertson 2018
	Agave subsimplex	leaf (leaf base), caudex, flower (stalk)	mezcal	century plant	CAM	Aschmann 1967' Felger & Moser 1985; Hodgson 2001
	Agave weberi	leaf (leaf base), caudex, flower (nectar, stalk)	maguey verde		CAM	Hernández-Sandoval *et al*. 1991
	Dasylirion leiophyllum	leaf (leaf base), caudex, flower (stalk)	smooth sotol	C3		
	Dasylirion longissimum	leaf (leaf base), caudex, flower (stalk)	padillo, varacuete,	sotol	C3	Hernández-Sandoval *et al*. 1991
	Dasylirion texanum	leaf (leaf base), caudex, flower (stalk)	sotol, cucharilla, palmilla de serrucho, sawo, saño	sotol	C3	Hernández-Sandoval *et al*. 1991
	Dasylirion wheeleri (incl. *D. gentryi)*	leaf (leaf base), caudex, flower (stalk)	sotol, cucharilla, palmilla de serrucho, sawo, saño	desert spoon, sotol	C3	Hodgson 2001
	Hesperoyucca whipplei	caudex, flower stalk			C3	Wilken-Robertson 2018
	Triteleiopsis palmeri	bulb	cobena	blue sand-lily	C3	Hodgson 2001; Felger & Moser 1985
	Yucca baccata (incl. Y. arizonica & hybrids)	fruit	dátil, palma crolla, palmilla, sota	Arizona yucca	CAM	Aschmann 1967; Hodgson 2001; Felger & Moser 1985; Pinkava 1984
	Yucca elata	flower	palmilla, yuca, sota, cortadillo, palmito, soyate	soaptree yucca, soapweed	C3	Hodgson 2001
	Yucca filifera	flower	Izote, palma china	giant yucca	CAM	Hernández-Sandoval *et al*. 1991; Solano-Picazo & Blancos 2015
	Yucca schidigera	flower, fruit	datil, palmilla	Mohave yucca	CAM	Aschmann 1967; Wilken-Robertson 2018
	Yucca treculeana		palma pita	Spanish dagger	C3	Hernández-Sandoval *et al*. 1991
Anacardiaceae	*Cyrtocarpus edulis*	fruit	ciruelo cimarron, ciruelo del monte	Baja wild plum	C3	Aschmann 1967
	Rhus ovata	berries	mangle	sugarbush	C3	Wilken-Robertson 2018
Asteraceae	*Tagetes lucida*	flower	herbanís		C3	Hernández-Sandoval *et al*. 1991
	Thymophyllapentacheta	leaves			C3	Hernández-Sandoval *et al*. 1991
	Thymophyllasetifolia	leaves	arnica, engordo cabra		C3	Solano-Picazo & Blancos 2015
Bataceae	*Batis maritima*	root	chamiso, dedito, vidrillo	beachwort, saltwort	C3?	Felger & Moser 1985
Berberaceae	*Berberis haematocarpa*	fruit	agarito	blood-red barberry	C3	Hernández-Sandoval *et al*. 1991
	Berberis trifoliata	fruit	agarito, palo amarillo	three-leaved barberry	C3	Hernández-Sandoval *et al*. 1991; Latorre & Latorre 1977
Bixaceae	*Amoreuxia gonzalezii*	flower, fruit, root	saiya, mome, témaqui	yellowshow	C3	Aschmann 1967; Felger & Moser 1985; Hodgson 2001;
	Amoreuxia palmatifida	flower, fruit, root	saya, saiya, témaqui	yellowshow	C3?	Felger & Moser 1985; Hodgson 2001;

Table 4: Continued

Bombacaceae	*Ceiba acuminata*	root	pochote	cottontree	C3	Hodgson 2001
	Ceiba pentandra	flower, seed, root	ceiba	kapok	C3	Hernández-Sandoval *et al*. 1991
Boraginaceae	*Amsinckia intermedia*	leaf		common fiddleneck	C3	Rea 1997
	Amsinckia tessellata	leaf		bristly fiddleneck	C3	Rea 1997
	Ehretia anacua	fruit	anacua	knockaway, sugar berry	C3	Latorre & Latorre 1977
Brassicaceae	*Brassica juncea*	leaf	mostaza oriental	Chinese mustard	C3	Hodgson 2001
	Descurainia pinnata	seed, leaf	pamita	tansy-mustard	C3	Hodgson 2001;Rea 1997
	Lepidium virginicum	seed	lentejilla	poorman's pepperweed	C3	Hernández-Sandoval *et al*. 1991; Hodgson 2001
Cactaceae	*Carnegiea gigantea*	fruit, seed	sahuaro	giant cactus, saguaro	CAM	Felger & Moser 1985 Hodgson 2001
	Cylindropuntia acanthocarpa	flower (bud)	civiri, choya, tasajo	buckhorn cholla	CAM	Hodgson 2001; Rea 1997
	Cylindropuntia alcahes	flower (bud)	choya	island cholla	CAM	Felger & Moser 1985; Hodgson 2001
	Cylindropuntia arbuscula	flower (bud)	choya, tasajo	pencil cholla	CAM	Felger & Moser 1985 Hodgson 2001
	Cylindropuntia bigelovii	flower (bud)	choya, ciribe	teddy-bear cholla	CAM	Felger & Moser 1985; Hodgson 2001
	Cylindropuntia fulgida	flower (bud), fruit, stem (cladode)	choya de coyote, vela de coyote	chain-fruit cholla	CAM	Felger & Moser 1985; Hodgson 2001
	Cylindropuntia imbricata	flower (bud), fruit, stem (cladode)	candil, choya. coyonoxtle	cane cholla, tree cholla	CAM	Hernández-Sandoval *et al*. 1991; Hodgson 2001
	Cylindropuntia leptocaulis	fruit	choya tasajillo	Christmas cactus	CAM	Hernández-Sandoval *et al*. 1991; Hodgson 2001
	Cylindropuntia x kelvinensis	flower (bud)	choya	Gila cholla	CAM	Hodgson 2001; Rea 1997
	*Cylindropuntia thurberi*subsp. *versicolor*	flower (bud), fruit, stem (cladode)	choya	staghorn cholla	CAM	Felger & Moser 1985; Hodgson 2001
	Echinocactus platyacanthus	fruit, trunk	biznaga burra	barrel cactus	CAM	Hernández-Sandoval *et al*. 1991
	Echinocereus engelmannii	fruit	pitahayita, sinita barbona	hedgehog, strawberry cactus	CAM	Felger & Moser 1985; Hodgson 2001
	Echinocereus enneacanthus		pitaya	strawberry cactus	CAM	Hernández-Sandoval *et al*. 1991
	Echinocereus fasciculatus	fruit	pitahayita	hedgehog cactus	CAM	; Hodgson 2001
	Echinocereus fendleri	fruit	pitahayita	hedgehog cactus	CAM	Felger & Moser 1985; ; Hodgson 2001
	Echinocereus grandis	fruit	pitahayita	Island hedgehog cactus	CAM	Felger & Moser 1985; Hodgson 2001
	Echinocereus nicholii	fruit	pitahayita	hedgehog cactus	CAM	Hodgson 2001
	Echinocereus pectinatus	fruit	pitahayita	rainbow hedgehog	CAM	Felger & Moser 1985; Hodgson 2001
	Ferocactus cylindraceus	fruit	biznaga	California barrel	CAM	Aschmann 1967; Felger & Moser 1985; Hodgson 2001
	Ferocactus emoryi	fruit, stem (pulp)	biznaga	barrel cactus	CAM	Aschmann 1967;; Hodgson 2001; Felger & Moser 1985;
	Ferocactus hamatacanthus			Texas barrel cactus	CAM	Hernández-Sandoval *et al*. 1991
	Ferocactus pilosus		biznaga de cabuches		CAM	Solano-Picazo & Blancos 2015
	Ferocactus stainesii	flower bud, fruit	biznaga roja	Mexican lime cactus	CAM	Hernández-Sandoval *et al*. 1991
	Ferocactus wislizeni	fruit, stem (pulp)	biznaga de agua	compass barrel	CAM	Hodgson 2001
	Lophocereus schottii	fruit, stem	cabeza de viejo, garambullo, sina	old man cactus, senita	CAM	Aschmann 1967; Hodgson 2001
	Mammillaria dioca	fruit	cabecita de viejo	pincushion	CAM	Aschmann 1967; Hodgson 2001
	Mammillaria grahamii	fruit	cabeza de viejo	fishhook cactus	CAM	Felger & Moser 1985; ; Hodgson 2001
	Mammillaria heyderi	fruit	pichilinga	little nipple cactus	CAM	Hernández-Sandoval *et al*. 1991; Hodgson 2001
	Myrtillocactus cochal	fruit	cochal	cochal	CAM	Hodgson 2001
	Myrtillocactus geometrizans	fruit	garambullo	bilberry cactus, blue candle	CAM	Solano-Picazo & Blancos 2015
	Opuntia chlorotica (=gosseliniana)	fruit	nopal	pancake prickly pear	CAM	Aschmann 1967; Hodgson 2001 Hodgson 2001
	Opuntia engelmannii	fruit, stem (cladode)	nopal del monte, tuna	cactus-apple prickly pear	CAM	Aschmann 1967; Felger & Moser 1985; Hodgson 2001
	Opuntia leucotricha	fruit	duraznillo		CAM	Hernández-Sandoval *et al*. 1991
	Opuntia lindheimeri	Fruit, stem (cladode)	nopal	Lindheimer prickly pear		Hernández-Sandoval *et al*. 1991; Latorre & Latorre 1977
	Opuntia phaecantha	fruit, stem (cladode)	nopal	tulip prickly pear	CAM	Aschmann 1967; Hodgson 2001
	Opuntia santa-rita	stem (cladode)	nopal	purple prickly pear	CAM	Aschmann 1967; Hodgson 2001
	Pachycereus pecten-aboriginum	fruit, seed	etcho, cardón barbón	hairbrush cardon	CAM	Felger & Moser 1985; Hodgson 2001
	Pachycereus pringlei	fruit	sahueso, cardón pelón	cardon cactus	CAM	Aschmann 1967; Felger & Moser 1985; Hodgson 2001

Table 4: Continued

	Peniocereus greggii	fruit, root	sarramatraca, reyna de la noche	deerhorn night-blooming cereus, queen of the night	CAM	Felger & Moser 1985; Hodgson 2001
	Peniocereus striatus	root	sacamatraca, reyna de la noche	night-blooming cereus, queen of the night	CAM	Felger & Moser 1985; Hodgson 2001
	Steonocereus griseuse	fruit	pitayo	organpipe cactus	C3	Hernández-Sandoval *et al*. 1991
	Stenocereus gummosus	fruit, seed	pitahaya agria, pitayo agridulce	bittersweet pitaya	CAM	Aschmann 1967; Felger & Moser 1985;; Hodgson 2001
	Stenocereus thurberi	fruit, seed	pitahaya dulce	organ-pipe cactus	CAM	Aschmann 1967; Felger & Moser 1985; Hodgson 2001
Cannabaceae	*Celtis laevigata*	fruit	cúmaro, granjeno, palo blanco	netleaf hackberry	C3	Estrada-Castillón 2014; Hernández-Sandoval *et al*. 1991; Hodgson 2001; León de la Luz *et al*. 2008; Pennington 1980; Pinkava 1984
	Celtis lindheimeri	fruit	palo blanco	Lindheimer hackberry	C3	Latorre & Latorre 1977
	Celtis pallida	fruit	garambullo, granjeno	desert hackberry	C3	Estrada-Castillón 2014; Hernández-Sandoval *et al*. 1991; León de la Luz *et al*. 2008; Pennington 1980, Pinkava 1984
Cleomaceae	*Peristema arborea*	floral buds, flowers	ejotillo, ruda del monte	bladderpod, stinkweed	C3	Wilken-Robertson 2018
Cucurbitaceae	*Cucurbita digitata*	seed	calabacilla loca	coyote gourd	C3	León de la Luz *et al*. 2008; Pinkava 1984; Rea 1997
	Cucurbita foetidissima	seed	chichicoyote, calabacilla	buffalo gourd	C3	Estrada-Castillón 2014; León de la Luz *et al*. 2008; Pinkava 1984;Russell 1908
Cupressaceae	*Juniperus californica*	fruit, ash from leaves	guata	California juniper	C3	Wilken-Robertson 2018
Cyperaceae	*Cyperus erythrorhizos*	leaf (base), tuber	coquito, chufa	red-root flat-sedge	C4	Aschmann 1967; León de la Luz *et al*. 2008; Pinkava 1984
	Cyperus esculentus	leaf (base), tuber	coquito, chufa	yellow nut-sedge	C4	Aschmann 1967; León de la Luz *et al*. 2008; Pinkava 1984
	Cyperus odoratus	leaf (base), tuber	coquito, chufa, cuentas de Santa Elena	rusty flat sedge	C4	Aschmann 1967; León de la Luz *et al*. 2008; Pinkava 1984
	Cyperus rotundus	leaf (base), tuber	coquito, chufa	purple nut-sedge	C4	Aschmann 1967; León de la Luz *et al*. 2008;Pinkava 1984
	Eleocharis geniculata	leaf (base), tuber	junco de ciénega	watergrass	C3	León de la Luz *et al*. 2008; Pinkava 1984
	Scirpus maritimus	seed, tubers	junco, juncia marina	tule	C3	León de la Luz *et al*. 2008; Pinkava 1984
Ericaceae	*Arbutus xalapensis*	fruit	amazaquitl manzanita, xoxocote	Texas madrone	C3	Latorre & Latorre 1977
	Arctostaphylos pungens	fruit	manzanita	manzanita	C3	Hernández-Sandoval *et al*. 1991; Wilken-Robertson 2018
Euphorbiaceae	*Cnidoscolus palmeri*	tuber	ortiguilla, mala mujer	bull nettle, tread softly	C3?	Estrada-Castillón 2014; Felger & Moser 1985; Hodgson 2001 León de la Luz *et al*. 2008; Nabhan, pers. obs
Fabaceae	*Acacia brandegeana*	seed	Teso, vinorama	vinorama	C3	Aschmann 1967; Hodgson 2001
	Acacia cochliacantha	seed	chirohui; chucharillo	boat-spined acacia		Hodgson 2001
	Acacia greggii	seed	uña de gato		C3	Aschmann 1967; Hodgson 2001
	Hoffmanseggia glauca	tuber	camote de ratón, coquito	hog potato, rush pea	C3	Hodgson 2001; Felger & Moser 1985; Pinkava 1984
	Lysiloma candida	fruit, seed	palo blanco	feathertree	C3	Aschmann 1967; Wilken-Robertson 2018
	Olneya tesota	seed	palo fierro	ironwood	C3	Felger & Moser 1985; Hodgson 2001; León de la Luz *et al*. 2008
	Parkinsonia florida	seed	palo verde azul	blue palo verde	C3	Felger & Moser 1985; Hodgson 2001; León de la Luz *et al*. 2008; Pinkava 1984
	Parkinsonia microphylla	seed	palo brea, palo verde común	littleleaf palo verde	C3	Aschmann 1967; Felger & Moser 1985;Hodgson 2001; León de la Luz *et al*. 2008 Pinkava 1984; Wilken-Robertson 2018
	Phaseolus acutifolius	seed	frijol tépari	tepary bean	C3	Felger & Moser 1985; Nabhan & Felger 1978; Pinkava 1984
	Phaseolus filiformis	seed	frijolillo	desert bean	C3	Felger & Moser 1985; Nabhan & Felger 1978; Pinkava 1984
	Pithecellobium dulce	fruit	guamuchil	Malay tamarind	C3	Hernández-Sandoval *et al*. 1991; Hodgson 2001

Table 4: Continued

	Pithecellobium leucospermum	seed	palo pinto	spotted monkeypod	C3	Hodgson 2001; Pennington 1980
	Prosopis glandulosa	fruit (pod)	mezquite	honey mesquite	C3	Aschmann 1967; Estrada-Castillón 2014; Hodgson 2001; Felger & Moser 1985; Latorre & Latorre 1977 León de la Luz *et al*. 2008
	Prosopis pubescens	fruit (pod)	mezquite	screwbean mesquite	C3	Aschmann 1967; Estrada-Castillón 2014; Hodgson 2001; León de la Luz *et al*. 2008; Nabhan 2008; Russell 1908i
	Prosopis velutina	fruit (pod)	mezquite	velvet mesquite	C3	Aschmann 1967; Estrada-Castillón 2014; Nabhan 2008; León de la Luz *et al*. 2008; Rea 1997
Fagaceae	*Quercus agrifolia*	fruit (acorn)	encino	coast live oak	C3	Wilken-Robertson 2018
	Quercus albocincta	fruit (acorn)	cusi, encino roble, encino, hachuka, encino negro	white-banded oak	C3	Pennington 19809; Rea ms
	Quercus arizonica	fruit (acorn)	encino blanco	Arizona white oak	C3	Latorre & Latorre 1977
	Quercus emoryii	fruit (acorn)	bellota	Emory oak	C3	Estrada-Castillón 2014; Hernández-Sandoval *et al*. 1991; Hodgson 2001; León de la Luz *et al*. 2008; Nabhan per s obs.; Pinkava 1984
	Quercus oblongifolia	fruit (acorn)	encino		C3	Estrada-Castillón 2014; Hodgson 2001; León de la Luz *et al*. 2008; Pennington 1980; Pinkava 1984
	Quercus peninsularis	peninsular oak	bellota dulce, encino roble		C3	Wilken-Robertson 2018
Fouquieriaceae	*Fouquieria macdougalii*	fruit	ocotillo macho	tree ocotillo	C3	León de la Luz *et al*. 2008; Pennington 1980
	Fouquieria splendens	flower (bud, nectar)	ocotillo	ocotillo	C3	Estrada-Castillón 2014; Felger & Moser 1985; Hodgson 2001; León de la Luz *et al*. 2008; Pinkava 1984
Juglandaceae	*Carya illinoinensis*	fruit (nut)	nogalillo, nogal pecanero	pecan	C3	Latorre & Latorre 1977
	Juglans major	fruit (nut)	nogal	Arizona walnut	C3	Hernández-Sandoval *et al*. 1991; Hodgson 2001
Lamiaceae	*Poliomintha longiflora*	leaves	oregano	rosemary mint, southwestern oregano	C3	Latorre & Latorre 1977
	Salvia apiana	seed	salvia blanca, salvia orejona	white sage	C3	Wilken-Robertson 2018
	Salvia carducea	seed	chia	thistle chia	C3	Wilken-Robertson 2018
	Salvia columbariae	seed	chia, salvia	desert chia	C3	León de la Luz *et al*. 2008; Pinkava 1984; Rea 1991
	Vitex mollis	fruit	uvalama, igualama	uvalama	C3	Hodgson 2001; Nabhan per sobs.
Lennoaceae	*Pholisma sonorae*	stalk	camote de los medanos, flor de tierra	sandfood	C3	Nabhan 1982
Liliaceae	*Allium drummondi*	bulb	cebollín	wild onion	C3?	Hernández-Sandoval *et al*. 1991; Latorre & Latorre 1977
	Allium haematochiton	bulb	cobena	red-skin onion	C3?	Felger & Moser 1985; Hodgson 2001; Pinkava 1984
	Allium macroptetalum	bulb	cebollín	desert hyacinth	C3	Castetter & Underhill 1935; Pinkava 1984; Hodgson 2001, Rea 1997
Malpighiaceae	*Malphigia umbellata*	fruit	acerola, cerecita	Barbados cherry	C3	León de la Luz *et al*. 2008; Pennington 1980
Malvaceae	*Eremalche exilis*	leaf	malva	desert five-spot	C3	Nabhan 1982; Rea 1991
	Guazuma ulmifolia	seed	guásima	guásima	C3	Pennington 1980
Martyniaceae	*Proboscidea altheaefolia*	seed	uña de gato, cuernitos	devil's claw	C3	Felger & Moser 1985; Hodgson 2001; León de la Luz *et al*. 2008
	Proboscidea parviflora	seed	uña de gato, cuernitos	devil's claw	C3	Nabhan 1982; León de la Luz *et al*. 2008; Pennnington 1980
Moraceae	*Ficus palmeri*	fruit	camuchín, chinito, nacapule	Sonoran strangler fig	C3	Aschmann 1967; Felger & Moser 1985; Hodgson 2001; León de la Luz *et al*. 2008; Wilken-Robertson 2018
	Ficus petiolaris	fruit	tescalama	rock fig	C3	Felger & Moser 1985
	Ficus radulina	fruit	chalate	chalate	C3	Pennington 1980; Rea ms
Nyctaginaceae	*Boerhaavia coulteri*	leaf	mochis, juaninipili	Coulter's spiderling	C3?	Felger & Moser 1985; León de la Luz *et al*. 2008; Pinkava 1984

Table 4: Continued

Oleaceae	*Forestiera angustifolia*	fruit	panalero	desert olive	C3	Hernández-Sandoval *et al*. 1991
Orobanchaceae	*Orobanche cooperi*	stalk	flor de tierra	desert broomrap	C3	Felger & Moser 1985; Hodgson 2001; León de la Luz *et al*. 2008; Pinkava 1984; Rea ms
Passifloraceae	*Passiflora arida*	fruit	sandía de la pasión, rosal de la pasión	passion flower	C3	Felger & Moser 1985 ; Hodgson 2001; León de la Luz *et al*. 2008
	Passiflora palmeri	fruit	granadilla, sandia de la pasión	passion flower	C3	Felger & Moser 1985; Hodgson 2001; León de la Luz *et al*. 2008
Pinaceae	*Pinus cembroides*	Seed (nut)	pino piñon		C3	Hernández-Sandoval *et al*. 1991
	Pinus nelsonii	Seed (nut)	piñon duro		C3	Hernández-Sandoval *et al*. 1991
Pinaceae	*Pinus quadrifolia*	seed (nut)	pino piñonero	singleleaf pinyon	C3	Wilken-Robertson 2018
	Pinus muricata	seed (nut)	pino piñonero	four-leaf pinyon	C3	Wilken-Robertson 2018
Plantaginaceae	*Plantago ovata*	seed pastora	plantain, psyllium		C3	Estrada-Castillón 2014; Felger & Moser 1985; León de la Luz *et al*. 2008;Pinkava 1984
	Plantago patagonica	seed	pastora	Plantain	C3	León de la Luz *et al*. 2008; Pinkava 1984;Rea 1991
Poaceae	*Bouteloua barbata*	seed (caryopsis)	navajita anual	six weeks grama	C4	Felger & Moser 1985; León de la Luz *et al*. 2008; Pinkava 1984
	Distichlis palmeri	seed (caryopsis)	nypa	Palmer's saltgrass	C3	Felger & Moser 1985; Hodgson 2001
	Muhlenbergia microsperma	seed (caryopsis)	liendrilla chica	little-seed muhly	C4	Felger & Moser 1985; León de la Luz *et al*. 2008; Pinkava 1984
	Panicum hirticaule	seed (caryopsis)	panizo cauchín, sagui	Mexican panic grass	C4	León de la Luz *et al*. 2008; Nabhan *et al*. 1985; Pinkava 1984
	Phalaris caroliniana	seed (caryopsis)	alpiste bravío	Carolina canarygrass	C4	Rea 1991
	Phragmites australis	honey edudate, root, stalk		carrizo cane	C4	Hernández-Sandoval *et al*. 1991; Hodgson 2001
	Setaria liebmannii	seed (caryopsis)	zacate tempranero	Liebmann's bristle grass	C4?	Felger & Moser 1985; León de la Luz *et al*. 2008; Pinkava 1984
	Setaria macrostachya	seed (caryopsis)	zacate tempranero	plains bristlegrass	C4?	Felger & Moser 1985; León de la Luz *et al*. 2008 Pinkava 1984
	Sporobolus airoides	seed (caryopsis)			C3	Castetter & Underhill 1935; Hodgson 2001
	Sporobolus cryptandra	seed (caryopsis)			C3	Castetter & Underhill 1935; Hodgson 2001
	Sporobolus virginicus	seed (caryopsis) zacate marino zacate alkalino		seashore dropseed	C4?	Felger & Moser 1985; Pinkava 1984
Polygonaceae	*Antigonum leptopus*	seed, root	Corralito, San Miguelito, vaiburin	coral vine, queen's wreath	C3	Aschmann 1967; León de la Luz *et al*. 2008; Pennington 1990; Aschmann 1967
	Rumex hymenosepalus	stalk	caña agria, hierba colorada, raiz del indio	canaigre, dock, wild rhubarb	C3	Hodgson 2001; Rea 1997
	Rumex violascens	leaf, stalk	caña agria, lengua de vaca	violet dock	C3	
Portulacaceae	*Portulaca oleracea*	leaf, stalk	verdolagas	common purslane	C4 & CAM-like dur ing drought	Aschmann 1967; Estrada-Castillón 2014; León de la Luz *et al*. 2008; Nabhan 2008; Pennington 1980; Pinkava 1984
Resedaceae	*Oligomeris linifolia*	seed		desert cambess, line-leaf whitepuff	C3?	Felger & Moser 1985; León de la Luz *et al*. 2008; Pinkava 1984
Rhamnaceae	*Colubrina texensis*	fruit	coma	hog plum	C3	Latorre & Latorre 1977
	Condalia spathulata	fruit	tecomblate	knife-leaf condalia	C3	Latorre & Latorre 1977
	Condalia warnockii	fruit	frutillo, guichutilla	Warnock's snakewood	C3	Castetter & Underhill 1935; León de la Luz *et al*. 2008; Pennington 1980; Pinkava 1984
	Karwinksia humboldtiana	fruit	cacachila, tullidora	cacachila	C3	Estrada-Castillón 2014; Hodgson 2001; León de la Luz *et al*. 2008; Pennington 1980; Pinkava 1984
	Ziziphus obtusifolia	fruit	bachata, barchata, capulin, ciruela de monte	lotebush, graythorn	C3	Felger & Moser 1985; Latorre & Latorre 1977 León de la Luz *et al*. 2008; Pinkava 1984
Rhizophoraceae	*Rhizophora mangle*	fruit	mangle colorado, mangle rojo	red mangrove	C3	Felger & Moser 1985; Hodgson 2001
Rosaceae	*Heteromeles arbutifolia*	fruit	fusique, toyon	Christmas berry, toyon	C3	Wilken-Robertson 2018
	Prunus ilicifolia	fruit	islaya	hollyleaf cherry, islay	C3	Hodgson 2001;Wilken-Robertson 2018

Table 4: Continued

Rubiaceae	*Randia echinocarpa*	fruit	papache picudo, cirián chino	indigo-berry, papache	C3	Aschmann 1967; León de la Luz *et al*. 2008; Hodgson 2001;Pennington 1980; Pinkava 1984
	Randia laevigata	fruit	sapuche, crucecilla de la sierra	indigo-berry, papache	C3	Aschmann 1967; Hodgson 2001León de la Luz *et al*. 2008; Pennington 1980; Pinkava 1984
	Randia obcordata	fruit	papache borracho, papachillo	indigo-berry, papache	C3	Hodgson 2001
	Randia sonorensis	fruit	vachata Negra,	indigo-berry, papache	C3	Aschmann 1967; Hodgson 2001 León de la Luz *et al*. 2008; Pennington 1980; Pinkava 1984; Rea ms
	Randia thurberi	fruit	papache borracho	indigo-berry, papache	C3	Aschmann 1967; Felger & Moser 1985; León de la Luz *et al*. 2008
	Rhamnus crocea	fruit	yerba del oso	spiny redberry		Wilken-Robertson 2018
Sapotaceae	*Sideroxylon occidentale*	fruit	bebelama		C3	Estrada-Castillón 2014; Felger & Moser 1985; Hernández-Sandoval *et al*. 1991; León de la Luz *et al*. 2008; Pinkava 1984
	Sideroxylon cf. *persimile*	fruit			C3	Pennington 1980; Rea ms
Simmondsiaceae	*Simmondsia chinensis*	fruit	jojoba	jojoba, goat nut	C3?	Aschmann 1967; Estrada-Castillón 2014; Felger and Moser 1985; León de la Luz *et al*. 2008; Wilken-Robertson 2018
Solanaceae	*Capsicum annuum*	fruit	Chiltepín chile quipin	chiltepin, wild chile	C3	Castetter & Underhill 1935; Estrada-Castillón 2014; Felger & Moser 1985; León de la Luz *et al*. 2008 Nabhan 1985; Latorre & Latorre 1977
	Lycium andersonii	fruit	salicieso, frutilla, cacaculo	wolfberry	C3	Aschmann 1967; Felger & Moser 1985; León de la Luz *et al*. 2008; Nabhan 1985; Pinkava 1984
	Lycium berlandieri	fruit	cilindrillo, tomatillo	wolfberry		Hodgson 2001
	Lycium brevipes	fruit	frutilla	Baja desert-thorn	C3	Aschmann 1967; Felger & Moser 1985; Nabhan 1985; Pinkava 1984
	Lycium fremontii	fruit	frutilla, salicieso	Fremont wolfberry	C3	Aschmann 1967; Felger & Moser 1985; Nabhan 1985; Pinkava 1984
	Physalis acutifolia	fruit	tomatillo	sharp-leaf ground-cherry	C3	Curtin 1949; Estrada-Castillón 2014; Hodgson 2001; León de la Luz *et al*. 2008; Pinkava 1984; Rea 1991; Rea ms
	Physalis angulata	fruit	tomatillo			Hodgson 2001
	Physalis crassifolia	fruit	tomatillo del desierto, tomate de culebra	yellow nightshade ground-cherry	C3	Estrada-Castillón 2014; Felger & Moser 1985; Hodgson 2001; León de la Luz *et al*. 2008; Nabhan 1985; Pinkava 1984
	Physalis hederifolia	fruit	tomatillo		C3	Hernández-Sandoval *et al*. 1991; Hodgson 2001
	Physalis philadelphia	fruit	tomatillo		C3	Hernández-Sandoval *et al*. 1991; Hodgson 2001
	Solanum eleagniflolium	fruit	tomatillo, buena mujer	white horse-nettle, Silver-Leaf Nightshade	C3	Curtin 1949; Estrada-Castillón 2014; Hodgson 2001; Pinkava 1984
	Solanum nigrescens	fruit	chichiquelite, yerba mora	American black nightshade	C3	Estrada-Castillón 2014; Hernández-Sandoval *et al*. 1991; Hodgson 2001; León de la Luz *et al*. 2008; Nabhan pers obs.; Pennington 1980; Pinkava 1984
Themadaceae	*Dichelostemma capiatum*	corm	cacomite, coquito	blue dicks	C3	Wilken-Robertson 2018
Theophrastaceae	*Bonellia macrocarpa*	fruit	amole, limoncillo	cudjoewood	C3	Felger & Moser 1985; Nabhan 1985
Typhaceae	*Typha domingensis*	root, stalk	junco, tule	southern cat-tail	C3	Curtin 1949; Estrada-Castillón 2014; Hernández-Sandoval *et al*. 1991; Nabhan 2008; Rea 1991
Verbenaceae	*Glandularia delticola*	leaf	verbena	verbena	C3	Estrada-Castillón 2014; Pennington 1980
	Lantana horrida	fruit	confiturilla, hierba de cristo	lantana	C3	Estrada-Castillón 2014; Felger & Moser 1985; León de la Luz *et al*. 2008; Pinkava 1984
	Lippia graveolens	leaves	orégano	orégano,	C3	Hernández-Sandoval *et al*. 1991, Latorre & Latorre 1
	Lippia palmeri	leaf	orégano, batayaqui	Mexican oregano	C3	Estrada-Castillón 2014; Felger & Moser 1985; Pinkava 1984

Table 4: Continued

Viscaceae	*Phorandendron californicum*	fruit	tojí, secapalo, visco	desert mistletoe	C3?	Estrada-Castillón 2014; Felger & Moser 1985; León de la Luz *et al*. 2008; Pinkava 1984
Vitaceae	*Vitis arizonica*	fruit			C3	
	Vitis mustangensis	fruit	uva cimarron, uva mesteña	mustang grape	C3T	Hernández-Sandoval *et al*. 1991
Zosteraceae	*Zostera marina*	seed caryopsis	trigo del mar, zacate del mar	seawrack	C4?	Felger & Moser 1985; Nabhan pers. obs.

[†]Spanish and English common names from Arizona Sonora Desert Museum Sonoran Desert Digital Library. Accessed 25 November 2019 (http://www.desertmuseumdigitallibrary.org/); Hodgson, W. (2001) *Food Plants of the Sonoran Desert* (Tucson: University of Arizona Press);Schoenhals, L.C. (1988) *A Spanish-English Glossary of Mexican Flora and Fauna* (Hidalgo: Instituto Linguistico de Verano); Sobarzo, H. (19--). *Vocabulario Sonorense* (México, D.F.: Editorial Porrua).

within this inventory. For example, near a fourth (23%) of the characteristic wild food and beverage plant species in Arid America are succulents that utilize the CAM pathway for high water use efficiency photosynthesis. We do not know of any comparable estimate for any other biocultural region in the world. Nevertheless, we suspect that this may be the benchmark ratio (1 edible succulent species for every 4 edible species) against which all other biocultural regions can be compared. It is one of several indicators that could be used to determine the relative climate resilience of biocultural regions across the plant.

This regional inventory has a particular high number of edible species in the genera of *Agave*, *Amaranthus, Atriplex, Cylindropuntia, Echinocereus, Ferocactus, Opuntia, Physalis, Quercus, Randia* and *Salvia.*That five of these ten genera are CAM succulents and another two are droughty hardy trees suggests that these food plants can help for a basis for climate-resilient food security (Nabhan *et al*. 2020). As we will document in later discussions, these genera are particularly rich in bio-active compounds that can potentially reduce diseases and maladies of oxidative stress. In addition, the plants from five succulent genera have also been utilized to elaborate the probiotic beverages we will discuss in later sections (Olivera-Linares *et al*. 2021).

In general, Table 4 makes it abundantly clear that Arid American diets may not have been as rich in species as Mesoamerican diets before the Spanish Invasion, but neither were they "impoverished" or lacking in a variety of plants that provided a diverse array of nutrients. They were not only rich in macro-nutrients, but also offered a diverse array of micro-nutrients and secondary compounds that enhanced flavor, fragrance and in some cases, palatability. In fact, many of these wild foods retain intensive flavor and significant levels of secondary compounds rich in antioxidants that have selected out of domesticated varieties. These secondary compounds may be plant chemical defences that reduce damaging herbivory by pests or damaging solar radiation, while also providing antioxidants in quantities sufficient to reduce oxidative stress (Linhart and Thompson 1999).

This may be partularly true for many of the crop wild relatives listed in Table 5, which compares in a general manner the relative abundance of crop wild relatives among the total number of wild foods in each of the two regions. There are clearly many species of crop wild relatives in each region whose use as food probably predated the presence of their domesticated congers. They may have "pre-adapted" the taste preferences and gut metabolisms of Arid American and Mesoamerican dwellers to the use of the crops that later became hyper-abundant in many localities.

While Indigenous communities in both cultural regions have continued to utilize an impressive number of wild and incipiently-managed species to the present time (eg. Hodgson 2001), they have maintained a particularly intense interest in the wide variety of wild crop relatives that can be used directly as food (Contreras-Toledo *et al*. 2018; Riordan and Nabhan 2019). These continuing traditions give us insight into the evolution of the prehistoric Arid American and Mesoamerican diets (Zizumbo-Villarreal and Colunga-GarcíaMarín 2010).

There are some interesting features of this continued reliance of wild harvests of crop wild relatives, particularly in Arid America where it may have granted Indigenous communities a modicum of food security and resilience not witnessed in neighboring non-Indigenous communities (Hernández-Santana and Narchi 2018; Minnis 2021; Riordan and Nabhan 2019). Because of the constraints of an arid climate, frequent or prolonged droughts and poor soils placed on most Arid American inhabitants attempting to grow certain crops, some dwellers of these region have continued to rely heavily on the desert-adapted crop wild relatives which consistently produce products similar or superior to those of congeneric Neotropical domesticates (Table 5).

Table 5: Wild Relatives of Crops Used for Food in Western Mesoamerica and Arid America (Full citations for references are in Supplemental Materials)

Genera cultivated in the two cultural regions	Wild analog eaten in Mesoamerica	Wild analog eaten in Arid America
	A.americana, A. angustifolia, A cupreata, A. maximiliana, A. rhodocantha	*A. aktites, A. Americana, A. angustifolia, A, bovicornuta, A. colorata, A. jaiboli, A. palmeri, A. parryi, A. shrevei*
Amaranthus	*A. hybridus, A. spinosus*	*A. fimbriatus, A. palmeri, A. powellii*
Annona	*A. longiflora, A. reticulata*	
Casimiroa	*C. edulis*	*C.edulis*
Capsicum	*C. annuum*var.*glabriusculum*	*C. annuum*var.*glabriusculum*
Chenopodium	*C. berlandieri*	*C. annuum, C. fremontii, graveolens, C. murale, C. neomexicanum*
Crataegus	*C. pubescens*	
Cucurbita	*C. radicans, C. sororia*	*C. digitata, C. foetidissima, C. sororia*
Diospyros		*D. sonorae, D. texana*
Dysphania	*D. ambrosioides*	
Ficus	*F. obtusifolia, F. padifolia*	*F. inspidia, F. petiolaris*
Helianthus		*H. anomalus, H. tuberosus*
Hylocereus	*H.ocamponis, H. pupusi*	
Manilkara	*M. zapota*	
Opuntia	*O. atropes, O. jaliscana, O. hypiacantha*	*O. engelmannii, O., O.inacea, O. polycantha, O.*
Pachyrhizus	*P. erosus*	*Ipomoea (Exogonium) braceteata*
Panicum	*P. hirticauile*	*P. capillare, , hirticaule*
Parmentiera	*P. aculeata*	
Phaseolus	*P. coccineus, P. lunatus. P. vulgaris*	*P. acutifolius, P. maculatus*
Physalis	*P. angulata, P. philadelphica*	*P. philadelphica*
Porophyllum		*P. gracile*
Prunus	*P. serotina*	*P. serotina*
Psidium	*P. guajava, P. sartorianum*	
Solanum tubers	*S. cariophyllum, S. ehrenbergii*	*S. fendleri, S. jamesii*
Solanum fruit	*S. lycopersicon* var. *cerasiforme, S. nigrescens*	*S. americanum, S. douglasii, S. eleaginifolium,*
Spondias	*S. edulis*	
Tagetes	*T. anisatum, T. erecta*	*T. lucida*
Yucca	*Yucca*	*Y. angustissima, Y. baccata, Y. elata, Y. schottii.*

Many of these wild relatives of domesticated crops retain intensive flavor and significant levels of secondary compounds rich in antioxidants that have selected ouyt of domesticated varieties. These secondary compounds may be plant chemical defences thar reduce damage by pests and or daming solar radiation, whilealso providing nutritional benefits that reduce oxidative stress (Linhart and Thompson 1999).

Nevertheless, the domesticated species did not necessarily "replace" or "make obsolete" their wild congeners, especially during periods of drought or famine (Mapes and Basurto 2016; Minnis 2021). To this day, the popularity of the wild foods such as amaranth greens, chiltepín peppers, wild grapes and plums, or prickly pear cactus fruits in Arid America has not waned. That may be surprising to some agronomists and crop breeders, given the fact thattheir domesticated counterparts were introduced to the region centuries or millennia ago.

In essence, most of the crop wild relatives have the potential provide more yield stability under varying climatic conditions than do their domesticated congeners. They are also ideal to use as rootstock, trap crops for pests in hedgerows and as pollinator attractants in orchards. Nutritionally, these wild crop relatives also retain many of the nutritionally-beneficial secondary compounds than have been selected out of domesticated crops by centuries of breeding.

Table 6 compares the richness of crop wild relatives in two local floras. We compared to the two local floras to the crop wild relatives listrs in Contreras *et al*. (2018) and Riordan and Nabhan (2019). One of thge floras is derived from the Sierra de Manantlán of Jalisco and Colima, not far from the putative "cradle" of Mesoamerican domestication of maize and beans in the Rio Balsas watershed (Vásquez *et al*. 1995). The other is derived from the Sierra El Aguaje of coastal Sonora, on the Sonoran Desert ecotone with semi-arid subtropical thornscrub. The Sierra del Aguaje lies within the 530, 000 ha Guaymas region and harbors roughly 700 vascular plant species (Felger *et al*. 2017). In contrast, the Sierra de Manantlán area ---surrounding the biosphere of the same name--- covers less than a fourth of the área (140, 000 ha) of the

Table 6: Comparison of Crop Wild Relatives in Two Localized Floras, One from Meosamerica, the Other from Arid America (Full citations for references are in Supplemental Materials)

Food Crop Family	Crop-related Genus	Crop common name Spanish	Number of species in Sierra del Aguaje, Son./Arid America	Number of species in Sierra de Manantlan, Jal./Mesoamerica
DICOTS				
Amaranthaceae	*Amaranthus*	bledo, quelite	2+	6+
	Chenopodium	chual, huazontle	2	2
Anacardiaceae	*Spondias*	ciruela	-	
Annonaceae	*Annona*	anona, chirimoya	-	6
Asteraceae	*Helianthus*	girasol	-	16
	Poropyllum	papoquelite	1	6
	Stevia	Stevia, yerba dulce	-	16
	Tagetes	anís, yerbanís	-	6
Bixaceae	*Bixa*	achiote	-	1
Brassicaceae	*Brassica*	mostaza	-	1
Cactaceae	*Hylocereus*	pitahaya	-	2
	Opuntia	nopal, tuna	1	3
	Stenocereus	pitaya	1	1
Caricaceae	*Carica*	papaya		1
Convolvulaceae	*Ipomoea*	camote, jicama	3	33+
Cucurbitaceae	*Cucurbita*	calabaza	-	1
	Sechium	chayote	-	1
Ebenaceae	*Diospyros*	persimo	-	2
Ericaceae	*Vaccinium*	capulin	-	2
Euphorbiaceae	*Cnidoscolus*	chaya	-	3
	Manihot	yuca	-	5
Fabaceae	*Canavalia*	frijolón	-	4
	Inga	juaniquil		4
	Leucaena	guaje	-	2
	Pachyrhizus	jicama	-	1
	Phaseolus	frijol	1+	7
	Pithecellobium	guamúchil	-	3
Juglandaceae	*Juglans*	nogal	-	1
Lamiaceae	*Hyptis*	chan, chia grande, conivari	-	8
	Salvia	chia	--	36
Lauraceae	*Persea*	aguacate	-	2
Malvaceae	*Hibiscus*	jamaica	1	2
Moraceae	*Ficus*	higuera, tescalama	3	14
Myrtaceae	*Psidium*	guayaba	-	3
Passifloraceae	*Passiflora*	flor de la pasión	2	13
Portulacaceae	*Portulaca*	verdolaga	3	1
Rosaceae	*Crataegus*	tejocote	-	2
	Fragaria	fresa	-	1
	Prunus	capulín	-	5
	Rubus	zarzamora	-	7
Rutaceae	*Casimiroa*	zapote blanco	-	1
Sapotaceae	*Pouteria*	mamey	-	1
Solanaceae	*Capsicum*	chile de iguana, chiltepin	1	2
	Jaltomata	jaltomata	-	2
	Physalis	tomatillo	3	10
	Solanum	chichiquelite, hierba mora, papa, tomatillo	1	30+
Vitaceae	*Vitis*	uva criolla	-	1
MONOCOTS				
Agavaceae/ Asparagaceae	*Agave*	mezcal, maguey	3	8+
	Yucca	izote	-	2
Dioscoreaceae	*Dioscorea*	camote	-	11
Liliaceae	*Allium*	cebollín	-	1
Orchideaceae	*Vanilla*	vainilla	-	1
Poaceae	*Panicum*	chri chiri, mijo de Guinea, sagui	1	14+
	Setaria	pasto de palma	2	5+
	Zea	maiz	-	3

Table 7: Traditional Culinary Preparations and Biodiversity Processed withthem into Two Uto-Nahua Communities, One in Western Mesoamerica and One in Arid America (Full citations for references are in Supplemental Materials)

Cooking Technique	Spanish Term	Nahuatl Term	Mesoamerican SpeciesUsed	Hopi term	Arid American SpeciesUsed
To sun dry	Secar	tlauatsa, uaki	*Brosimum, Prosopis, Psidium, Quercus, Spondias*	qöqööopi	*Amaranthus, Capsicum, Cleome, Cucurbita, Echinocereus, Eriogonum, Helianthus, Monarda, Pectis, Phaseolus, Poliomintha, Thelesperma, Wislizenia, Zea*
To salt dry	A salar	istatl, ixtatl	Meat? Fish?	oönga, oöngtosi	Meat? Fish?
To smoke-cure	Ahumar	pocheua	*Capsicum*	kwits'-òopokiwta	Meat? Fish?
To bake or roast in pit(earth oven)	Tatemar (así dicen en Zapotitlán)	ikxa, tlakualchiualia, potze	*Iguana, Lippia, Odocoileus, Nasua, Notocitellus, Pappogeomys, Pecari, Physalis, Solanum, Sylvilagus*	tuupe	*Agave, Yucca*
To steam in pit-		temaststli?	*Agave, Dasypus, Enterolobium, Iguana, Meleagris, Nopalea, Odocolieus, Opuntia, Oreopanax, Pecari, Phaseolus, Physalis, Vitis, Tilia, Zea*	koysi, t?	*Descurainia, Eriogonum, Zea*
To bake on griddle	Colalear, A la plancha, Cocinar al comal	komali	*Capsicum, Persea, Solanum, Zea*	tuma	*Atriplex, Zea*
To wrap in leaves &/or corn masa as a filling	Relleno como Tlacoyo	tlacoyo, tlataoyo	*Oreopanax, Tilia, Vitis, Zea*	siitangu'viki	*Zea*
To grill over flames	A la parrilla	tepostlapech-tlatsaloni, tlatsoyonia, tlecuil- ("3 armed barbecue)	Meat? Fish?	tu'tsi, tu'tsivi	Meat? Fish?
To pop (then grind) Seeds	Reventar palomitas	tlekueponi	*Amaranthus, Zea*	lemotuk	*Mentzelia*
To germinate seed sprouts	Germinar retoños	?		haruu, ngàa-kuyvani	*Phaseolus lunatus, Triticum*
To boil in water	Hervir	kuakualaki, potsonia	*Amaranthus, Anas Brosimum, Capsicum, Chenopodium, Cucurbita, Iguana, Ipomoea, Jacararatia, Nopalea, Meleagris, Opuntia, Ortalis, Phytolacca, Stenocereus, Portulaca, Prosopis, Psidium, Solanum, Spondias Tagetes, Theobroma, Vanilia, Zea, Zenaida*	kwiiva	*Artemesia, Atriplex, Chenopodium, Cleome, Opuntia, Portuluca, Solanum (*with clay), *Stanleya*
To bake in ashes/ on coals	-Hornear en el rescoldo (cenizas)	tlekonextli	*Enterolobium, Zea*	tovutpe	Zea
To soak in water with ashes or lime to soften	Nixtamal-Iizar	nextli+tamalli, nextamali, texia (to grind masa)	*Zea*	qotsvi	*Zea*
To toast or parch then grind seeds into flour or sauce	Chichinar, chamuscar	chichinoa	*Capsicum, Cucurbita, Guazuma, Hyptis, Phaseolus, Physalis, Quercus, Pithecollobium, Solanum, Zea*	kutuki	*Achnatherum, Chenopodium, Eriogonum, Muhlenbergia Panicum, Phaseolus, Sporobolus*
To fry in fat or in seed oil	Freír	?		kutukta, wiikwiva, witrikna	*Capsicum, Citrullus, Helianthus, Lepus, Meleagris, Odocoileus, Ovis, Sylvilagus*
To pickle in vinegar or cure in sour juice	Curtir en escabeche o vinagre	xokoktli	Fish?	?	*Lycium?*
To ferment beverages or leaven yeast bread	Fermentar, Chichil?	aui, chichilia, xoxola	*Agave, Ananas, Bromelia, Cucurbita, Prosopis, Spondias*	ivaqwri, peek-yewma	*Agave, , Carnegiea, Opuntia, Zea?*
To distill alcohol	Destilar alcohol or into syrup		*Agave?*	?	
To candy with sugar	Caramelizar				

Guayma region, yet harbors at least 2, 770 vascular plant species. That is nearly four times the species richnessof the desert region. As one might expect, the Sierra de Manantlán in Mesoamerica is home to many more genera (45) of wild relatives than the number of genera represented in the Sierra del Aguaje in Arid America (17).

Remarkably, the Sierra de Manantlán conserves *in situ* over 330 species of crop wild relatives compared to the 30 species that the Sierra del Aguaje conserves. In essence, the Mesoamerican biosphere reserve harbors ten times the number of species that the Arid American biosphere reserve harbors, even though the latter is roughly four times larger in land area. These trends suggest three patterns: 1) that Mesoamericans had far more opportunities to domesticate food plant species from local wild floras; 2) that the constraints on those opportunities in desert areas may have encouraged Arid American communities to actively seek out crops first domesticated in more tropical climes, or 3) that they sought to diversify the number of locally-adapted land races of the few species they themselves brought into cultivation that were derived from their own regional flora.

Table 8: Comcaac (Seri) Food and Beverage Preparation Techniques in Arid America (Full citations for references are in Supplemental Materials)

Cooking technique	Spanish term	In Seri language Cmique iitom	Foodstuffs prepared this way	Water- & wood-conserving technique
To pop seeds on hot rocks (or on comal griddle)	Reventar palomitas	hamaptx	Amaranth & iodine bush seeds then finely ground for pinoles	Minimal use of fuelwood, no water
To toast seeds or pods on top of hot rocks or in gravel	Tostar, chichinar en piedras	coozin, quizin (transitive form)	Mesquite & other legume pods, seeds of cactus & trigo del mar	Minimal use of fuelwood, no water
To cook in or under ashes	Hornear en cenizas y en la encima carbon y lumbre	caat	Starchy tubers, (as well tortillas & breads of corn, wheat, amaranth, cactus seeds, etc)	Modest use of fuelwood, no water
To parch in hot sand or in a frying pan		ccaaat	Mesquite pods or *Olivella* "snails"	Minimal use of fuelwood, no water
To singe thorns or spines off in flames	Chamuscar espinas con la llama	cozliom, cziiom (transitive form)	De-spined prickly pear or cholla cactus pads	Minimal use of fuelwood, no water
To burn in or over flames	Quemar	camatis	Remove fur from packrats, squirrels, seaweed from swimming crabs	Minimal use of fuelwood, no water
To stew or sauteé	Guisar o hacer cocidos y casuelas	cooznij, quiznij (transitive form)	Wolfberries & figs, vegetables & meats	Modest use of fuelwood, no water
To cook with wood fire on top &/or underneath	Tatemar	camaai	Agaves & sotol	Significant use of fuelwood, no water
To steep by adding warm or immersing in boiled water	Hervir, escarpar o dejar en infusión	coaotoj, quiztoj (transitive form)	Atoles, chocolate, instant coffee, or mashed mesquite pods & tepary beans	Modest use of fuelwood & water
To cook in hot pit atop stones and coals	Tatemar en horno	hant caamac	Agaves, (& elsewhere, sotol & cholla buds)	Minimal use of fuelwood, no water
To fry in animal (eg., sea turtle) fat (or oil from sunflower or squash seeds)	Freír	zihàx quih ano quisni	Shellfish (mollusks), eggs, meats of sea turtles, iguanas, birds, deer & other mammals,	Modest use of fuelwood, no water
To roast or grill on skewer (usually) elevated above coals	Asar (a la parilla)	quisni, [eenm iti icoosni is the grill itself]	Swimming crabs, fish, sea turtle, venison, bighorn sheep, etc	Modest use of fuelwood, no water
To roast or grill on a wooden skewer or coa placed in smoke upright near fire	Asar/ahumar	camequet	Sea turtle, venison, bighorn sheep mutton, etc.	Modest use of fuelwood, no water
To steam or smoke in roasting pits	Ahumar or cocer al vapor	caxaat, hax iháaxat	Fish, (elsewhere, cholla buds)	Modest use of fuelwood, no water
To bake (post-Colonial, still rare)	Hornear, cocer al horno	casiimet	Breads, pies, puddings	Modest use of fuelwood, no water
To parch or toast whole or cracked corn or other grains in a basket with coals	Tostear o tatemar como pinole	caamn	Amaranth, corn & wheat pinoles, served as gruels with a minimum of water used	Minimal use of fuelwood, no water
To sun-dry (sometimes with salt)		cöcahootij	Sea lion or javelina jerky	No use of fuelwood, nor water
To ferment fruit juices with wild yeasts	Fermentar	camaax	Tepache, tesguino, nawait, mesquite pod & cactus fruit & wine	Minimal use of water, no fuelwood

Characterizing the Food Processing Traditions of Arid America and Mesoamerica: In the following discussion, we have highlighted the food processing techniques documented in Zapotitlán de Vadillo, Jalisco in Western Mesoamerica, a munipality whose inhabit inhabitants are largely descendents of Nahuatl speakers and those of the Hopi, O'odham (Piman) and Comcaac (Seri) speaking villages of the greater Sonoran Desert region in Arid America. Allexcept for the Comcaac are Indigenousagricultural communities in the Uto-Nahua linguistic family. The Comcaac of the coastal Sonoran Desert are possibly of the Hokan language family and are among the last hunter-gatherers in North America. They uniquely use marine resources as food, including *Zostera marina*, a seagrass with a nutritious, high fiber grain.

The compilations in Tables 7, 8 and 9 demonstrate that a remarkable range of food preparation techniques have been retained in both communities. Table 7 demonstrates that some of these techniques were shared across Uto-Nahua cultures throughout Mesoamerica and Arid America. The only possible cognate shared by Nahual and Hopi for a food prepation technique is for curing foods in smoke, *pocheua*versus *òopokiwta*, but they are distinctive enough as lexemes to suggest an ancient divergence. There is uncanny similarity in at least of their culinary preparations.

However, there is also a relative paucity of words for frying in oil or fat, pickling in vinegar, carmelizing or candying with sugar, or distilling into alcohol. Ironically, the modern "Western" culinary techniques of frying meats and vegetables in fat, of picking vegetables in vinegar, of salting, candying, or curing in acidic juices and of fermenting then distilling alcohols were but a small if not neglible component of traditional processing of foods and beverages prior to the Spanish, French and English Invasion of North and Central America. This historic absence of certain cooking techniques that were elsewhere introduced during the Spanish Invasion are also echoed in Tables 8 and 9.

Table 9: O'odham (Piman) Food and Beverage Preparation Techniques in Arid America (Full citations for references are in Supplemental Materials)

Cooking technique	Spanish term	In Northern Pima languages (O'odham ha-neok)	Foodstuffs prepared this way	Water- & wood-conserving technique
To pop seeds on hot rocks (or on comal griddle)	Reventar palomitas	sipañ, sipuna	Amaranth, corn	Minimal use of fuelwood, no water
To toast seeds or pods on top of hot rocks or in gravel, then grind into pinole	Tostar, chichinar en piedras	jajka	Tansy mustard seeds, chenopod seeds, tepary beans, wheat	Minimal use of fuelwood, no water
To cook or roast in a pit with coals or ashes	Hornear en un horno de tierra, con cenizas la encima carbon y lumbre	chuama; cuama	Hog potato tubers, sandfood stalks	Minimal use of fuelwood, no water
To toast or parch with hot coals in a basket or frying pan, then mix with water, then grind into pinole	Tostar con brazas en una canasta, guari o sarten	hahake. hahage, hahk, sitorhaca	tepary beans, wheat	Minimal use of fuelwood & water by reducing particle size & increasing absorption rates
To singe thorns or spines off in flames	Chamuscar las espinas/ Espinarse	voIca; wohiw	Prickly pear fruit	Minimal use of fuelwood, no water
To stew or sauteé	Guisar o hacer cocidos y casuelas	bahida, bahu baha, bai, bajdi, guisarta	Beef, venison, squash, beans, tubers, onions	Modest use of water & fuelwood
To roast for a few minutes on top of wood coals, with hot ashes on top &/or underneath	Tatemar en olla pasar un dia y recoger	mohona	Broomrape stalks, sandfood stalks	Minimal use of fuelwood, no water
To boil or immerse in hot water (with neither salt or fat added)	Hervir, escarpar o dejar en infusión	ku'iwona, posholt poxolt;totpada	Chia seeds, wheat grains with saltbush stems; patota leaves (with fat & salt)	Modest use of fuelwood & water
To cook in hot pit atop stones and coals w/o saltbushes	Tatemar en olla o horno	devartam kuadad bajdi	Agave and sotol hearts & stalks	Minimal use of fuelwood, no water
To fry in animal (eg., deer fat or oil from sunflower or squash seeds)	Freír in fish oil tutle oil venado Borrego cimarron	iolith, urha cotorhca	Purslane leaves & stems with onion, tomato & cheese	Modest use of fuelwood, no water
To roast or grill on skewer elevated above coals	Asar (a la parilla)	gai, ga'a, kuhag, kukkag	Meat from deer, rabbit, packrat, dove or quail	Minimal use of fuelwood, no water
To steam or smoke in roasting pits	Ahumar or cocer al vapor	kupsimda	Cholla cactus buds wrapped in seepweed, or saltbush leaves to produce steam	Modest use of fuelwood, no water
To bake (post-Colonial, still rare)	Hornear, cocer al horno	pahnmt	Breads, pies	Modest use of fuelwood, no water
To parch whole or cracked corn or other grains in a basket with coals	Tostar o tatemar como pinole	jajka	Pinole	Minimal use of fuelwood, no water
To sun-dry (sometimes with salt)	Secar en el sol como carnes seca machaca	gakidag, gakidi	Strips of beef, venison, or saguaro fruit pulp	No use of fuelwood, nor water
To ferment fruit or pod juices with wild yeasts or kefir	Fermentar	mawait, naupait gekvidi (=fortify), baki (=make ripe)	Saguaro fruit pulp and seed	No use of fuelwood, nor water
To dry fruit pulp in sun on rocks or cloth	Secar carne de fruta en el sol encima de piedras o telas	gakidi, gak im, gakijid	Saguaro fruit pulp	Minimal use of fuelwood & water by reducing particle size & increasing absorption rates
To grind	Moler o machacar carnes, camotes o semilla	chuhi, cuhivi, tuhi	Banana yucca fruit pulp with seeds & fiber removed to for cakes	Minimal use of fuelwood & water by reducing particle size & increasing absorption rates
To mash or shred	Machacar	sonbi, xoñvi	Mesquite & screwbean pods (the latter leaching in a streamside pit)	Minimal use of fuelwood & water by reducing particle size & increasing absorption rates
To grind into paste	Moler masa de nixtamal	matmid tui	Maize	Minimal use of fuelwood, no water
To burn or singe	Quemarse	cusa, cusapa, mehi, meiji	Chiles	Minimal use of fuelwood, no water
To steam	Vapor	gakidatuda, kuhbs wo'iwa, kuhbs wo'iwa sudog kubich	Cholla buds	Minimal use of fuelwood & water

This is most evident in Table 8's accounting of hunter-gather culinary techniques still used by the Comcaac on the Sea of Coast of Sonora (Luque-Agraz, 2012). As Table 8 demonstrates, many of their techniques for food preparation and cooking in Arid America conserved both water and fuelwood. Of 18 Comcaac culinary preparations, one uses virtually any water; one uses a mimium amount of fuelwood but no water; seven use minimum amounts of water but no fuelwood; eight use modest amounts of water and fuelwood; and one uses significant amounts of fuelwood, but no water. Sadly, the few sucrose- and fructos-rich sweeteners once harvested and processed by the Comcaac (Seri)--- represented by sixteen fruits, four agave species, one perennial halophyte, pollen paste ('beebread") and honey from *Apis* honeybees—have been replaced by enormous volumes of industrially processed high-fructose corn syrups, or granulated cane and beet sugars in their contemporary diets (Narchi *et al*. 2020).

Table 10: Genera of plants and insects used as primary substrates for fermented (and micro-distilled) beverages before and after the Spanish Invasion

Plant Genus (*=Historic Introduction as Crop to North & Central America)	Indigenous or Spanish Name for Probiotic/Fermented Beverage	Presence in Arid America (*=Pre-Spanish Invasion)	Presence in Mesoamerica (*=Pre-Spanish Invasion	References on Traditional or Microbial Processing or Nutritive Value
Acaciella	coyote, pulque colorado, revoultijo	X*	X*	Wilson & Pineda 1963
Acromia	chicha de coyol, pulque de coyol, taberna, tuba		X*	Alcantara-Hernandez *et al*. 2010; Ojeda-Linares at al. 2021; Wilson & Pineda 1963
Agave	agua miel/pulque (various), bingarrote, bingui, excomunión, mezcal, mistela por alambique, vino mezcal, vino resacado, vino tepeme	X*	X*	Ojeda-Linares at al. 2021; Romero-Luna *et al*. 2017; Wilson & Pineda 1963
Ananas	tepache, pulque curado de piña, sendechó, vino resacado	X	X*	Butu & Rodino 2019; Islam *et al*. 2021; Ojeda-Linares at al. 2021; Romero-Luna *et al*. 2017; Wilson & Pineda 1963
Annona	pulque de chirimoya, pulque de chirmoia	X*	X*	Wilson & Pineda 1963
Bromelia	timbiriche, tepache de timbiriche, tumbiriche	X*	X*	Wilson & Pineda 1963
Carnegiea	colonche, imam hamáax, navait, vino de saguaro	X*		Felger & Moser 1974; Ojeda-Linares at al. 2021
*Cicer**	Resoli			Wilson & Pineda 1963
*Citrullus**	Resoli	X	X	Wilson & Pineda 1963
*Citrus**	pulque de naranja, poche de cidra, zagadardica,		X	Wilson & Pineda 1963
*Cocos**	Tuba	X	X	Ojeda-Linares at al. 2021; Romero-Luna *et al*., 2017; ilson & Pineda 1963
Dasylirion	Sotol	X*		Flores-Gallegos *et al*. 2019
Echinocactus	agua de biznaga	X*		del Castillo & Trujillo 1991; Peña-Sánchez & Hernández-Albarrán 2014
Escontria	colonche, nochoctli, vino de xuega		X*	Ojeda-Linares *et al*. 2020
*Hordeum**	cerveza, chicha, resoli	X	X	Wilson & Pineda 1963
Lonchocarpus	Balché		X*	Ojeda-Linares at al. 2021
Lophophora	Peyote	X*	X*	Wilson & Pineda 1963
*Malus**	chuanuco, sidra	X	X	Wilson & Pineda 1963
Myrtillocactus	vino de garambullo		X*	Peña-Sánchez & Hernández-Albarrán 2014
Nopalea?	vino de xoconostles, pulque curado de xonocostles		X*	Peña-Sánchez & Hernández-Albarrán 2014
Opuntia	chiquitto, colonche, nochocle, nochoctli, pulque colorado, revoultijo, sangre de conejo, vono de tuna	X*	X*	Ojeda-Linares *et al*. 2020; Romero-Luna *et al*., 2017; Wilson & Pineda 1963
Pachycereus	colonche, nochoctli, vino de cardón		X*	Ojeda-Linares *et al*. 2020
Psidium	pulque de guayaba			Wilson & Pineda 1963
Polaskia	colonche, nochoctli		X*	Ojeda-Linares *et al*. 2020
Prosopis	vino de mezquite	X*	X*	Nabhan 2019
Prunus	atole de capulin, chuanuco, v licor de capulin, polla ronca, pulque de almendra, pulque de Durazno, tepache de ciruelas pasadas		X	Wilson & Pineda 1963
*Punica**	vino de Granada		X	Peña-Sánchez & Hernández-Albarrán 2014
*Pyrus**	Sidra			Wilson & Pineda 1963
Rubus?	polla ronca		X	Wilson & Pineda 1963
*Saccharum**	charanda, guaxapo, pox, sinque, vino de caña		X	Ojeda-Linares at al. 2021; Wilson & Pineda 1963
*Schisnus**	copalotile, cuauchan, tolonze		X	Wilson & Pineda 1963
Spondias	jobo, obo, pulque de obos, tepache de jobo		X*	Sagrero-Nieves & de Pooter 1992; Wilson & Pineda 1963
Stenocereus	colonche, imam hamáax, navait, vino de pitahaya dulce	X*	X*	Felger & Moser 1974; Ojeda-Linares *et al*. 2020; Quiroz *et al*. 2018 Felger & Moser 1974
*Tamarindus**	cerveza		X	Wilson & Pineda 1963
Theobroma	chorote		X*	Ojeda-Linares at al. 2021
*Triticum**	cerveza	X	X	Wilson & Pineda 1963
Vitis (wild)*	aguardiente criolla, aguardiente de uva silvestre, vino generoso	X	X	Wilson & Pineda 1963
Zea	atole agrio, chorote, ostoche, ostozti, pox, pozole, sakásendecho, sendechó, tecuín, tejuino, tesguino	X*	X*	Ojeda-Linares at al. 2021; Wilson & Pineda 1963
Honey from *Apis**	balché, chinguirito		X	Ojeda-Linares at al. 2021; Wilson & Pineda 1963
Honey from *Melipona* bees (Xunan Kab)	balché, xtabentún		X*	Ojeda-Linares at al. 2021
Honey from Scaptotrigona bees (Pisil Nejmeh))	balché, xtabentún		X*	Ojeda-Linares at al. 2021

Returning to another Uto-Nahua farming culture in some of the driest reaches of the Sonoran Desert of Arid America, we see a set of culinary preparation techniques among the binational Tohono O'odham (Moraga Campuzano 2016; Tohono O'odham Community Action 2010) that appear to be intermediate between the foraging Comcaac (Table 8) and Uto-Nahua riverine farming cultures such as Yoeme (Yaqui) and Yoreme (Mayo) (Yocupcio Buuiimea 2000).

The twenty-six traditional O'odham culinary preparation tehniques include five that minimize both fuelwood and water; fourteen that minimize fuelwood but use no water at all; five that use a modest amount of fuelwood, but no watert; and two that require no water nor any fuel. This intriguing set of food and beverage preparations practices remains largely intact in remote desert rancherias of the Tohono O'odham, where the average resident uses less than a third of the per capita water use per day of the average Arizona resident (120 gallons per day). The routine uses of locally cut fuelwood may at first appear to be a significant cause of greenhouse gas emissions but the total use of energy per O'odham household is insignificant to the use of gas, wood. And electricity from mixed sources most North American cities.

Finally, we give special consideration to Arid American and Mesoamerican beverages, to contrast with most studies of Indigenous gastronomy, which almostalways offer an exclusive focus on foods. It is overwhelming clear that Mesoamerican beverage traditions are far more developed and diverse than those in Arid America (Ojeda-Linares at al. 2021). However significant use of traditional fermented beverages persists in the Sierra Madre Occidental with the Raramuri (Tarahumara), Tepehuan and Guarigio; in the Soinoran Desert, with the Comcaac and Toho O'odham); and in the Altiplano -Chihuahuan Desert transtition with the Wirikuta (Huichol) and neighboring Indigenous communities.

Remarkably at least 38 genera of plants and honeys from 3 genera of bees have been employed in México for fermented and distilled beverages (Table 10). At least 12 (or possibly 14) of the plant genera and 2 of the genera of bees were already employed in the preparation of fermented beverages as primary substrates before the Spanish Invasion. Of the fermented, mostly probiotic beverages elaborated prior to the Spanish Invasion, ten genera of plants were used as primary substrates for fermentation in Arid America, whereas eighteen plant genera and at least two genera of honey from bees and wasps were utilized as primary substrates for fermentation (Olivera-Linares *et al*. 2021.)

That these traditional food and beverage techniques have undergone a demise in the 20^{th} and 21th centuries has hypothetically contributed to the vulnerability of desert dwellers to many of the diseases of oxidative stress now being aggravated by climate change. And yet because few nutritional studies of Indigenous diets compare the raw foodstuff with the traditionally processed food or beverage—and with its industrialized analog (Kuhnlein and Receveur 1996; Kuhnlein and Calloway 1987)—we can only speculate about their impacts.

DISCUSSION

As explicitly stated earlier, our goal is to detail how the composition of the food plants in these two regional sets of diets--when interacting with Indigenous culinary processing techniques--can help reduce the health impacts of climate change, especially for Indigenous dweeler of arid landscapes. We hypothesized that a) the phytochemical and physiological adaptations of food plants to abiotic stresses in arid environments incidentally serves to buffer their human consumers from diseases of oxidative stress; and b) lessons learned from both gastronomic traditions have the capacity to help desert dwellers manage diabetes and other diseases of oxidative stress now being aggravated by climate change.

The documentation and analysis offered so far indicate that the floras of both Arid America and Mesoamerica have a great diversity of food and beverage plants with superb adaptations to the stresses ofwater scarcity, heat and damaging solar radiation that are becoming more evident as climatre change proceeds. There is a high ratio of succulent plants using the CAM photosynthetic pathway to food and beverage plants utilizing the C3 and C4 photosynthetic pathwaysin Arid American diets. Nevertheless, there remains an even greater species richness of CAM plants in Mesoamerica, given its many edaphic and rain-shadow deserts and semi-arid subtropical habitats.

Our novel hypothesis is these phytochemical and physiological adaptations to abiotic stresses in arid environments incidentally buffer the human consumers of these food and beverage plants from diseases of oxidative stress, especially adult-onset diabetes. While there is emerging evidence from several isolated studies which convinces us that this is a viable hypothesis worthy of further investigation, no single research paper can prove or disprove such a sweeping hypothesis. Nevertheless, our research has revealed one key pattern that bears more research by desert plant physiologists, human physiologists and epidemiologists: that the same complex polysaccharide mucilages, gums and other soluble fibers that slow the water loss from the tissues of many desert plants also slow the digestion and absorption of sugars in the human g.i. tract, thereby reducing pancreatic stress due to widely-varying levels of insulin production resulting from spikes in blood glucose (Nabhan 2013b).

This research, like many other investigatyions in recent years, brings into question that genetic determinism embedded in Neel's (1962) "thrifty gene hypothesis" which posited that a gene (or a very few genes) predominant in Indigenous populations were historically advantageous in accumulating body fat in feast and famine environment like deserts, hence the tagline "thrify genes." However, this gene became detrimental to the humans that carried it in the modern world where ample foodstuffs were available year-round, predisposing them to adult-onset diabetes and other diseases of oxidative stress. Unfortunately, when this hypothesis was explained to IndigenousO'odham (Pima) communities on both sides of the México-U.S., it fostered a fatalism that their contemporary tribal members were all destined to die prematurely due to carrying this gene (sic).

Tenty years after first popularizing the thrifty gene concept, Neel (1982) himself already had doubts about the reductionistic nature of his hypothesis. While there were also racist consequences of applying this hypothesis to so called "primitive" (sic) hunter-gatherers as well as subsistence farmers in famine-prone deserts, it remained the dominant driver of adult-onset diabetes research until the onset of the Human Genome Project. Hundreds of millions of dollars were spend on genetic research in diabetes-prone Indigenous communities in attempts to prove and apply this hypothesis, while the prevalence and incidence of type two, adult-onset diabetes continued to rise within them.

There is now clear evidence "that past positive selection has not been a powerful influence driving the prevalence" of alleles that put individuals at risk for type two diabetes mellitus (Ayub *et al*. 2014). The same researchers further found only nominal evidence for positive (prehistoric) selection at fourteen of the loci statistically associated with the risk of diabetes. They concluded that overall, "Selection favored the protective and risk alleles in similar proportions, rather than the risk alleles specifically as predicted by the thrifty gene hypothesis and may not be related [at all] to influence on diabetes (Ayub *et al*. 2014).

About the same time the Human Genome Project began in 1990, one of us assisted a National Institute of Health and Australian research teams with reconstructing the Arid American dietary composition of the O'odham (Pima) Indians for clinical studies (Boyce and Swinburn 1993; Brand-Miller *et al*. 1990; Cowen 1990; Nabhan 2013b; and Swinburn *et al*. 1991.

When placed on a reconstructed Arid American diet for fourteen days that was then compared with a modern, globalized diet of the U.S.A., the traditional diet increased oral glucose tolerance and insulin sensitivity, while decreasing plasma lipids much more than "Causasians" placed on the same diets (Boyce and Swinburn 1993). The researchers deemed that a return to the traditional diet was sufficient to prevent or reverse symptoms of type two, adult-onset diabetes (Swinburn *et al* 1991).

The reconstructed Arid American diet had less simple sugars and more complex carbohydrates for a total of 70-80% carbohydrates (Boyce and Swinburn 1993), but many of the carbohydrates were "slow-release" hypoglycemic foods like tepary beans, and mesquite pods (Brand-Miller *et al* 1990; Nabhan 2013b). In addition, the traditional diet was comprised of 8-12% fat, but some of these vegetal fats –like those in tannin-rich acorns--were also excellent "slow-release" hypoglycemic foods (Brand-Miller *et al* 1990). Importantly, the Arid American diets, while seasonally variable in greens in fruits (Boyce and Swinburn 1993), generally increased insulin sensitivity in addition to lowering plama glucose levels (Brand-Miller *et al* 1990; Swinburn *et al*. 1991), thereby offering diabetes-prone individuals a greater metabolic capacity over extended time to digest and absorb carbohydrates without increasing blood glocuse levels (Swinburn *et al*. 1991).

At another level of analysis, it is clear to us that the selection of "raw materials" forthe plant components of Mesoamerican and Arid American diets is not the only gastronomic dimension of these diets that offered nutrition benefits that can mute diseases of oxidative stress (Kuhnlein and Calloway 1977). The food and beverage processors and cooks in Indigenous communities –particularly middle-aged and elderly women-- skillfully processed many of these plants into nutritious, probiotic and antioxidant rich foods and beverages(Luque-Agraz 2012). Some, if not many, of their prepared foods and beverages could likely prevent or at least reduce the symptoms of the diseases of oxidative stress that are now proliferating in part because of climate change. The big question, of course, is whether these place-based gastronomies only served Indigenous communities well prior to European Invasion and subsequent globalization, or whether they have relevance for dealing with the daunting health challenges of the present and future conditions of the Anthropocene.

Table 11: Documentation of bioactive compounds in the food plant genera of Arid America that may potentially protect desert dwellers from diseases of oxidative stress exacerbated by climate change (Full citations for references are in Supplemental Materials)

Family	Genus	References
Adoxaceae	*Sambucus*	Acuña *et al*., 2002; Aðalar, Demirci, & Can Baþer, 2014†; Wu *et al*., 2004
Amaranthaceae	*Amaranthus*	Bradow & Connick, 1988†, Jiménez-Aguilar & Grusak, 2017; Kasozi *et al*., 2018; Kim *et al*., 2006; Tang & Tsao, 2017; Yelisyeyeva *et al*., 2012
	Atriplex	Chikhi, *et al*. 2014; Geron *et al*., 2006†; Lopez & Uria-Silvas, 2007; Urias-Silvas *et al*., 2008
	Chenopodium	Pellegrini *et al*., 2018; Tang & Tsao, 2017
Amaryllidaceae	*Allium*	Petkova *et al*., 2019; Roman-Ramos *et al*., 1995
Asparagaceae	*Agave*	Leach & Sobolik, 2010; López & Urias-Silvas, 2007; Nazaruk & Borzym-Kluczyk, 2015; Ojeda-Linares *et al*. 2020; Santos-Zea *et al*. 2012; Stewart, 2015; Urias-Silvas *et al*., 2008
	Dasylirion	Lopez & Uria-Silvas, 2007; Urias-Silvas *et al*., 2008
	Yucca	Cheeke, Piacente, & Oleszek, 2006; Piacente, 2004; Rodriguez, 1983†; Svensson *et al*., 2005†
Bixaceae	*Amoreuxia*	Hoffman *et al*., 1993
Cactaceae	*Carnegiea*	Cruse, 1949; Ojeda-Linares *et al*., 2020; Santos-Díaz & Camarena-Rangel, 2019; Shetty, Rana, & Preetham, 2011
	Cylindropuntia	see opuntia
	Echinocereus	Kay, 1996
	Ferocactus	Perez-Guiterrez & Mota-Flores, 2010; Elansary *et al*., 2020
	Opuntia	Chavez-Santoscoy *et al*., 2009; Chiej, 1984; Farag *et al*., 2017†; Guenther *et al*., 1999†; Hwang *et al*., 2017; Hernandez-Galicia *et al*., 2002; Lopez & Uria-Silvas, 2007; Ojeda-Linares *et al*., 2020; Ramos *et al*., 1995; Santos-Díaz & Camarena-Rangel, 2019; Wright & Wright, 2013†
	Pachycereus	Hernández-Martínez *et al*., 2016; Ojeda-Linares *et al*., 2020; Santos-Díaz & Camarena-Rangel, 2019; Shetty, Rana, & Preetham, 2011
	Stenocereus	Hernandez-Galicia *et al*., 2002; Ojeda-Linares *et al*., 2020; Santos-Díaz & Camarena-Rangel, 2019
Cannabaceae	*Celtis*	Adedapo *et al*., 2009; Gastelum, Mejía-Velázquez, & Lozano-García, 2016†
Cucurbitaceae	*Cucurbita*	Andrade-Cetto & Heinrich, 2005; Hernandez-Galicia *et al*., 2002; Leach & Sobolink, 2010; Nazaruk & Borzym-Kluczyk, 2015; Roman-Ramos *et al*., 1995
Fabaceae	*Parkinsonia*	Divya, Mruthunjaya, & Manjula, 2011; Marzouk *et al*., 2013†; Mulat, Pandita, & Khan, 2019
	Phaseolus	Brand *et al*., 1990; Hayat, *et al*., Oomah *et al*., 2007†; 2014; Hernandez-Galicia *et al*., 2002; Ranilla, Genovese, & Lajolo, 2007; Roman-Ramos *et al*., 1995; Suárez-Martínez *et al*., 2015; Türkan *et al*., 2005
	Prosopis	Brand *et al*., 1990; Choge *et al*., 2007; Gastelum, Mejía-Velázquez, & Lozano-García, 2016†; Guenther *et al*., 1999†; Kay, 1996; Johnson Salazar, & Estudillo, 1996
Lamiaceae	*Condea (Hyptis)*	McNeil *et al*. 2011
	Salvia	Alarcon-Aguilar *et al*., 2002; Ayerza & Coates, 2005; Pellegrini *et al*., 2018;
Martyniaceae	*Proboscidea*	Schauss, 2010
Moraceae	*Ficus*	Chiang & Kuo, 2000†; Chiang & Kuo, 2001†
Plantaginaceae	*Plantago*	Frati-Munari *et al*., 1989; Viljoen, Mncwangi, & Vermaak, 2012
Poaceae	*Panicum*	Bisoi *et al*., 2012; Quanzhen *et al*., 2012; Pradeep & Guha, 2011
	Sporobulus	Toqeer *et al*., 2018
Portulaceae	*Portulaca*	Bai *et al*., 2016; Lee *et al*., 2012; Ramadan, Schaalan, & Tolba, 2017; Tkachenko, 2015*
Rhamnaceae	*Ziziphus*	Balderrama-Carmona *et al*., 2019; Guenther *et al*., 1999*; Olajuyigbe & Afolayan, 2011
Rubiaceae	*Randia*	Alarcon-Aguilara *et al*. 1998; Juarez-Trujillo *et al*., 2018
Sapotaceae	*Sideroxylon*	Araújo-Neto, 2009
Solanaceae	*Capsicum*	Forero, Quijano, & Pino, 2009*; Silva *et al*., 2013; Rodríguez-Maturino *et al*., 2011; Willard 1992
	Lycium	Geron *et al*., 2006*; Guenther *et al*., 1999*; Qiong *et al*. 2005; Zhang *et al*., 2016
	Physalis	Bernal *et al*. 2018; Hernandez-Galicia *et al*. 2002; Yilmaztekin, 2014*
	Solanum	Aburjai, *et al*., 2014*; Hernandez-Galicia *et al*., 2002
Verbenaceae	*Lippia*	Calvo-Irabíen *et al*., 2014*; Leyva-Lopez *et al*., 2016

†Reference includes biogenic organic volatile compounds (BVOCs)

Given the many technological advances in food harvesting, storage, processing technologies and medical care, it is unlikely that all the labor-intensive foraging, farming and food processing practices of the past can (or should be) revived. There may indeed be social, ecological or economic disincentives for contemporary Indigenous communities to revive some of these traditions of plant food procurement, even though there are clearly nutritional, medical and cultural reasons for doing so.

Nevertheless, as Table 11summarizes, there are at least 50 genera of Neotropical food plants that were historically part of Arid American and Mesoamerican diets that have bioactive compounds characteristic of nutraceuticals. Although we cannot speculate on the necessary serving sizes needed for these food and beverage plants to have positive nutritional and medical impacts, their potential value in grappling with some of the mostly costly health crises in human history cannot be dismissed. If harvested sustainably and prepared carefully to retain key nutrients and antioxidants, they can potentially help prevent or at least moderate the many diseases of oxidative stress, especially diabetes.

For most of these genera, there are one or more species already commercially available as raw foods, prepared foods, as herbal supplements, or as newly designed nutriceuticals. The issues of access and of barriers to affordability are then worthy of evaluation. However, the possibilities of "rebirthing, " "reviving" or "restoring" these foods and beverages are not necessarily beyond affordability in Indigenous communities. This is particularly in those communities where philanthropic or governmental subsidies for healthy (including "native" foods are offered to Indigenous communities in either México or the U.S.A. For example, USDA Women, Infants and Children (WIC) food subsidy programs subsidizes the collection or propagation of certain native foods, as does the Comisión Nacional Forestal (CONAFOR) in México. In addition, the 2014 Farm Bill in the U.S.A. authorized funding for a new program called the Food Insecurity Nutrition Program, that has begun to offe grant funds to non-profit organizations (including some community health clinics and hospitals) that wish to improve access to healthy, culkturally-appropriate foods in their community.

In several regions, food prescription programs are available though medical insurance or other health care programs (Nischan 2010). Regarding the latter, "Food Prescription programs make it easier for low-income patients and their families to access the fresh fruits and vegetables they need in order to ensure that they are eating balanced, healthy diets. The programs generally begin with a partnership between a hospital and a local farmer's market or CSA (community supported agriculture)" (Miller 2020).

As an example, the Wholesome Wave Foundation's Fruit and Vegetable Rx Program (FVRx) is a four-to-six-month program designed to link healthcare providers, local food producers and families with diet-related illnesses that currently operates in five U.S.A. states. According to monitoring studies of participants (Miller 2020):

- By 2013, nearly 55% of FVRx Food Prescription participants who completed all aspects of the program increased their daily consumption of fruits and vegetables by an average of 2 cups.
- In addition of 95% of participants stated that they were happier with their healthy weight management program due to their participation in FVRx.
- 41% of youth participants who were vulnerable to childhood obesity and pre-diabetic symptoms decreased their Body Mass Index (BMI).

Finally, as Nabhan *et al*. (2020) have also proposed, the cultivation of many of these Indigenous foods of Arid America in needed in newly designed or renovated agroforestry systems to address the "coming food security and agricultural crises" (Nabhan 2013a, Nabhan 2020) triggered by climatic changes and the pandemic. These arid-adpted food crops-- when planted in perennial-dominated polycultures--may restore land health, especially soil moisture holding capacity, while reducingcrop consumptive water use and providing yield stability in the face of climatic uncertainty (Nabhan *et al*. 2020).

CONCLUSIONS

We have concluded that the following geographic patterns exist relative the pre-Invasion foods of Indigenous diets of Ard America and Mesoamerica, particularly regarding their health benefits:

- Both regions have a great diversity of plant foods of various lifeforms (trees, herbs, succelent perrenials) etc which contain a great array of phytochemical and physiological adaptations to hot, dry climates that allow them to survive in the hot, dry climates that humankind is increasing facing.
- While Mesoamerica is much more floristically diverse, with greater food plant species richness than Aridamerica, the latter region has a high percentage of endemic succulents which have been elaborated into prebiotic foods and probiotic beverages for millennia.
- The biotic componds found in 50 genera of food and beverage plants shared between the two regions —including antioxidants and hypoglycemic mucilages—have promising health benefits for dealing with the maladies of hot, dry climates and likely protected pre-Invasion Indigenous peoples from diabetes and other nutritoion related diseases.

- It is not merely the food plants themselves, but the traditional knowledge of processing techniques--such as culinary ash enhancement and fermentation of probiotic beverages—thatr assured healthful diets.
- Given that many Indenous communities have taken it upon theseselves to reintegrate these plants and culinary techniques into their contemporary diets, it is entirely possible that they can serve as an effective dietary intervention to manage type two, aldult-onmset diabetes and other diseases of oxidative stress already being exacerbated by climate change.

As noted in the Introduction, our objectives for this reappraisal of healthful, plant-based diets that evolved prior to the Spanish Invasion is to evaluate the possibility of their revival so that a) they can reduce the number of people suffering from climate- and nutrition-related diseases while B) contributing to the restoration of food sovereignty to Indigenous communities in ways that reinforce their cultural identity and assure thgeir continuity.

Regarding the first objective, we have established a tentative link between Indigenous diets high in the consumption of succulent plants (of the CAM photosynthetic pathway) such as agaves, columnar cactus friuit, pineapples and sotol that have superlative adaptations to abiotic stresses and the capacities of diets based on these plants to prevent or reduce diseases of oxidative stresses in cultural communities that regularly consume them. This linkage--- of arid-adapted plants that can reduce water loss and heat loads affecting their productivity and survival-- with the foods and beverages (derived from these same plants) that are chemo-protective in the human metabolism---is so potentially valuable in an era of rapid climate change that it demands more exploration and verification.

With regard to the second objective, we wish to emphasize that many of the initial efforts to revive to the original structure and composition of the Mesoamerican and Arid American diet have already emerged from Indigenous communities themselves (eg., Calvo and Rueda Esquibel 2015; Edaakie and Enote 1999; Kavena 1980; Mihesuah 2005; Patchell and Edwards 2013;Tohono O'odham Community Action 2010; and Wolfe *et al*. 1985). Even before many of the books were published by authors of Indigenous heritage, their communities in México and the U.S.A. were quietly reintegrating traditional foods long part of Mesoamerican and Arid American diets into their contemporary feasts and health care strategies.

In essence, the revival of Mesoamerican and Arid American gastronomic traditions is not a top-down or exogeneous pressure toward dietary change, but a grassroots or community-based movement toward true food sovereignty (Patchell and Edwards 2013). Our research only validates many of the tenets that underlie this Indigenous movement and points to the nutritional benefits of lesser-kown culinary practices, such as culinary ashes and probiotic beverages fermented from succulent plants that are then infused with high antioxidantherbs and fruits. Conservating the wild plants, protecvting the traditional crop lanr races and protected as well as celebrating traditional ecological, gastronomic and horticultural knowledge of Indigenous Nations in Arid America and Mesoamerica will be just as critical as policies to foster their food sovereignty. As climate change deferentially threatens Indigenous communities, food sovereignty will be paramount.

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