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Nutrient composition of selected traditional United States Northern Plains Native American plant foods☆,☆☆

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ABSTRACT

Ten wild plants (cattail broad leaf shoots, chokecherries, beaked hazelnuts, lambsquarters, plains prickly pear, prairie turnips, stinging nettles, wild plums, raspberries, and rose hips) from three Native American reservations in North Dakota were analyzed to expand composition information of traditional foraged plants. Proximates, dietary fiber (DF), vitamins, minerals, carotenoids, and folate vitamers were assayed using standard methods and reference materials. Per serving, all were rich in Mn (100–2808 μg). Several provided >10% DRI of Fe (cattail shoots, steamed lambsquarters, and prairie turnips), Ca (steamed lambsquarters, prickly pear, and prairie turnips), Mg (cattail shoots, lambsquarters, prickly pear, and prairie turnips), vitamins B6 (chokecherries, steamed lambsquarters, broiled prickly pear, and prairie turnips), C (raw prickly pear, plums, raspberries, rose hips (426 mg/100 g), and K (cattail shoots, chokecherries, lambsquarters, plums, rose hips, and stinging nettles). DF was >10 g/serving in chokecherries, prairie turnips, plums and raspberries. Rose hips, plums, lambsquarters, and stinging nettles were carotenoid-rich (total, 3.2–11.7 mg/100 g; β-carotene, 1.2–2.4 mg/100 g; lutein/zeaxanthin, 0.9–6.2 mg/100 g) and lycopene (rose hips only, 6.8 mg/100 g). Folate (primarily 5-methyltetrahydrofolate) was highest in raw lambsquarters (97.5 μg/100 g) and notable in cattail shoots, raw prairie turnips, and blanched stinging nettles (10.8, 11.5, and 24.0 μg/100 g, respectively). Results, provided to collaborating tribes and available in the National Nutrient Database of the United States Department of Agriculture (USDA) (www.ars.usda.gov/nutrientdata), support reintroduction or increased consumption of foraged plants.

1. Introduction

The diets and nutrient intakes of Native Americans have changed over time. From the 1800s until the 1970s, the fundamental nutritional concern of Native people was a lack of adequate food (Story et al., 1998). The composition of the traditional diet of Native Americans has changed gradually, with increased intakes of fat and decreased consumption of harvested plant foods (Byers, 1996). Traditional foods of Native Americans (American Indians and Alaska Natives), largely influenced by climate, geography and tribal mobility, are specific to each Native American nation tribe. Fishing, hunting, harvesting and to some extent, agriculture, permitted the tribes to make the best use of indigenous resources. Also specific to the tribes are ceremonial dishes and everyday dishes, where cultural and/or spiritual meaning is very important (Kittler and Sucher, 2001).

Currently, traditional foods and particularly plant foods are not being eaten on a regular basis. A 2002 survey found that fewer than 10% of Native American children consumed traditional foods (Lytle et al., 2002). Moreover, among the foods actually being eaten at

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present, only 7 of the more than 1300 foods listed were identified as traditional. Surveys have shown that Native Americans regard traditional foods as health-promoting (Powers and Powers, 1990), but these foods are usually consumed only at special ceremonies and celebratory events (Bass and Wakefield, 1974; deGonzague et al., 1999; Toma and Curry, 1980; Woolf et al., 1999; Zephier et al., 1997).

The under-nutrition among Native Americans prevalent in the 1970s has been replaced by over-nutrition, in which contemporary food products, which are low in micronutrients (vitamins and minerals) but high in energy content (particularly fat) and are known to promote obesity, predominate (Lytle et al., 2002; Stang et al., 2005; Story et al., 1998; Taylor et al., 2005; Zephier et al., 1997). Studies of dietary intakes of Native Americans in Arizona, North Carolina, North and South Dakota, and Oklahoma found that vitamin and mineral intake fell under the recommended levels, but that fat consumption exceeded what is recommended in health guidelines, at >35% of daily energy intake (deGonzague et al., 1999; Zephier et al., 1997).

Many plant foods are rich in health-promoting components, including vitamins, minerals, and other bioactive factors, and have low fat and high fiber contents. It is likely that promoting consumption of traditional Native American foods could improve nutrition in these populations (Burns Kraft et al., 2008); however, there is a paucity of information on the nutrient contents of these plant foods, particularly the ones traditionally consumed among tribes in the Northern Plains (Schauss, 2010; Woolf et al., 1999). Nutrient composition data for these foods are needed to develop nutrient databases that support both practical and research applications that rely on food composition data (Amy and Pehrsson, 2003; Ershow, 2003; Pennington, 2003), to increase knowledge of biodiversity in food composition (Burlingame et al., 2009), and to facilitate health intervention research and programming.

Although some reports exist on some of the nutrients in a few of the foods (e.g. Andersson et al., 2011; Bhargava et al., 2008; Guil et al., 1997; Guil-Guerrero et al., 2003; Kuhnlein, 1990; Yildirim et al., 2001), without common control samples between studies it is impossible to compare nutrient concentrations because inter-laboratory analytical uncertainty could be confused with a true difference in composition (Phillips et al., 2006a). Additionally, different growing conditions can affect the concentration of nutrients in the same plant species (Bhargava et al., 2008; Pennington, 2008). Biodiversity of food composition is of increasing interest for sustainable food supplies (Burlingame et al., 2009; Charrondière et al., 2013; Heywood, 2011; Toledo and Burlingame, 2006).

This study focused on determining the nutrient composition of ten traditional wild plant foods collected in season by Native American tribes from reservations in the Northern Plains region of the US, as part of the US Department of Agriculture (USDA) National Food and Nutrient Analysis Program (Haytowitz et al., 2008), with detailed quality control including analysis of commercially available reference materials, to increase data on the composition of traditional Native American foods (Amy and Pehrsson, 2003).

2. Materials and methods

2.1. Samples

Staff from United Tribes Technical College (UTTC) (Bismarck, ND, USA) contacted tribal leaders and elders of the Turtle Mountain Band of Chippewa (Belcourt, ND, USA), three affiliated tribes of Ft. Berthold, ND (Mandan, Hidatsa, Arikara), and Standing Rock Sioux reservation (ND) and received permission for participation in this study. UTTC staff accompanied selected tribal elders who collected traditional plant foods: prairie turnips (*Psoralea esculenta* Pursh.), lambsquarters (*Chenopodium album* L.), cattail broad leaf shoots (*Typha latifolia* L.), stinging nettles (*Urtica dioica* L.), wild plums (*Prunus americana* Marshall), chokecherries (*Prunus virginiana* L.), wild rose hips (*Rosa pratincola* Greene), wild raspberries (*Rubus idaeus* L.), beaked hazelnuts (*Corylus cornuta* Marshall), and plains prickly pears (*Opuntia polyacantha* Haw.) in a culturally respectful manner in 2005 during the typical foraging season (May and June) at each of the three reservations located as indicated in Fig. 1. A late frost and other impediments to optimal growing conditions limited the number and amounts of plant foods that were available for collection; therefore, a total of 0.5–2 kg of each plant was sampled. The total amount comprised one sample for each food except prairie turnips (2 samples), chokecherries (3 samples), stinging nettles (2 samples), cattail shoots (3 samples), and lambsquarters

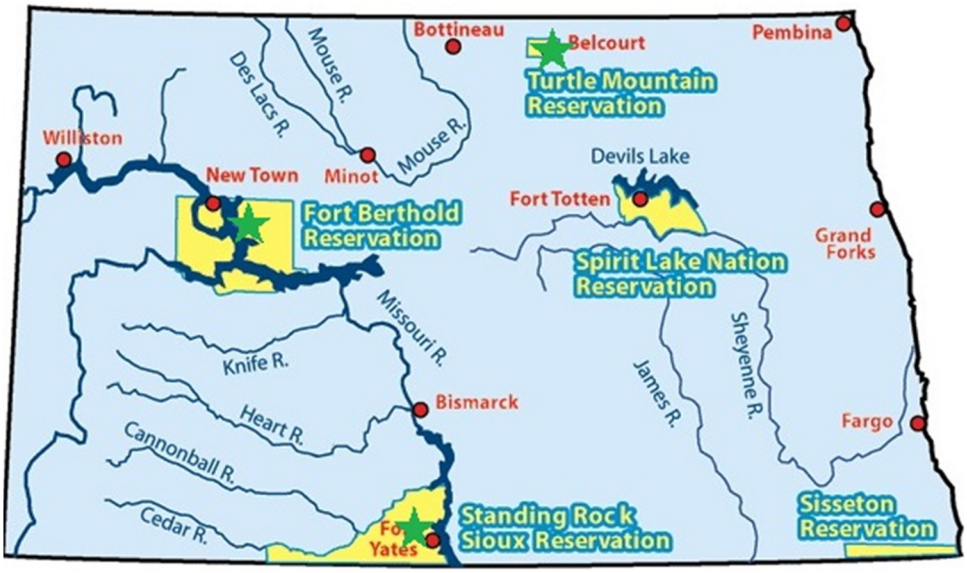


Fig. 1. Sampling locations (★) for Native American Plains Indian food samples (source of underlying map: North Dakota Studies Program, State Historical Society of North Dakota, http://www.ndstudies.org/images/aind/reservations.gif).

(2 samples), with a "sample" being the material collected from a given location on a given day. Each sample was homogenized and subsampled for analysis, except for lambsquarters where the two samples were composited, and cattails shoots where two of the samples were combined for analysis and the third was analyzed individually.

Plant species were identified as closely as possible by horticulturalists in the UTTC Extension Department using information from the sample gathering log sheets and photographs of the collected plant material, including consideration of sampling locations, compared to entries in a reference manual on native regional plants (Gilmore, 1991) and the USDA PLANTS database (USDA Natural Resource Conservation Service, 2013).

The plant samples were shipped with overnight delivery to the Food Analysis Laboratory Control Center (FALCC) at Virginia Tech (Virginia Polytechnic Institute and State University, Blacksburg, VA, USA), taking care to ensure the integrity and preservation of nutrients in the samples, as previously reported (Trainer et al., 2010). The beaked hazelnuts and the rinsed wild raspberries and chokecherries were frozen prior to shipment and shipped frozen; all other samples were shipped at refrigerated temperature using cold packs. Upon receipt at Virginia Tech, samples were inspected to ensure integrity of packaging. Refrigerated samples were stored at 2–5 °C and prepared within 4 days of receipt. Frozen samples were stored at −12 to −15 °C and prepared within 9 days of receipt, except beaked hazelnuts which were held frozen 5 months. Most products were analyzed raw; cooked plants were processed by methods specified by tribal elders.

2.2. Sample preparation

For each food, samples or composites of samples (Section 2.1) were homogenized and dispensed into subsamples for analysis. Most products were analyzed raw; cooked plants were processed by methods specified by tribal elders.

For each food the sample material to be included was cleaned and the inedible portion was removed just before homogenization. First, the material was rinsed thoroughly for 1–2 min with tap water, then 1 min with distilled deionized (DDI) water, and then patted dry with a clean, lint-free cloth. Inedible portions were as follows: damaged or discolored areas from stinging nettles, lambsquarters, and cattail broad leaf shoots; roots from the lambsquarters and cattail broad leaf shoots; stems, leaves, and pits from wild plums; twigs and leaves from wild raspberries and chokecherries; stems and leaves from wild rose hips; bark and roots from prairie turnips; shells from beaked hazelnuts; needles and tough, outer layer of paddles from plains prickly pear; any seeds from lambsquarters. Plains prickly pear was broiled 23 cm from a pre-heated broiler for 9 min. Stinging nettles were blanched by boiling in DDI water for 1 min and then draining in a colander. Prairie turnips were boiled in DDI water until tender (~15 min). Lambsquarters were steamed over boiling water for 8 min. All cooking was carried out using stainless steel pots.

The prepared samples for each composite were cut into approximately 1 cm pieces, immediately frozen in liquid nitrogen, and homogenized to a fine powder using a 6L stainless steel industrial food processor (Robot Coupe 6L Blixer; Robot Coupe USA, Jackson, MS) while kept frozen in liquid nitrogen, accomplished with a total of approximately 1 min grinding time in 30-s intervals after an initial 10-s pulse. Subsamples (12–15 g) of the material were dispensed, while still frozen in liquid nitrogen, among 60-mL straight-side glass jars with Teflon™ lined lids and sealed under residual nitrogen. The the jars were wrapped with aluminum foil and stored at −60 ± 3 °C until analyzed.

2.3. Analytical methods

Macronutrients, vitamins, and minerals, carotenoids, and folate vitamers were assayed. Standard and/or published methods were used, consistent with the methods of analysis for other foods in the USDA National Food and Nutrient Analysis Program (NFNAP) (Haytowitz et al., 2008). Table 1 summarizes methods used for determination of proximate composition, niacin, pantothenic acid, riboflavin, thiamin, vitamin B6, vitamin C, macro- and trace-elements (Covance Laboratories, Madison, WI, except for beaked hazelnuts which were analyzed at Silliker Inc., Crete, IL), vitamin K (USDA-HNRCA Laboratory, Tufts University, Boston, MA), choline (University of North Carolina, Chapel Hill, NC), and folate vitamers (Food Analysis Laboratory Control Center, Virginia Tech, Blacksburg, VA).

Carotenoids were analyzed at Craft Technologies Inc. (Wilson, NC) by reversed-phase HPLC with UV–vis detection using published methodology (Craft, 2001). The HPLC system consisted of a solvent degasser, gradient pump, temperature controlled autosampler, and programmable UV–vis detector (Thermo Separation Products, San Jose, CA). The column was a Spherisorb ODS2, 250 mm × 4.0 mm, 3 μ with titanium frits (ES Industries, West Berlin, NJ), and the mobile phase was 800 mL acetonitrile, 150 mL p-dioxane, 50 mL methanol:isopropanol (50:50) containing 150 mM ammonium acetate and 1 mL triethylamine, with flow rate of 1.0 mL/min. Briefly, samples were evaluated with regard to their matrix for chlorophylls or esterified carotenoids and saponified if necessary before extraction. Extracts were diluted in mobile phase and 15 μL was injected for HPLC. Carotenoids were detected at 450 nm and peaks were identified by coelution with authentic standards, and in some cases with diode array detection. The method was calibrated with neat standards that were assigned concentrations determined using molar extinction coefficients and correction for HPLC purity, and analytes were quantified based on external standards using peak areas.

Samples of well-characterized control composites (CC) with established tolerance limits developed for the NFNAP (Phillips et al., 2006a) and/or certified reference materials (CRMs) were included in each analytical run to validate results, as described previously (Phillips et al., 2006a, 2007). CRMs were obtained from the National Institute of Standards and Technology (NIST, Gaithersburg, MD) (SRM® 2383 Babyfood, SRM® 2387 Peanut Butter) and the Institute of Reference Materials and Methods (Geel, Belgium; purchased from RT Corp., Laramie, WY) (CRM 485 Lyophilized Mixed Vegetables, CRM 431 Lyophilized Brussels Sprouts).

2.4. Data analysis

Results for the CCs and CRMs analyzed with the samples were compared to the certified ranges (for the CRM) and to established in-house tolerance limits (for the CC) to validate the accuracy of the measurements (Phillips et al., 2006a). The limited availability of sampling locations and harvested material allowed only a single analytical value for most foods; therefore, the precision (relative standard deviation, RSD) of inter-day results for these materials analyzed at the same laboratory were used to estimate precision of a value in the case of single analysis of a given nutrient/food. When samples of a food from multiple locations were analyzed, data are reported as the mean of the values from all locations (e.g. the three reservations), and the range is given for reference. This action fulfilled the agreement with the tribes that specific nutrient information would not be reported by location.

Nutrient concentrations are reported on a per 100 g fresh-weight basis and are also discussed per serving and as a percent of

Table 1
Analytical methods.

Analyte	Method[a]	Method description	Reference citation for method details
Moisture	Pressure drying	Sample (5–10 g) dried under pressure at 70 °C for 6 h	AOAC (2011), method 934.06 (37.1.10) *Moisture in dried fruits*
Protein	Combustion determination of nitrogen	Nitrogen determined by a combustion–detection technique (Dumas method), with the percent nitrogen converted to protein using a factor of 6.25	AOAC (2011), method 968.06 (4.2.04), *Protein (crude) in animal feed*
Fat	Acid hydrolysis	Total fat determined gravimetrically after acid hydrolysis and recovery of extractable fat using ether and hexane	AOAC (2011), method 954.02 (4.5.02 or 7.063) *Fat (crude) or ether extract in pet food*
Dietary fiber	Enzymatic–gravimetric	Duplicate samples digested with enzymes in a phosphate buffer, precipitation of soluble fiber with ethanol, followed by gravimetric determination of fiber in residue corrected for protein and ash content	AOAC (2011), method 991.43 (32.1.17) *Total, soluble, and insoluble dietary fiber in foods*
Folate vitamers	LC–MS spectrometry, after trienzyme extraction	Tri-enzyme extraction of sample, isolation of folates by solid-phase extraction, and quantification of individual folate vitamers by LC–MS. Total folate calculated as the sum of molar equivalent concentrations of 5-methyltetrahydrofolate, 10-formylfolic acid, and 5-formyltetrahydrofolate	Phillips et al. (2006b)
Niacin	Microbiological	Sample hydrolyzed with sulfuric acid; pH adjusted to remove interferences. Niacin determined by comparing the growth response *Lactobacillus plantarum* using the sample compared to the growth response for a niacin standard, measured turbidimetrically	AOAC (2011), methods 944.13 (45.2.04), 960.46 (45.2.01), and 985.34 (50.1.19), *Niacin in foods*
Pantothenic acid	Microbiological	Sample treated with an enzyme mixture to liberate pantothenic acid from co-enzyme A; pH adjusted to remove interferences. Pantothenic acid determined by comparing the growth response of *Lactobacillus plantarum* using the sample compared to the growth response for a calcium pantothenate standard, measured turbidimetrically	USP (1995), AOAC (2011), methods 945.74 (45.2.05) and 960.46 (45.2.01), *Pantothenic acid in foods*
Vitamin B6	Microbiological	Sample hydrolyzed with dilute sulfuric acid in an autoclave; pH adjusted to remove interferences. Vitamin B6 determined by comparing the growth response of *Saccharomyces carlsbergenesis* using the sample compared the growth response for a vitamin B6 standard, measured turbidimetrically	AOAC (2011), method 961.15 (45.2.08), *Vitamin B6 (pyridoxine, pyridoxal, and pyridoxamine) in food extracts*
Riboflavin	Microbiological	Sample hydrolyzed with dilute hydrochloric acid (HCl); pH adjusted to remove interferences. Riboflavin determined by comparing the growth response of *Lactobacillus casei* using the sample compared to the growth response for a riboflavin standard, measured turbidimetrically	AOAC (2011), 940.33 (45.2.06) riboflavin (Vitamin B2) in vitamin preparations
Riboflavin	Fluorometric	Sample autoclaved in dilute acid; pH adjusted with NaOH. Dilute HCl added to precipitate protein and the sample is filtered. Acetic acid and then 4% potassium permanganate are added. Hydrogen peroxide is added to destroy the permanganate color. Fluorescence is measured, $Na_2S_2O_4$ added and fluorescence is measured again	AOAC (2011), method 970.65, *Riboflavin (vitamin B2) in foods and vitamin preparations*
Thiamin	Fluorometric	Sample autoclaved in dilute acid to extract thiamin. Resulting solution incubated with a buffered enzyme solution to release bound thiamin. Solution purified on an ion-exchange column. Aliquot taken and reacted with potassium ferricyanide to convert thiamin to thiochrome. Thiochrome extracted into isobutyl alcohol and read on a fluorometer against a known standard	AOAC (2011), methods 942.23 (45.2.05), 953.17 (45.1.06), and 957.17 (45.1.07), *Thiamine in bread*
Vitamin C	HPLC	Vitamin C assayed as total ascorbic acid. Sample extracted with 5% metaphosphoric acid buffer (pH 1.8); dehydroascorbic acid reduced with TCEP. Ascorbic acid quantified by reverse-phase HPLC with UV detection at 254 nm, using calibration with external standards	Tarrago-Trani et al. (2012)
Vitamin K	HPLC	Samples extracted with hexane extraction and purified by solid phase extraction on silica columns. Phylloquinone content determined by reversed-phase high-performance liquid chromatography (HPLC) followed by fluorescence detection, with $K_{1(25)}$ as an internal standard	Booth and Sadowsi (1997)
Choline	LC/ESI/IDMS	Samples spiked with deuterium-labeled internal standards of the different forms of choline. Choline compounds partitioned into aqueous and non-aqueous solvents and analyzed directly by liquid chromatography/electrospray ionization-isotope dilution mass spectrometry	Koc et al. (2002)
Elements (Ca, Mg, K, Na, P, Cu, Fe, Mn, Zn)	ICP	Dry ashing (500 °C ± 50 °C) and dissolution in concentrated HCl, or wet ashing (digestion in concentrated acid, with heat) of sample. Followed by appropriate dilution, followed by quantitation of each element using an ICP spectrometer and comparing the emission of the unknown sample against the emission of each element in standard solutions	AOAC (2011), methods 985.01 (3.2.06) and 984.27 (50.1.15), *Metals in food by ICP*
Selenium	ID-GC–MS	Digestion of sample using nitric acid, orthophosphoric acid, and hydrogen peroxide and the formation of 5-nitropiazselenol. Samples spiked with enriched ^{82}Se and the isotopic ratio of ^{82}Se to ^{80}Se is measured by GC–MS using dual ion monitoring	Reamer and Veillon (1981)

[a] ESI, electrospray ionization; GC, gas chromatography; HPLC, high performance liquid chromatography; ICP, inductively coupled plasma emission spectroscopy; ID, isotope dilution; LC, liquid chromatography; MS, mass spectrometry; TCEP, tris(2-carboxyethyl)phosphine.

Table 2
Traditional Native American and comparable contemporary plant foods and serving sizes (see Table 3 for further description of the Native American plants).

Traditional Native American food			Comparable contemporary food			Suggested serving size	
Common name	Scientific name	NDB no.[a]	Common name	Scientific name	NDB no.[a]	Volume[b]	Grams
Cattail broad leaf shoots, steamed	*Typha latifolia* L.	35195	Asparagus, boiled	*Asparagacea officinalis*	11012	½ cup	90
Chokecherries	*Prunus virginiana* L.	35204	Gooseberries	*Ribes* spp.	09107	½ cup	75
Hazelnuts, beaked	*Corylus cornuta* Marshall	35233	Hazelnuts	*Corylus* spp.	12120	½ cup	25.4
Lambsquarters, raw	*Chenopodium album* L.	11244	Spinach, raw	*Spinacia oleracea*	11457	1 oz.	30
Lambsquarters, steamed	*Chenopodium album* L.	35197	Spinach, boiled	*Spinacia oleracea*	11458	2 cups	180
Plains pricklypear, raw	*Opuntia polyacantha* Haw.	35198	Apple, raw	*Malus domestica*	09003	1 cup	149
Plains pricklypear, broiled	*Opuntia polyacantha* Haw.	35199	Apple, microwaved	*Malus domestica*	09006	1 cup	115
Prairie turnips, raw	*Psoralea esculenta* Pursh.	35200	Turnips, raw	*Brassica rapa* (Rapiferagroup)	11564	½ cup	130
Prairie turnips, boiled	*Psoralea esculenta* Pursh.	35201	Turnips, boiled	*Brassica rapa* (Rapifera group)	11565	1 cup	156
Stinging nettles, blanched	*Urtica dioica* L.	35205	Peppermint leaves	*Mentha* × *piperita* L. *nothosubsp. Piperita*	02064	1 cup	20
Wild plums	*Prunus americana* Marshall	35206	Plums	*Prunus* spp.	09279	½ cup	132
Wild raspberries	*Rubus idaeus* L.	35202	Raspberries	*Rubus* spp.	09302	2 large	61.5
Wild rose hips[c]	*Rosa pratincola* Greene	35203	Cranberries	*Vaccinium macrocarpon*	09078	½ cup	48

[a] Database entry number, USDA Nutrient Database for Standard Reference (USDA, 2011).
[b] 1 cup = 237 mL.
[c] Also known as prairie rose (*Rosa arkansana* Porter var. *suffulta* (Greene) Cockerell) (USDA Natural Resources Conservation Service, 2013).

the Dietary Reference Intake (DRI) (Institute of Medicine (IOM), 1997, 1998, 2000, 2001, 2002, 2004, 2011) and compared to the concentrations in similar contemporary foods to facilitate consideration in the context of food choice recommendations to promote health. Contemporary foods considered as comparable in proximate composition and key minerals and vitamins were used for comparison; in some cases, wild and domesticated versions of the same plant type (e.g. wild and domestic plums) were used when available. However, there were some differences in key components, e.g. moisture content. "Fresh weight" was the edible portion, as prepared for analysis. Traditional and contemporary foods were matched based on similarity of type or use (e.g. type: cattail broad leaf shoots versus asparagus; use: served in tea form, such as stinging nettle versus peppermint leaves). Standard serving sizes and data for the contemporary foods were obtained from the USDA National Nutrient Database for Standard Reference, Release 21 (USDA, 2011). The traditional foods analyzed, the corresponding contemporary foods, and serving sizes are given in Table 2.

3. Results and discussion

3.1. Composition of the traditional Native American foods

Photographs of the samples of each food collected are shown in Table 3, along with a description of typical preparation and use of the traditional foods. The assayed proximate composition and concentrations of selected elements, vitamins, carotenoids, and folate are shown in Tables 3–7, along with results for the corresponding quality control sample(s) analyzed and the adult DRI for each nutrient. For standardization of data, the assayed nutrient concentrations have been given on a per 100 g fresh weight basis, but the discussion focuses on the nutrient content per typical serving size (Table 2) to enable meaningful evaluation of the contribution of the food to daily intake. For brevity, % DRI in the discussion refers to the male DRI only. Nutrient values are shown as the mean based on analysis of the composite sample, and, in cases where more than one composite of a food was analyzed, the range is shown as an indicator of sample-to-sample variability. The mean and inter-day relative standard deviations for the matrix-matched RM and/or CC assayed along with the foods are also included for each nutrient reported.

3.1.1. Proximate composition

The results of proximate analyses are summarized in Table 4. Fat content was significant in the beaked hazelnuts (53 g/100 g; 13.5 g/serving) and negligible (<2 g/100 g or <0.1 g/serving) in the other foods. Steamed lambsquarters had the highest protein content (7.3 g/serving), which was substantially more per serving than in the other foods. Importantly, total dietary fiber was >50% of total carbohydrates in all samples except for wild plums (22%), raw prairie turnips (24%), and beaked hazelnuts (43%). Wild plums, prairie turnips, wild raspberries, and chokecherries had the highest dietary fiber contents per serving (10.6–15.0 g), with two servings meeting the dietary guidelines for daily fiber intake (Institute of Medicine, 2002). Most of the fiber was insoluble, with raw plains prickly pear having the highest soluble fiber content per serving (3.7 g; 2.5 g/100 g) and as a proportion of total fiber (~50%).

3.1.2. Macro- and trace-elements

Overall the traditional Native American plant foods were excellent sources of several macro- and trace-elements, particularly manganese (Table 5). Mn was ≥10% of the DRI per 100 g fresh weight in all foods except wild plums, wild raspberries, and stinging nettles, and those products still contained 5–9.8% DRI per serving. On a per serving basis, cattail broad leaf shoots, beaked hazelnuts, and steamed lambsquarters were especially notable sources of Mn, providing 81%, 84%, and 122% of the DRI (1868–2808 μg). All of the foods except wild plums, wild raspberries, and stinging nettles had Mg ≥10% DRI per serving. For other elements some of the foods had very high levels per serving relative to the DRI. Per serving of steamed lambsquarters, calcium (628 mg), potassium (1926 mg), and magnesium (295 mg) were all >40% of the DRI. A few of the foods (cattail broad leaf shoots, steamed lambsquarters, and prairie turnips) were good sources of iron (10% DRI per serving). For some elements most foods were a minor source, but one or two foods had a particularly high content. For example, most foods were low in selenium but prairie turnips were a rich source with 14.7 μg/100 g fresh weight (19.1 μg/serving, 35% DRI), and beaked hazelnuts contained 34% of the DRI for copper per serving (305 μg).

3.1.3. Vitamins

Several of the foods provide a substantial amount of vitamin B6, thiamin, vitamin C, and vitamin K (Table 6). Prairie turnips (raw and boiled) and steamed lambsquarters were the richest sources of

vitamin B_6 (pyridoxine), and contained >40% of the DRI per serving (0.619, 0.650 and 0.418 mg, respectively). Chokecherries and broiled plains prickly pear also contained vitamin B6 at >10% of the DRI per serving (0.146 and 0.198 mg/100 g, 0.149 and 0.168 mg/serving). Prairie turnips (raw and boiled) and beaked hazelnuts had relatively high thiamin contents (0.126–0.550 mg/100 g, 0.140–0.231 mg/serving). Vitamin C was notably high in wild rose hips relative to the other foods and contained 227% of the DRI per 48-g serving (205 mg). Wild plums, wild raspberries, and raw plains prickly pear were also rich in vitamin C (10.3–26.4 mg/100 g, and ≥10% DRI/serving). Lambsquarters and stinging nettles were by far the highest in vitamin K and were particularly good sources, with 347 mg/100 g (raw) (87% DRI/serving) and 499 mg/100 g (83% DRI), respectively. Wild plums, chokecherries, cattail broad leaf shoots, and wild rose hips also were excellent sources of vitamin K (11.2–25.9 μg/100 g; ≥10% DRI/serving).

Only steamed lambsquarters showed high riboflavin content per serving (0.370 mg/100 g, 51% DRI). Chokecherries, raw and boiled prairie turnips, wild rose hips, beaked hazelnuts all contained riboflavin ≥10% DRI. However, it should be noted that the inherent high RSD for this assay as indicated by the results for the control samples (see Table 6) precludes drawing a definitive interpretation of results based on from the limited number of analyses. Other vitamins were present at lower amounts in all of the foods. Moderate contents (5–10% DRI/serving) of niacin were found in broiled plains prickly pear, raw and boiled prairie turnips, beaked hazelnuts; and pantothenic acid in chokecherries, wild plums, wild rose hips). Choline was <4% DRI/serving in all of the foods, with the highest amount of total choline in cattail broad leaf shoots (23.7 mg/100 g).

Only lambsquarters contained significant levels of total folate, with 96.8 μg/100 g (raw) and 7.3% DRI per serving (Table 7). Total

Table 3
Traditional foraged Native American Northern Plains plant foods.

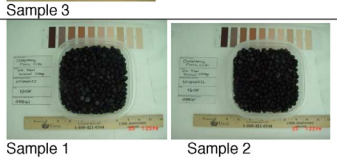
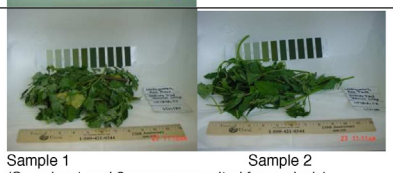
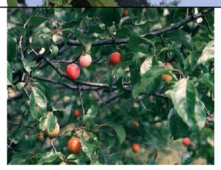
Food	Photograph of wild plant[a]	Photograph of collected sample(s)	Traditional uses and preparation[b]	
Cattail broad leaf shoots *Typha latifolia* L.		 Sample 1 Sample 2 (Samples 1 and 2 were composited for analysis)  Sample 3	Eaten raw in salads, or cooked like asparagus.	Shoots-The pointy end of the rootstock is peeled to the tender white core. Eaten raw or cooked for fifteen min or so
Chokecherry *Prunus virginiana* L.		 Sample 1 Sample 2 	Eaten raw or used in pies, jams, syrup and pudding.	For recipes using only berry juice –rinse berries cover with water, simmer for 15 min. Strain juice.
		Sample 3		
Beaked hazelnut *Corylus cornuta* Marshall			The nuts can be eaten raw, or cooked whole or in pieces in cakes and cookies.	Hazelnuts can be chopped finely with a knife or blender and sprinkled on baked goods or vegetables.
Lambsquarters *Chenopodium album* L.		 Sample 1 Sample 2 (Samples 1 and 2 were composited for analysis)	Steamed	Steam leaves and stalks for less than 10 min – dash with olive oil and garlic. Seeds are also edible.
Plains prickly pear *Opuntia polyacantha* Haw.			It is also called cactus pear and Indian fig. Whether you add sliced or cubed pads to omelet's or gently urge the fruit from its sticker skin and eat it fresh or cooked into jelly, this cactus has much to offer. Even the seeds can be eaten in soups or dried and ground into flour.	Remove the needles by breaking off the big ones and burn off the rest either over a fire on the stove or by using a torch. Peel and chop the paddles (used in pie) or the paddles (pads) may be eaten raw.

Table 3 (*Continued*)

Prairie turnip *Psoralea esculenta* Pursh.		 Sample 1 Sample 2	Prairie turnips are also known as ground potatoes. They were an important food source for tribes who lived on the Great Plains. Lakota's dig *tinpsila* in June when it blossoms.	Prairie turnips are prepared by removing the bark or outer layer of the plant with roots intact and braided hung and dried for storage. May be cooked for immediate use.
Stinging nettle *Urtica dioica* L.			Used in soups, sauces and salad.	Fresh nettle, blanched in boiling water for a minute (this removes the "sting"), drained and roughly chopped
Wild plum *Prunus americana* Marshall			Used to make jam and butter.	5 cups pitted, tart plums (about 2 1/2 pounds) 4 cups sugar 1 cup water Sterilize canning jars. Combine all ingredients. Bring slowly to boiling, stirring until sugar dissolves. Cook rapidly almost to the jellying point, about 15 min, stirring frequently to prevent sticking. Pour hot preserves into hot jars, leaving 1/4 inch head space. Wipe jar rims and adjust lids. Process 10 min in a boiling water bath at 5,000 feet.
Wild raspberry *Rubus idaeus* L.			Eaten raw or used in pies and jams.	Rinse berries and towel dry before freezing.
Wild rose hips[c] *Rosa pratincola* Greene			Wild Rose fruits sometimes called rose hips or berries make a good tea. Rose hips were used for food and as a medication for multiple stomach and eye problems. Dried, they keep well, and will always be available in winter.	Berries need to be strained to remove the hairs and seeds. Steeped and used in teas. Dried rose hips need to be boiled about 10 min to make a tea of them; just pouring hot water over them results in a fairly tasteless brew. Use 2 tablespoons per pint of water, boil covered. The hips must expand, split, and let the water get at the soft seeds within. The resulting tea may be pinkish, depending on the type of roses whose berries are used. The hot tea is acid-tasting, but not as sharp as lemon juice. Some like it sweetened. A half-teaspoon of dried mint may be added to give it a different flavor. Purchased rosehips for tea you'll find only the hardened dried shell of the berry. Boil that 15 min for your tea.

[a] Photographs reproduced with permission. From the University of Wisconsin-Stevens Point Robert W. Freckmann Herbarium database (http://wisplants.uwsp.edu): lambsquarters and plains prickly pear ©Paul S. Drobot (Franklin, Wisconsin, USA); prairie turnip ©James R. Sime (Middleton, Wisconsin); beaked hazelnut, ©Wisconsin Department of Natural Resources (Madison, Wisconsin); wild plum, ©Robert W. Freckmann (University of Wisconsin-Stevens Point); wild raspberry, © Matthew L. Wagner (Summit Lake, Wisconsin). Photographs of cattail shoots, chokecherry, and stinging nettle from Plantsytematics database (http://plantsystematics.org/), © Kevin C. Nixon (Cornell Univeristy, Ithaca, New York, USA). Photograph of rose hips ©Rob Hull (Marvao, Portugal).

[b] Typical preparation instructions for species samples were documented after collaborative conversation and recipe testing between United Tribes Technical College (Bismarck, North Dakota, USA) Extension staff and invited tribal elders.

[c] Also known as prairie rose (*Rosa arkansana* Porter var. *suffulta* (Greene) Cockerell) (USDA Natural Resources Conservation Service, 2013).

folate was >10 μg per 100 g fresh weight in prairie turnips, stinging nettles, and cattail broad leaf shoots, but was negligible (<10 μg/100 g) in the other foods. The major vitamer in all cases was 5-methyltetrahydrofolate (5-H_3C-H_4folate), except in cattail broad leaf shoots in which 10-formyl folate (10-HCO folate) predominated. Lambsquarters also showed notable 10-formylfolate and 5-formyltetrahydrofolate (5-HCO-H_4 folate) contents.

Many of the traditional plant foods were rich in carotenoids (Table 8). Total carotenoids were by far the highest in wild rose hips (11.8 mg/100 g). Wild plums, stinging nettles, and lambsquarters also contained substantial concentrations (3.2–8.5 mg/100 g). β-Carotene and lutein + zeaxanthin were the predominant vitamers in all cases, as illustrated in Fig. 2. α-Carotene was found only in wild plums, stinging nettles, and wild rose hips, α-cryptoxanthin only in wild plums and wild rose hips, β-cryptoxanthin only in wild raspberries, chokecherries, wild plums, and wild rose hips, and lycopene only in wild rose hips. The lycopene content of wild rose hips was significant (6.8 mg/100 g) and represented more than half of total carotenoids (Fig. 2). HPLC chromatograms are shown in Fig. 3 to illustrate the carotenoid profile of a representative sample of each food analyzed.

3.2. Dietary contributions of traditional and comparable conventional plant foods

In the following sections the nutrient contents of the traditional Native American plant foods relative to their contemporary

Table 4
Proximate composition of traditional Native American plant foods (per 100 g fresh weight). Number of samples: *n = 1; **n = 2; ***n = 3. Lambsquarters raw and steamed were each a composite of samples from two locations (see Table 3).

Food	Serving Size (g)	Energy[a]		Total fat	Moisture	Nitrogen	Protein	Ash	Fiber		
		kcal	kJ						Total[b]	Insoluble	Soluble
Cattail broad leaf shoots**	90	25	105	0.1	92.65	0.2	1.2	1.03	4.5 *(87%)*	4.2	0.3
Chokecherries***	75	162	678	1.7	60.72	0.5	3.0	0.93	20.0 *(60%)*	18.5	1.5
Lambsquarters, raw**	30	47	197	0.3	85.23	0.7	4.2	3.32	6.3 *(90%)*	4.8	1.5
Lambsquarters, steamed**	180	48	201	0.2	85.02	0.6	4.1	3.30	5.2 *(69%)*	4.1	1.1
Plains pricklypear, raw*	149	42	176	0.1	89.22	0.0	0.1	0.38	5.3 *(52%)*	2.8	2.5
Plains pricklypear, broiled*	115	91	381	0.3	75.83	0.1	0.4	1.90	n/a	n/a	n/a
Wild plums*	132	157	657	0.4	76.68	0.4	2.6	0.8	8.0 *(22%)*	7.4	0.7
Prairie turnips, raw**	130	130	544	0.3	60.70	0.3	1.6	0.65	7.2 *(24%)*	6.1	1.1
Prairie turnips, boiled**	156	62	260	0.3	67.68	0.2	1.1	0.36	7.5 *(54%)*	6.9	0.6
Wild raspberries*	61.5	162	678	0.3	84.48	0.3	1.6	0.28	24.1 *(63%)*	21.2	2.9
Wild rose hips*	48	32	134	0.1	58.66	0.5	3.2	1.18	4.8 *(100%)*	4.5	<0.5
Stinging nettles, blanched**	20	42	176	0.1	87.67	0.4	2.7	2.03	6.9 *(92%)*		
Beaked hazelnuts*	25.4	628	2629	53.0	5.92	2.4	14.9	3.22	9.8 *(43%)*		
Mixed Vegetable Control Composite, mean (RSD, n)[c]				*0.29 (52.3, 4)*	*90.64 (0.6, 5)*		*1.6 (7.4, 5)*		*2.4 (10.3, 6)*	*1.8 (0.1, 4)*	*0.6 (26.1, 4)*
Peanut Butter Control Composite, mean (%RSD, n)[c]				*52.47 (2.5, 7)*	*1.15 (15.7, 8)*				*5 (3.3, 6)*		

n/a = not assayed.
[a] Calculated using the Atwater system based on assayed moisture, protein, fat content (Merrill and Watt, 1973).
[b] Total fiber as percent of total carbohydrates shown in parentheses.
[c] Relative standard deviation (RSD) for the control composite assayed with samples at the same laboratory, by the same method, over multiple days, as an estimate of analytical uncertainty in concentrations reported for samples.

Table 5
Macro- and trace-element content of traditional Native American plant foods. Number of samples: *n = 1; **n = 2; ***n = 3. Lambsquarters raw and steamed were each composite of samples from the same two locations. One cattail broad leaf shoots sample was a composite of material from two locations (see Table 3).

Food	Serving size (g)	Concentration (per/100g fresh weight)[a]									
		Macroelements (mg)					Trace elements (μg)				
		Ca	Mg	K	Na	P	Cu	Fe	Mn	Zn	Se
Cattail broad leaf shoots**	90	54	63	309	109	45	41	909	2075	245	0.6
Chokecherries***	75	60	27	379	<9	67	186	685	417	328	n/a
Lambsquarters, raw**	30	366	163	1270	<9	63	120	1160	1490	721	1.1
Lambsquarters, steamed**	180	349	164	1070	<9	56	100	1150	1560	611	n/a
Plains pricklypear, raw*	115	180	69	130	<9	11	25	200	583	138	0.1
Wild plums*	132	11	8	364	<9	30	35	174	76	94	n/a
Prairie turnips, raw**	130	130	63	156	<9	31	53	1270	266	371	14.7
Prairie turnips, boiled**	156	103	49	108	<9	21	38	955	209	277	n/a
Wild raspberries*	61.5	36	26	175	<9	41	97	645	368	470	n/a
Wild rose hips*	48	169	69	429	<9	61	113	1060	1020	245	n/a
Stinging nettles, blanched**	20	452	54	352	<9	87	86	1260	591	363	0.3
Beaked hazelnuts*	25.4	441	235	738	10	411	1200	3120	7600	2060	n/a
Mixed Vegetable Control Composite, mean (RSD, n)[b]		38.5 *(4.7%, 7)*	19.2 *(4.2%, 7)*	201 *(5.2%, 7)*	70.2 *(9.8%, 7)*	37.6 *(3.2%, 7)*	99 *(25.6%, 7)*	780 *(6.0%, 7)*	180 *(6.5%, 7)*	340 *(4.5%, 7)*	n/a
Starchy Vegetable Control Composite, mean (RSD, n)[b]		21.5 *(1.2%, 3)*	24.7 *(0.5%, 5)*	323 *(1.9%, 5)*	117 *(4.9%, 5)*	70.7 *(1.8%, 5)*	120 *(3.0%, 5)*	880 *(0.8%, 5)*	270 *(0.9%, 4)*	420 *(1.2%, 4)*	2.4 *(6.5%, 3)*
DRI[c]	Male	1000–1200	400-420	4700	1200–1500	700	900	8000	2300	11,000	55
	Female	1000–1200	310–320	4700	1200–1500	700	900	18,000	1800	8000	55

[a] Based on dietary reference intake (DRI[c]): Dark shaded cells contain values (per serving) ≥10% DRI; medium shaded cells contain values 5–9.9% DRI; lightly shaded cells indicate values 2–4.9% DRI; values in unshaded cells are <2% DRI; values in cells with bolded outline are >40% DRI.
[b] Relative standard deviation (RSD) for the control composite (Table 3) assayed with samples at the same laboratory, by the same method, over multiple days, as an estimate of analytical uncertainty in concentrations reported for samples.
[c] Institute of Medicine (1997, 2000, 2001, 2004, 2011)

Table 6
Vitamin content of traditional Native American plant foods. Means are shown in bold font; ranges in italics. Number of samples: *$n = 1$; **$n = 2$; ***$n = 3$. Lambsquarters raw and steamed were each composite of samples from the same two locations. One cattail broad leaf shoots sample was a composite of material from two locations (see Table 3).

Food	Serving size (g)	Concentration per/100g fresh weight[a]							
		Niacin (mg)	Pantothenic acid (mg)	Vitamin B6 (mg)	Riboflavin (mg)	Thiamin (mg)	Vitamin C (mg)	Vitamin K (μg)	Total choline (mg)
Cattail broad leaf shoots**	90	**0.441**	**0.235**	**0.123**	**<0.100**	**0.023**	**1.0**	**22.8**	**23.7**
		0.327–0.554	*0.154–0.315*	*0.094–0.141*	*0.020–0.078*	*0.008–0.037*	*1.0–1.0*		
Chokecherries***	75	**0.628**	**0.398**	**0.198**	**0.173**	**0.034**	**4.0**	**21.1**	**n/a**
		0.563–0.732	*0.338–0.463*	*0.155–0.231*	*0.114–0.242*	*0.031–0.037*	*1.0–9.4*		
Lambsquarters, raw**	30	**0.790**	**0.300**	**0.184**	**0.394**	**0.029**	**1.0**	**347**	**20.0**
			0.270–0.330		0.300–0.487				
Lambsquarters, steamed**	180	**0.623**	**n/a**	**0.232**	**0.370**	**0.047**	**4.9**	**n/a**	**n/a**
					0.270–0.470				
Plains pricklypear, raw*	149	**0.293**	**0.060**	**0.079**	**<0.100**	**0.008**	**11.3**	**2.9**	**4.3**
Plains pricklypear, broiled*	115	**1.000**	**0.150**	**0.146**	**<0.100**	**0.018**	**6.2**	***n/a***	***n/a***
Wild plums*	132	**0.367**	**0.301**	**0.093**	**<0.100**	**0.005**	**10.3**	**11.2**	**5.2**
Prairie turnips, raw**	130	**1.071**	**0.155**	**0.476**	**<0.100**	**0.178**	**5.6**	**0.0**	**4.8**
		0.972–1.17	*0.150–0.160*	*0.456–0.483*	*0.087–0.095*	*0.136–0.220*	*4.2–6.9*		
Prairie turnips, boiled**	156	**0.708**	**0.090**	**0.417**	**<0.100**	**0.126**	**2.1**	***n/a***	***n/a***
		0.549–0.867	*0.070–0.110*	*0.342–0.417*	*0.039–0.044*	*0.126–0.126*	*1.0–3.2*		
Wild raspberries*	61.5	**1.030**	**0.300**	**0.104**	**<0.100**	**0.018**	**26.4**	**6.6**	**9.5**

Food	Serving size (g)	Concentration per/100g fresh weight[a]							
		Niacin (mg)	Pantothenic acid (mg)	Vitamin B6 (mg)	Riboflavin (mg)	Thiamin (mg)	Vitamin C (mg)	Vitamin K (μg)	Total choline (mg)
Wild rose hips*	48	**1.300**	**0.800**	**0.076**	**0.166**	**0.016**	**426**	**25.9**	**12.0**
Stinging nettles, blanched**	20	**0.371**	**0.155**	**0.104**	**0.160**	**0.008**	**1.0**	**499**	**17.4**
		0.371–0.406	*0.140–0.170*	*0.100–0.107*	*0.152–0.168*	*0.008–0.008*	*1.0–1.0*		
Beaked hazelnuts*	25.4	**3.190**	**1.200**	**0.160**	**0.480**	**0.550**	***n/a***	***n/a***	***n/a***
Mixed Vegetable Control Composite, mean (RSD, n)[b]		0.531 (5.9%, 9)	0.188 (3.8%, 3)	0.070 (14.5%, 7)	0.067 (51.2%, 10)	0.036 (12.2%, 7)	n/a	48.5 (10.9%, 7)	2.08 (5.2%, 2)
Starchy Vegetable Control Composite, mean (RSD, n)[b]		0.765 (4.3%, 5)	0.330 (0.6%, 2)	0.134 (11.2%, 4)	0.051 (67.5%, 9)	0.045 (15.4%, 4)	n/a	0.96 (12.9%, 4)	n/a
BCR CRM 431 Lyophilized Brussels Sprouts, mean (RSD, n)[b,c]							464 3.1 (4)		
DRI[c]	**Male**	16	5	1.3–1.7	1.3	1.2	90	120	550
	Female	14	5	1.3–1.5	1.1	1.1	75	90	425

[a] Based on dietary reference intake (DRI) for adult male (Institute of Medicine, 2000, 2001, 2004): Dark shaded cells contain values (per serving) ≥10% DRI; medium shaded cells contain values 5–9.9% DRI; light shaded cells contain values 2–4.9% DRI; values in unshaded cells <2% DRI; values in cells with bolded outline are >40% DRI.
[b] Relative standard deviation (RSD) for the control composite assayed with samples at the same laboratory, by the same method, over multiple days, as an estimate of analytical uncertainty in concentrations reported for samples without replicate analyses.
[c] Institute of Reference Materials and Methods (Geel, Belgium). Vitamin C (certified), 459–507 mg/100 g.

counterparts (Table 2) are discussed. Emphasis is placed on cases in which the traditional Native American foods provided at least twice the nutrient content per serving as the contemporary food. Table 9 summarizes the profile of each food in terms of nutrient contributions to DRIs. This analysis is important because these foods were a significant segment of the historical diets of the Plains Indians. The foods are still available in the wild and could be nutritionally significant in contemporary tribal diets if they replace the less healthy, mainstream foods pervasive in the US diet as a whole. The purpose is to show, compared to similar mainstream

Table 7
Folate content and composition of traditional Native American plant foods. Means are shown in bold font, ranges are in italics. Number of samples: *$n = 1$; **$n = 2$; ***$n = 3$. Lambsquarters raw and steamed were each composite of samples from the same two locations. One cattail broad leaf shoots sample was a composite of material from two locations (see Table 3).

	µg/100g fresh weight					
					Sum of Folates	
Food	Serving size (g)	5-CH_3-H_4 Folate	10-HCO Folate	5-HCO-H_4 Folate	Folic acid equivalents (µg/100g)[a]	%DRI[b] per serving
Cattail broad leaf shoots**	90	**2.24**	**6.00**	**3.25**	**10.8**	2.4
		1.54 - 2.93	*5.69 - 6.31*	*1.73 - 4.78*	*8.45 - 13.2*	
Stinging nettles, blanched**	20	**17.3**	**5.99**	**1.83**	**24.0**	1.2
		13.7 - 21.0	*4.18 - 7.81*	*0.900 - 2.76*	*17.9 - 30.1*	
Prairie turnips, raw**	130	**10.2**	0.55	1.28	11.5	3.8
		(4.0%, 3)				
Lambsquarters, raw**	30	**47.6**	**42.9**	**12.2**	97.5	7.3
		(28.5%, 6)	*(13.0%, 2)*	*(13.8%, 2)*		
Wild raspberries*	61.5	< 8.0	0.18	1.47	4.78	0.7
Chokecherries***	75	< 8.0	0.27	2.28	3.92	0.7
Wild rose hips*	48	< 8.0	0.35	0.68	7.18	0.9
Wild plums*	132	0.86	0.34	0.40	1.52	0.5
BCR CRM 485 Freeze-Dried Mixed Vegetables[c]		239[d] (43, 6.3%)	< 1.0 (12, n/a)	3.63 (11, 13.5%)	234[e] (8, 7.1%)[f]	

[a] Molar equivalent folic acid.
[b] Dietary Reference Intake for adult males and non-pregnant females (Institute of Medicine, 1998), 400 µg/d. Based on the DRI for adult male, medium shaded cells contain values (per serving) ≥5-9.9% DRI; lightly shaded cells contain values 2–4.9% RI; values in unshaded cells are <2% DRI.
[c] Institute of Reference Materials and Methods (Geel, Belgium); values on dry weight basis.
[d] Indicative range, 172–256 µg/100 g dry weight (Finglas et al., 1998).
[e] Certified range for total folate by microbiological assay, 287–343 µg/100 g dry weight (Finglas et al., 1998).

Table 8
Carotenoid concentrations in traditional Native American plant foods. Number of samples: *$n = 1$; **$n = 2$; ***$n = 3$. Ranges are given italics. Lambsquarters raw and steamed were each composite of samples from the same two locations. One cattail broad leaf shoots sample was a composite of material from two locations (see Table 3).

Food	mg/100 g fresh weight						
	α-Carotene	β-Carotene	α-Cryptoxanthin	β-Cryptoxanthin	Lutein + zeaxanthin	Lycopene	Other carotenoids[a]
Cattail broad leaf shoots**	*nd*	0.006	*nd*	*nd*	0.076	*nd*	0.046
Wild raspberries*	<0.01	0.013	*nd*	0.031	0.130	*nd*	*nd*
Chokecherries***	<0.01	0.090		0.019	0.347	*nd*	*nd*
	(<0.01–<0.01)	*(0.055–0.117)*	*nd*	*(0.017–0.024)*	*(0.036–0.382)*		
Wild plums*	0.140	1.93	0.030	0.187	0.920	*nd*	*nd*
Lambsquarters, raw**	*nd*	1.17	*nd*	*nd*	3.62	*nd*	*nd*
Lambsquarters, steamed**	*nd*	2.33	*nd*	*nd*	6.16	*nd*	*nd*
Stinging nettles, blanched**	0.114	1.15	*nd*	*nd*	4.18	*nd*	*nd*
Wild rose hips*	0.031	2.35	0.084	0.483	2.00	6.80	*nd*
NIST SRM® 2383 Babyfood[b] ($n = 4$)	0.090 (5.8%)	0.309 (2.7%)	0.150 (2.3%)	0.148 (23.6%)	0.662 (23.1%)	0.084 (8.1%)	
[Certified range]	[0.067–0.099]	[0.249–0.375]	No value	[0.107–0.169]	[0.155–0.249]	[0.550–0.850[c]]	
NIST SRM® 2385 Slurried Spinach[b] ($n = 4$)	*nd*	1.17 (24.8%)	No value	*nd*	3.15 (6.5%)	*nd*	No value
[Certified range]		[1.63–2.21]					
BCR CRM 485 Lyophilized Mixed Vegetables[d] ($n = 3$)	0.854 (6.7%)	2.07 (8.7%)	No value	0.061 (54.8)	1.76 (27.2%)[e]	1.20 (2.3%)	No value
[Certified range]	[910–1050]	[2.44–2.68]			[2.10–2.36]		

nd = not detected (<0.005 mg/100 g).
[a] Not identified.
[b] National Institute of Standards and Technology (Gaithersburg, MD, USA). Value shown is mean, with relative standard deviation in parentheses. Relative standard deviations for the SRM® provide estimates of analytical uncertainty for the respective value for single analyses of food samples.
[c] Non-certified (reference) range.
[d] Institute of Reference Materials and Methods (Geel, Belgium). Concentrations are on a dry weight basis; relative standard deviation in parentheses.
[e] Lutein: 1.08 (7.3%), $n = 2$; certified range, 1.17–1.33.

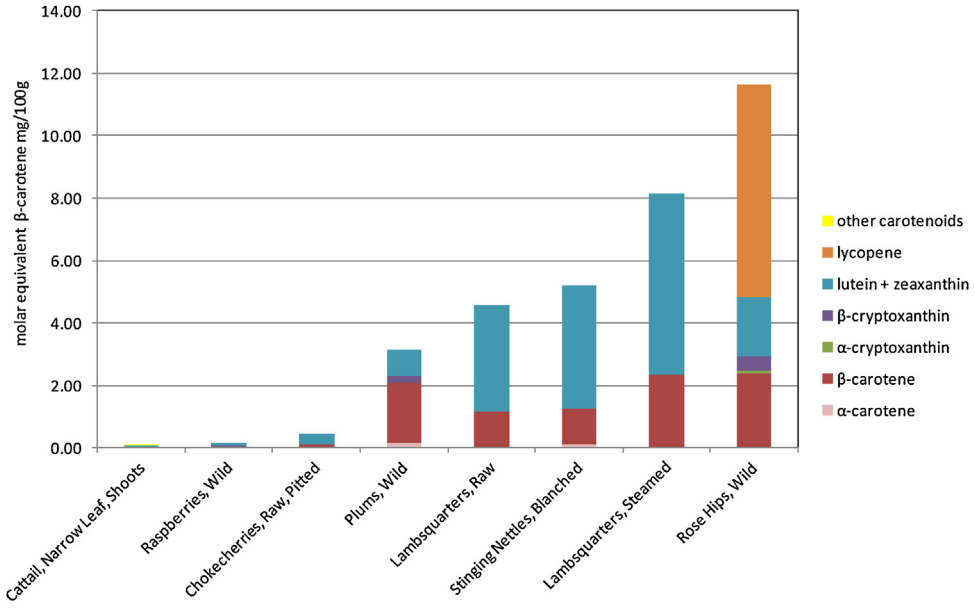


Fig. 2. Carotenoid composition of traditional Native American plant foods, as molar equivalent β-carotene mg/100 g.

plant foods, that readily available indigenous wild foods are comparable in nutritional quality and, in some cases, are higher in specific healthful components.

3.2.1. Proximate composition

Aside from beaked hazelnuts, none of the traditional foods or their contemporary counterparts were notable sources of fat or protein, as expected for plant foods. Beaked hazelnuts (*C. cornuta* Marsh.) did not differ notably in fat or protein content compared to hazelnuts (filberts) (*Corylus* spp.) (13.6 and 15.4 g fat/serving, respectively, and 3.8 g protein/serving for both foods). On the other hand, many of the foods were rich in dietary fiber. All of the traditional foods except wild rose hips, stinging nettles, and beaked hazelnuts contained more than twice as much dietary fiber than the corresponding contemporary food (Fig. 4). In the case of chokecherries (versus gooseberries), raw plains prickly pear (versus apple), wild plums (versus plums), and prairie turnips (versus turnips), the contemporary food contained <3 g total fiber per serving [<10% of the 25–30 g/day DRI (IOM, 2002)], whereas the traditional counterpart provided 7.9–15 g (26–50% of the DRI). Given the many health benefits attributed to dietary fiber (Topping, 2013), supplementing the diet with even one serving per day of these traditional foods could be recommended to significantly increase fiber intake.

Table 9
Summary of nutrient contributions of traditional Native American plant foods to the Dietary Reference Intake (DRI).[a] Shaded cells for each food and nutrient indicate a nutrient content >10% of the DRI per serving.

Food	Serving size (g)	Macroelements (mg)					Trace elements (μg)					Vitamins (mg)									Fiber (g)
		Ca	Mg	K	Na	P	Cu	Fe	Mn	Zn	Se	Niacin	Pantothenic acid	Vitamin B6	Riboflavin	Thiamin	Vitamin C	Vitamin K	Total choline	Carotenoids	Folate	Total dietary fiber
Cattail, broad leaf, shoots	90		■					■	■									■				■
Chokecherries	75						■		■					■				■				■
Lambsquarters, raw	30		■						■									■		■		
Lambsquarters, steamed	180	■	■	■				■	■	■				■	■					■		■
Plains pricklypear, raw	149	■	■			■			■								■					■
Plains pricklypear, broiled	115								■					■								■
Wild plums	132																■	■		■		■
Prairie turnips, raw	130	■	■					■	■					■		■						■
Prairie turnips, boiled	156	■	■					■	■					■		■						■
Wild raspberries	61.5																■					■
Wild rose hips	48								■								■	■		■		
Stinging nettles, blanched	20																	■		■		
Beaked hazelnuts	25.4					■	■		■							■						

[a] Based on DRI for an adult male, using lower limit in cases where a range is given (Institute of Medicine, 1997, 1998, 2000, 2001, 2002, 2004, 2011).

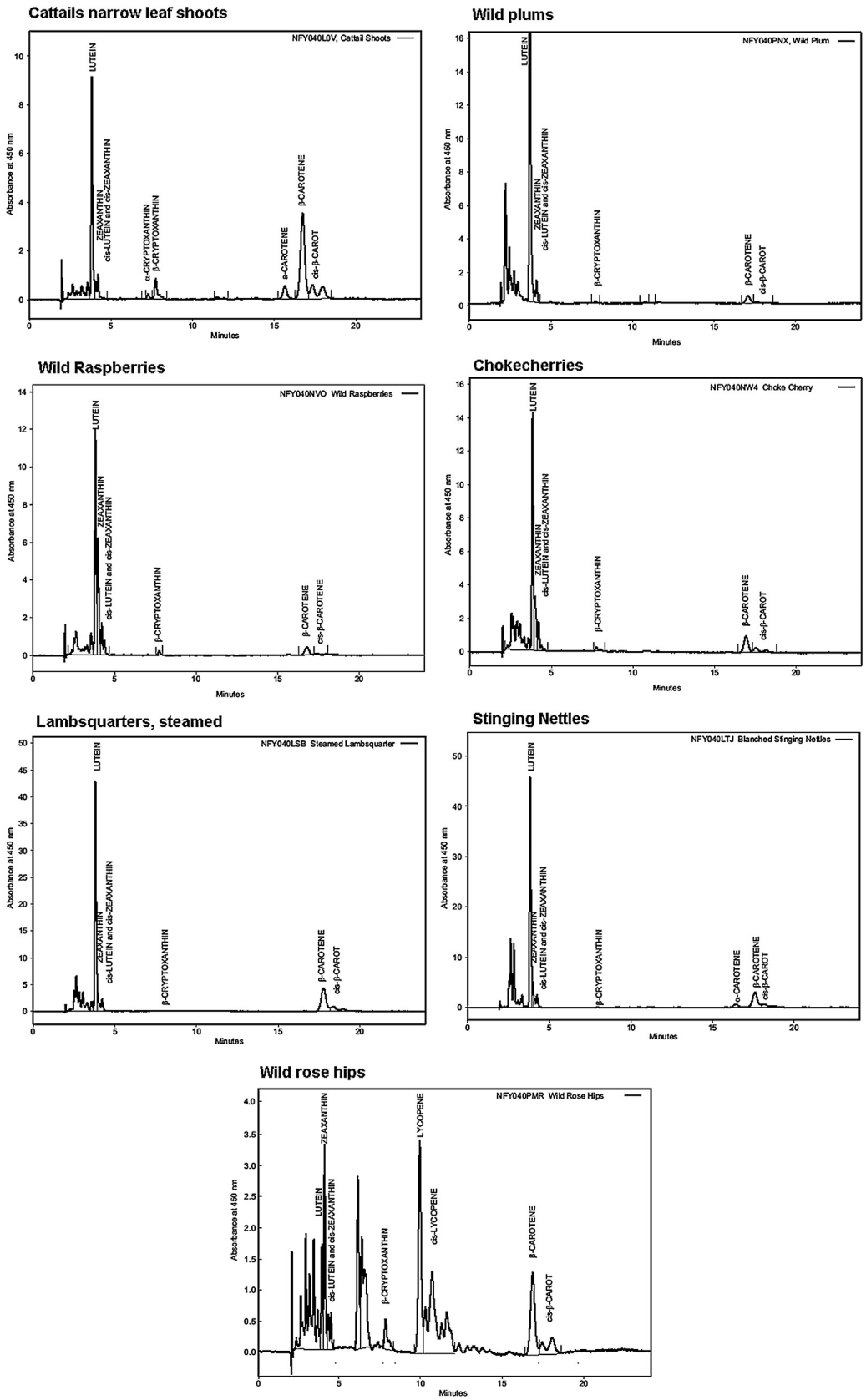


Fig. 3. HPLC chromatograms showing carotenoid profiles of traditional Native American plant foods. The HPLC system consisted of a solvent degasser, gradient pump, temperature controlled autosampler, and programmable UV–vis detector (Thermo Separation Products, San Jose, CA), with a Spherisorb ODS2 column, 250 mm × 4.0 mm, 3 μ with titanium frits (ES Industries, West Berlin, NJ); mobile phase 800 mL acetonitrile:150 mL p-dioxane:50 mL methanol:isopropanol (50:50) containing 150 mM ammonium acetate and 1 mL triethylamine; flow rate 1.0 mL/min; detection at 450 nm.

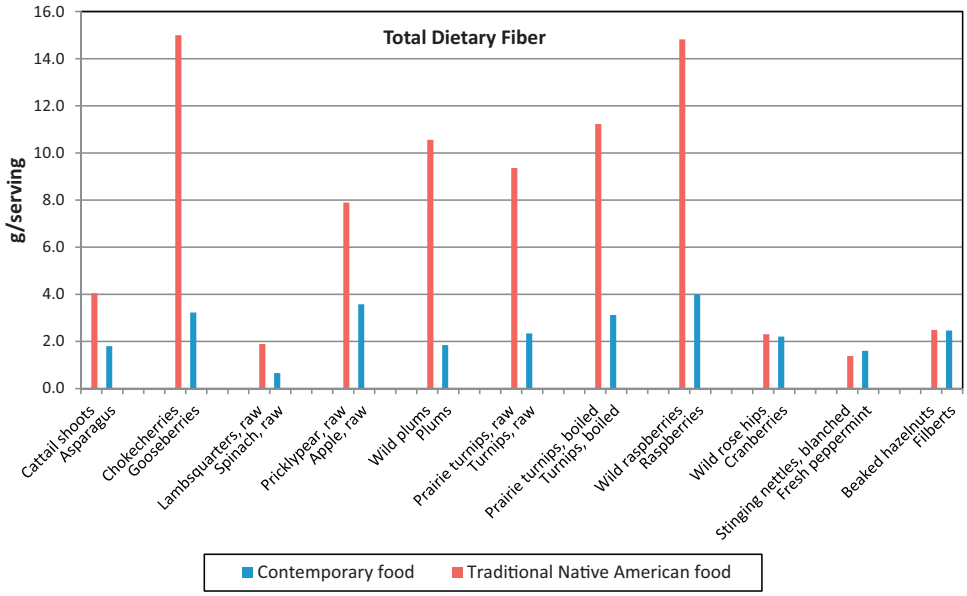


Fig. 4. Comparison of total dietary fiber per serving in traditional Native American plant foods (this study) and comparable contemporary foods (USDA, 2011). Serving sizes are given in Table 2.

3.2.2. Macro- and trace-elements

In several cases there were differences between the macro- and trace-element contents of the traditional foods and the contemporary counterpart (Fig. 5). The calcium contents of raw plains prickly pear and prairie turnips were substantially greater than in the corresponding contemporary foods (apples and turnips, respectively; 169 and 268 versus 39 and 7 mg/serving). Boiled prairie turnips, beaked hazelnuts, broiled plains prickly pears, raw and steamed lambsquarters, cattail broad leaf shoots, chokecherries, wild plums and wild raspberries, and blanched stinging nettles had more calcium per serving than their counterparts. Similarly, raw and boiled prairie turnips, raw plains prickly pears, raw and steamed lambsquarters, cattail broad leaf shoots, and chokecherries each had substantially more magnesium than their paired contemporary plant food. Iron value contents were improved only in prairie turnips, raw and boiled, compared to regular turnips (81 and 1 versus 14 and 0.14 mg/serving), although cooking reduced iron content. Lambsquarters, chokecherries, cattail broad leaf shoots, and wild plums had considerably more potassium than their contemporary counterparts. Native American cooking methods and differences in cultivar between the harvested wild plant and the domesticated version or similar plant might account for some of these differences, but assessing these variables was not part of this study and the multiple sampling locations for each food would include variation in traditional preparation methods.

3.2.3. Vitamins

There were some notable differences in vitamin contents between the traditional and corresponding contemporary foods (Fig. 6). Prairie turnips (raw or boiled) contained twice as much niacin as regular turnips. Beaked hazelnuts also contained more niacin than filberts (0.81 versus 0.46 mg/serving). Pyridoxine and thiamin levels were substantially higher in raw and boiled prairie turnips compared to regular turnips, and in raw plains prickly pear compared to apple (0.12 versus 0.06 mg/serving). Although riboflavin was higher in raw prairie turnips compared to regular turnips (0.26 versus 0.04 mg/serving), boiling reduced this difference. For some foods, the level of vitamin C in the traditional food was significantly higher than in its contemporary counterpart. The most remarkable was wild rose hips (204 mg/serving) compared to cranberries (6.4 mg/serving), in which the contemporary food provided <10% of the %DRI of vitamin C per serving, while the traditional food provided >200% of the DRI. Vitamin C levels were also higher in raw and broiled plains prickly pear compared to apple (17 and 7 mg/serving, respectively), although there was a marked reduction in vitamin C in both of the corresponding cooked foods (7 and 0.3 mg/serving, respectively). On the other hand, vitamin C was higher in the contemporary food in some of the pairs. Gooseberries had 21 mg vitamin C per serving compared to only 3.0 mg/serving in chokecherries. Raw prairie turnips had 7.2 mg vitamin C per serving compared to 27 mg/serving in raw turnips, and the difference was similar in the corresponding boiled vegetables (3.3 versus 18.3 mg/serving, respectively). In the remaining foods there was no notable difference in the vitamin C content of the traditional and corresponding contemporary food or the contribution to the DRI.

Epidemiological research strongly supports increased consumption of folate- and carotenoid-rich plant foods to reduce the risk of several chronic diseases (Li et al., 2003; Moat et al., 2004; Rao and Rao, 2007). The folate DRI is 400 μg (IOM, 1998), with evidence suggesting roles for specific folate vitamers (Gilbody et al., 2007; Robien and Ulrich, 2003). The folate content of the traditional and contemporary foods was difficult to compare due to differences in methodology. Measurement of naturally occurring folate by standard microbiological methodology (e.g. AOAC, 2011, Official Methods 960.46 and 992.05) shows higher variability and uncertainty than measurement of folic acid in fortified foods (Koontz et al., 2005). Folate values for the contemporary foods, taken from the USDA National Nutrient Database for Standard Reference (SR) (USDA, 2011), were determined by the microbiological assay. In this study we used the same tri-enzyme extraction that precedes quantitation of folic acid in the microbiological assay, but instead used LC–MS to measure the concentrations of the major individual folate vitamers (5-methyltetrahydrofolate, 10-formyl folic acid, and 5-formyltetrahydrofolate) and estimated "total folate" as the sum of their molar equivalent folic acid concentrations.

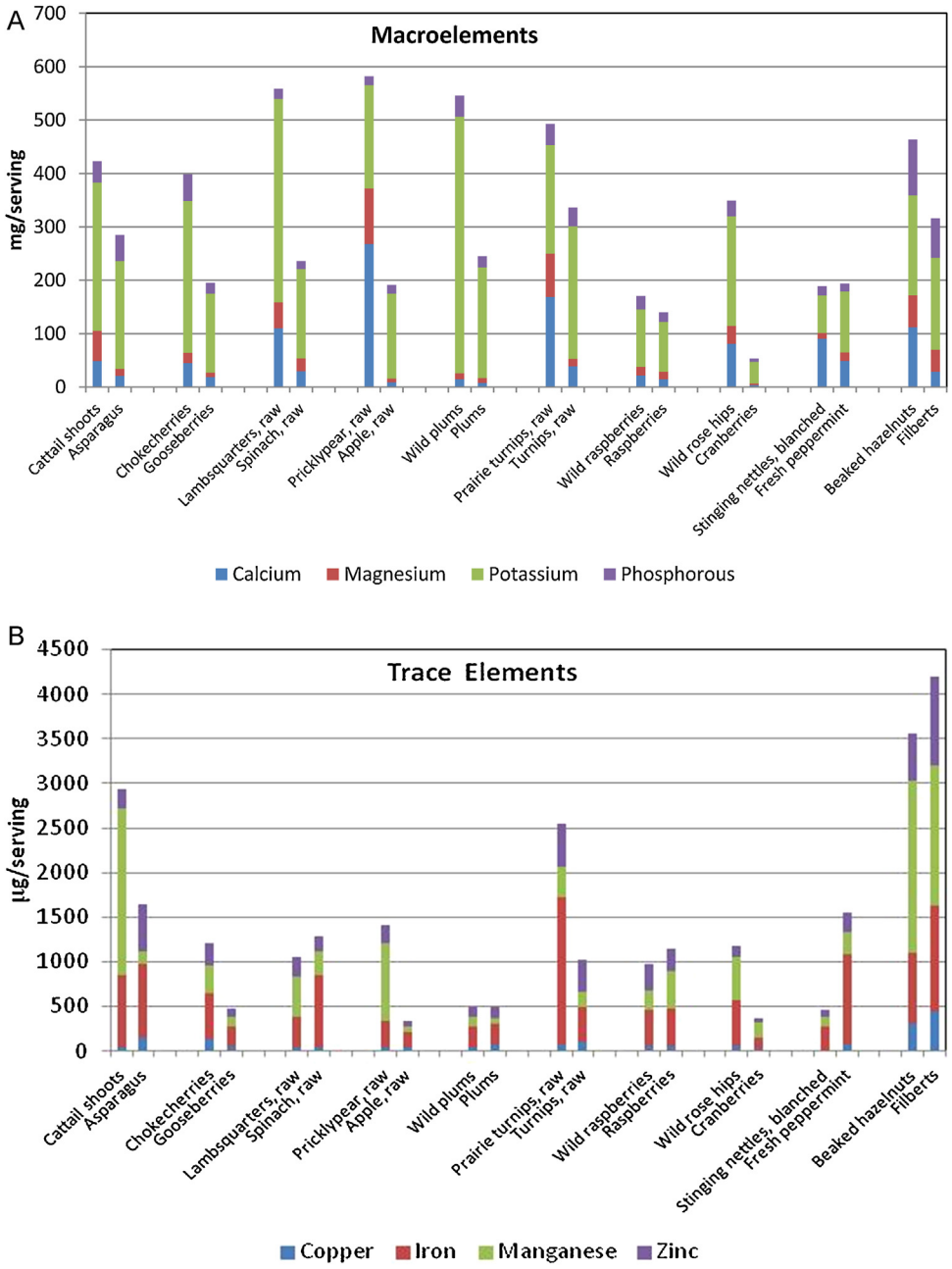


Fig. 5. Comparison of macro- (A) and trace- (B) element content of traditional Native American plant foods (this study) and comparable contemporary foods (USDA, 2011). Serving sizes are given in Table 2.

Similarly, the carotenoid content of the traditional and contemporary foods could not be compared directly because the SR does not contain values for carotenoids in all of the contemporary foods. Although there have been literature reports on carotenoids in some of the species studied (e.g. Andersson et al., 2011; Guil-Guerrero et al., 2003; Kuhnlein, 1990; Raju et al., 2007; Uusiku et al., 2010), the studies were on different samples, possibly of different variety and/or produced under disparate growing conditions and/or postharvest handling, all of which can affect carotenoid production, as has been demonstrated for other plant foods (de Faria et al., 2009; Hejtmánková et al., 2013; Reif et al., 2013; Rodriguez-Amaya et al., 2008). Without common control samples, it is impossible to make comparisons between the carotenoid composition of different samples of the same food that was determined at other laboratories, since it would not thus be possible to distinguish analytical uncertainty from differences in composition. This study was focused specifically on composition of indigenous plants consumed by US Northern Plains native Americans. The results for the quality control samples (Table 8), many of which are commercially available reference materials, allow assessment of accuracy and a basis by which values can be compared between other studies that include the same reference material. The relatively high carotenoid concentrations in the traditional Native American plants (Table 8 and Fig. 3) suggest that inclusion of these foods in the diet would contribute significantly to carotenoid intake. No recommended intake for individual carotenoids exists, but some can be converted to vitamin A (IOM, 2000).

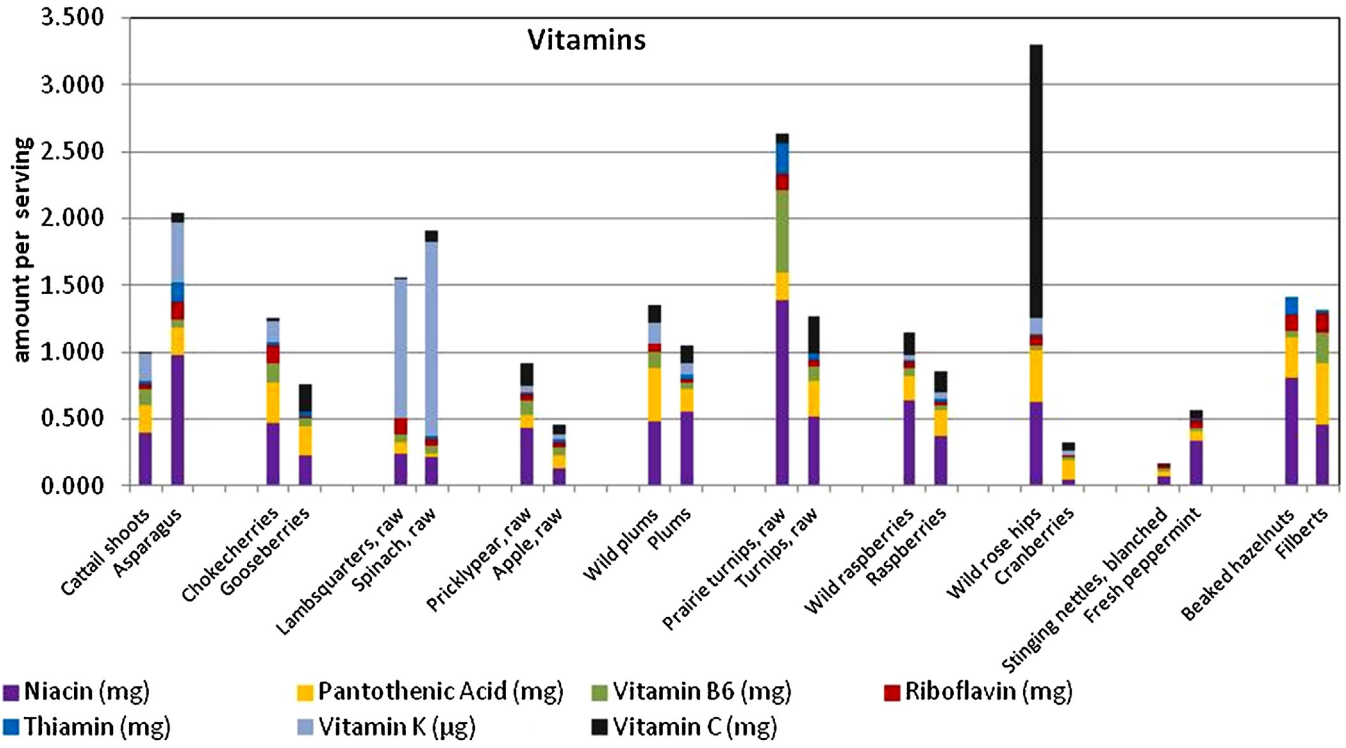


Fig. 6. Comparison of vitamin content of traditional Native American plant foods (this study) and comparable contemporary foods (USDA, 2011). Serving sizes are given in Table 2. (Data are not included for a nutrient and pair of foods when values were not determined in both foods.)

4. Conclusions

Consumption of wild plants, an important source of essential nutrients but for which data are limited, has declined among American Indians. The incidence of chronic disease has increased in US Native American Plains tribes in the last several generations along with a shift away from consumption of traditional foods (Conti, 2008; Taylor et al., 2005; Welty et al., 2002). Dietary interventions and recommendations that include increasing consumption of culturally relevant traditional foods have been promoted (Kattelmann et al., 2009; Holm et al., 2010; Jernigan et al., 2010; Schell and Gallo, 2012; Sinclair et al., 2011; Zephier et al., 1997). However, only limited data on the composition of indigenous plant foods exist. Moreover, Kuhnlein (2000), for example, has described the difficulties in collecting samples of traditional foods from native populations. The Native American Plains traditional plants analyzed in this study can potentially provide important nutrients to the diet of tribes of the region. For example, one serving of steamed lambsquarters, a rich source or many nutrients, contained more than 60% of the thiamin, 40% of the vitamin B6, 60% and 70% of the calcium and magnesium, respectively, and 10% of the potassium daily recommended intake (Institute of Medicine, 1997, 1998).

Recommendations to increase dietary calcium and magnesium to prevent cardiovascular diseases (Conti, 2008) support the consumption of plains prickly pears, prairie turnips, and beaked hazelnuts. Copper, which is highlighted to reduce the risk of stroke and heart attacks (Klevay, 2011), is appreciably high in beaked hazelnuts, lambsquarters, and chokecherries. Importantly, sodium, which is a risk factor for high blood pressure for which the recommended intake is generally exceeded in contemporary Native American populations (Stang et al., 2005) was low in all of the native plant foods (as well as the contemporary counterparts). Thus, these findings provide new evidence of the nutritional value of the traditional Native American plant foods. There have also been publications on the phytochemical composition and bioactivity of some of these foods (e.g. Budinsky et al., 2001; Burns Kraft et al., 2008; Hosseinian et al., 2007; Schauss, 2010), but further composition data would be valuable given the importance of bioactive non-nutrients such as procyanidins and flavanols (Bagchi et al., 2000; Ekström et al., 2011; Erdman et al., 2007; Lam et al., 2010; Schroeter et al., 2010).

It should be noted that nutrient content is not equivalent to bioavailability, and that antinutrients present in some foods may have an impact, depending on how the food is prepared. For example, oxalic acid has been reported in *C. album* L. (lambsquarters) in some studies, and this antinutrient could reduce the bioavailability of calcium (Guil et al., 1996, 1997). While it is not possible to discuss all aspects of potential antinutritional factors in a scientific report on nutrient composition of native plant foods, obviously any contraindications with respect to consumption of wild plants and any mitigation of those factors that might occur in different preparations (e.g. as described in Table 3) should be taken into consideration.

Data for these foods were incorporated into the USDA Nutrient Database for Standard Reference, release 20 (USDA, 2007) in a distinct food group, i.e. American Indian/Alaska Native foods (USDA, 2011). Additionally, this nutritional information has been shared with each participating tribe. It can be used by tribal leaders and dietitians in discussions of culturally appropriate dietary means to reduce risk of obesity, type 2 diabetes and cardiovascular diseases. A possible follow-up study is planned, if recommended by tribal leaders, that would examine the preparation of mixed meals composed of traditional plant and game foods to determine nutrient contents. This information would be shared with designated health-promotion groups at the participating reservations for use in community-based, participatory interventions to prevent obesity and diabetes among Native people. Finally, it is worth noting that many of these plants are often dried and preserved for year-round consumption and thus should be

sampled and analyzed in those forms in future studies, given the effect of drying on nutrient content. With many tribes pursuing a return to traditional foods, additional analyses of other components, including phytochemicals and other nutrients in indigenous wild plants, are also warranted.

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