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Review article

NORTH AMERICAN BIOACTIVE PLANTS FOR HUMAN HEALTH AND PERFORMANCE

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ABSTRACT

Native and naturalized bioactive plants of the Canadian and American temperate biome are examined for their health and performance enhancement properties. Some of these plants are now being used as natural health products, and many have a long history as traditional foods and/or medicines with indigenous groups. This paper reviews the medicinal/cultural uses and bioactive properties of selected plant families: the Holly family (Aquifoliaceae) as stimulants, the Celery family (Apiaceae) as normoglycemic aids and analgesics, the Ginseng family (Araliaceae) as energy-boosting aids, the Sunflower family (Compositae) as anti-inflammatory aids, and the Legume family (Fabaceae) and Nightshade family (Solanaceae) as functional foods. These North American plants show promising avenues for innovative health and performance enhancement aids and it is concluded that they should be investigated further for their bioactive properties.

KEY WORDS: Athlete; botanicals; complementary & alternative medicine; dietary supplement; ergogenic aid; grasslands; functional food; indigenous; natural health product; prairie; phytotherapy

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INTRODUCTION

North Americans are avid users of complementary and alternative medicine (CAM), such as dietary supplements and natural health products (NHP), for health risk reduction and performance enhancement. Regarding performance enhancement, the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine have a joint position statement on the use of supplements and ergogenic aids, due to the popularity of their use amongst athletes and fitness enthusiasts (American Dietetic Association *et al.,* 2009). Regarding other consumer group use of botanicals, in 2007, approximately 40% of surveyed USA adults used CAM, and 18% of these therapies are dietary supplements (Barnes *et al.,* 2008). In Canada, 71% of adults surveyed in 2005 have used NHP (Ipsos, 2005).

CAM is a broad group of diverse medical and health care systems (e.g., traditional / indigenous medicine), various practices (e.g., sweat lodge, meditation), and products (e.g., functional foods, supplements, and NHP). Natural health products are naturally occurring substances derived from organisms from the 5 life kingdoms: plants, animals, microbes, fungi, and protists. These products come in a variety of forms such as powders, extracts, ointments, capsules, and tablets. They include vitamins and minerals, botanical remedies, zootherapies, ergogenic aids, probiotics, homeopathic, and traditional medicines. Many traditional/indigenous food and medicines inform the research and development of relevant bioactive components into commercial NHP. Over 80% of Canadians believe that it is important to respect the role that NHP play in some cultures (Ipsos, 2005). Thus, traditional and indigenous knowledge systems continue to have a broad impact on the use of CAM by mainstream consumers.

Across Canada and the USA, a large temperate grasslands biome (3 million km^2) is host to a rich diversity of landscapes yielding a variety of native and naturalized plants. As well, this biome boasts a rich cultural diversity, including dozens of indigenous groups with a long history of use of botanicals for food and medicine. Despite being one of the most human altered landscapes on the planet, due to colonialism and agriculture, the grasslands biome continues to be a source of functional foods and medicines for indigenous and non-indigenous people today (Kindscher, 1987, 1992). While CAM is not evidence-based, and thus not part of allopathic medicine, this is changing. Increasingly, there is growing scientific evidence documenting the potential health and performance value of North American traditional foods and medicine products. For example, *Echinacea* species (family Compositae) are wild perennials used widely in North America by indigenous people for a variety of health and performance purposes. Today, *Echinacea* species are one of the most commonly utilized NHP by mainstream North Americans; as well, it is one of the most researched botanicals from the Americas (Price and Kindscher, 2007).

The National Institutes of Health (NIH) invested nearly $90 million in mechanistic, pre-clinical and clinical research studies of botanicals through two rounds of the Botanical Research Centers Program between 2000–2010. The center is currently in its third five-year funding cycle. The Office of Dietary Supplements and National Center for Complementary and Alternative Medicine (both NIH entities) jointly orchestrate a network of interdisciplinary centers devoted to the study of botanicals, with the Botanical Research Centers Program being the largest (Coates and Meyers, 2011). In Canada, the functional foods and NHP sector continues to grow, with total annual revenues of $3.7 billion CND, as estimated from the Functional Foods and Natural Health Products Survey 2007 (Statistics Canada, 2007). Growth of this Canadian sector is enhanced through the spending of $148 million CND (in 2007) for research and development by functional food firms and those producing and/or marketing NHP. New developments of this wide range of product lines (over 22,000) include extraction and processing of bioactive compounds to produce products with increased health and well-being benefits.

In this paper we give a brief introduction to the basic secondary metabolites in botanicals, and how they may be used for health and performance enhancement. We will then introduce selected native plants, organized by family, that come from a variety of habitats across the grasslands biome and have a history of utilization by indigenous people (past and/or present). Ethnobotanical and evidence-based information regarding the health and performance properties of the plant will be discussed with implications for future research. It is our hope that this multidisciplinary conversation regarding these plants will inspire indigenous interest in higher education; protection and appreciation of the varied habitats that occur in the North American grasslands biome; appreciation of the influence of traditional/indigenous knowledge on NHP use for health and performance; and scientific study of these bioactive plants.

SECONDARY METABOLITES

Plants produce many metabolites from secondary metabolism that may have clear roles in plant physiology (Wink, 2010). These secondary metabolites are organic molecules produced in response to influences such as developmental stage and environmental assaults (e.g., maturation and insects). When applied externally or internally, some of these plant compounds have purported beneficial effects in mammalian physiology. For example, as medicinal agents in folk remedies, veterinary medicine, and pharmacognosy, natural products continue to have significant medicinal, economic, and ecologic functions (Hopkins and Huner, 2009). There are 4 major classes of bioactive secondary metabolites: terpenes, phenolics, glycosides, and alkaloids.

Terpenes are a diverse group of isoprenoid compounds with over 15,000 structures, thus forming one of the largest phyto-chemical groups. While many terpenes are primary metabolites with significant plant growth and development roles (e.g., colour pigments, hormones, and sterols), the vast majority are secondary metabolites with roles in plant defense (e.g., essential oils and latex). Conifers and many flowering plants produce essential oils rich in terpenes and terpenoids, which may have medicinal properties. The native North American hops (*Humulus lupulus* L., Cannabaceae) are herbaceous perennial vines that grow in moist fertile soils in the prairie bioregion. The female flower clusters are valued by indigenous people for their sedative qualities and are used as an herbal analgesic and for insomnia. In the brewing industry, hops contribute anti-microbial, flavour, and aroma properties attributed in part to the terpene compounds. Beer has been used by athletes for its therapeutic qualities since recorded history; yet in immoderate doses alcohol continues to be abused amongst athletes (Ferreira and Willoughby, 2008).

Polyphenols are a diverse, large group of simple or complex phenolic compounds derived from secondary metabolism of the aromatic amino acids. Downstream product groups include coumarin, lignin, flavonoids, tannins, and alkaloids. Most of these compounds have a role in chemical defense, some are metabolic end products with unknown function, and lignin is a major structural component of vascular plant cells. Lignin has emerged as an important component of dietary fibre (undigested organic polymer) with antioxidant potential and suppresses carcinogenesis *in vitro* (Fardet, 2010) likely by acting as an absorbent for potentially carcinogenic molecules in the digestive tract *in vivo*. The Academy of Nutrition and Dietetics endorses consumption of a high fibre diet (e.g., fruits, vegetables, and whole grains) for good health (American Dietetic Association, 2008).

Glycosides are a class of compounds characterized by glycosidic bonds between a sugar molecule and another non-carbohydrate molecule with a hydroxyl group. This feature gives the compound the property to act as a detergent with a role in plant defense (e.g., antifungal). The four main groups of glycosides are saponins (have foaming properties), glucosinolates (anti-oxidants in cruciferous vegetables), cyanogenic glycosides (contains cyanide group), and cardiac glycosides (used to treat heart conditions). Although not native, the common dandelion, (*Taraxacum officinale* Webb, Compositae) is used in Mexican and Native American traditional medicine for a variety of ailments and health benefits (Rodriguez-Fragoso *et al.,* 2008). Glucosides (glucose-derived glycosides) from this plant have been shown to exhibit *in vitro* anti-inflammatory action as well as anti-oxidant action (Rodriguez-Fragoso *et al.,* 2008).

Alkaloids are a diverse group of chemically unrelated nitrogenous organic compounds with high biological activity. Herbaceous dicots (flowering plants) are rich in alkaloids, and many are repellant to vertebrates and invertebrates, likely due to their bitter taste. Many commercially important drugs are alkaloids, and most interfere with neurotransmitters (Hopkins and Huner, 2009). Thus, they often function as painkillers, muscle relaxers, and also as mood-altering substances. Caffeine, an alkaloid xanthine derivative, is one of the most widely used nutraceuticals in the world; and its use amongst athletes is similarly widespread and well-studied (Tarnopolsky, 2010).

Common dietary sources of caffeine include coffee (typically *Coffea arabica* L. and *C. canephora* Pierre ex A. Froehner, Rubiaceae), mate (*Ilex paraguariensis* A. St.–Hil., Aquifoliaceae), tea (*Camellia sinensis* (L.) Kuntze*,* Theaceae), cocoa (*Theobroma cacao* L., Malvaceae), and energy drinks. Currently not a banned substance by the International Olympic Committee, caffeine is well-established as a potential aid to physical and mental performance. However, not all people are caffeine responders, and the effects of dietary caffeine are contingent upon whether a person is a habitual or a 'naïve' user. Studies that appropriately control for confounding factors indicate that psychomotor and mood-enhancement benefits of caffeine use in habitual users are likely due to a reversal of withdrawal symptoms (James and Rogers, 2005).

According to a systematic review of the literature by Tarnopolsky (2010), caffeine has demonstrated adrenaline/noradrenaline receptor antagonistic effects upon skeletal muscle, adipose, and central nervous system tissues. Based upon his expert assessment of the currently available evidence, dietary doses of caffeine consumed prior to (2–6 mg/kg) or during (0.75–2 mg/kg) endurance exercise result in improved performance. While a reduction in central fatigue is a well-established benefit upon caffeine administration during endurance activities, caffeine does not significantly affect performance in high-intensity or strength activities.

HOLLY FAMILY (AQUIFOLIACEAE)

The presence of xanthines (caffeine, theobromine, and methylxanthine) is restricted to a few species of the *Ilex* genus in the Americas. Indigenous groups consume mate (*I. paraguariensis* A. St.-Hil.*)*, guayusa (*I. guayusa* Loes.), and yaupon (*I. vomitoria* Aiton). The first two are native to South America, and the latter to North America. Mate is used by the South American Guarani for socializing, mental and physical stimulation, and in herbal remedies. In southern South American culture, the consumption of mate rivals that of coffee as a mainstream stimulant. Of the 3 hollies, mate has been subject to the most scientific scrutiny and found to have compelling chemical profiles with important health implications (Heck and de Mejia, 2007). Guayusa is anecdotally used by the Amazonian Runa people as a balanced stimulant that energizes the body and mind while promoting restful sleep with lucid dreams. Consumed in social ceremony, the Runa appreciate mate's capacity to decrease bodily pain and to increase mental clarity. Yaupon, or the yaupon holly (also cassina) was used by Southeastern USA bands where it grew, and by Texas plains bands who traded for it (Browne, 1935; Havard, 1896). Records indicate that it was used as a mildly stimulating infusion for frequent use, or more famously, as part of the emetic 'black drink' associated with ritual purging (Havard, 1896).

Yaupon (Spanish: *Acebo de Yupon*)

Yaupon, or cassina, is a native North American member of the Holly family. This evergreen perennial is native to the southeastern coastal plains of North America and the piney woods and post-oak savannah of Texas (Smith and Rechenthin, 1964) and naturalized west to central Texas. It may be native or naturalized to some parts of Mexico. It is a dioecious shrub or small tree with a height of 3–6 m, and distributed across a variety of soil types and light intensities. However, it prefers moist acidic soil and has intermediate shade tolerance. Aerial plant parts (e.g., roasted leaves) are caffeine-rich and were used by indigenous groups in ceremony (e.g., as the 'black drink' decoction) and as a phyto-medicine (e.g., as an infusion). Natives called *I. vomitoria* Aiton, "cassina" (derived from the Timucua language) and *I. cassine* L. (commonly known today as dahoon holly) as "yaupon" and the black drink may have involved a mix of several species of *Ilex* (Power and Chestnut, 1919; Edwards and Bennett, 2005). The tangled nomenclature has been resolved, although confusion persists in the older literature (Edwin, 1963). In comparing the xanthine profiles of the two species, it has been demonstrated that caffeine and methylxanthine concentrations are higher in the yaupon than in the dahoon holly (Edwards and Bennett, 2005). It is also established that xanthine alkaloids (caffeine and theobromine) are present in the leaves of yaupon tree dependent upon soil nitrogen content (Palumbo *et al.,* 2007). Roasting the leaves facilitates solubilization of caffeine, as does the steeping in hot water. Yet, published quantification of the caffeine content of 'a cup of yaupon' is lacking, and cannot currently be compared to a cup of coffee, mate, or tea. Aqueous infusions of the plant are rich in phenolic acids (dicaffeoylquinic acids) and flavanols (quercetin and kaempferol glycosides) (Mertens-Talcott *et al.,* 2011).

Regarding the potential scientific merits of this plant for use as an ergogenic aid or nutraceutical, further work is encouraged. Yaupon holly has been analyzed by high-pressure liquid chromatography (Edwards and Bennett, 2005; Mertens-Talcott *et al.,* 2011; Palumbo *et al.,* 2007), and discerned to have a number of phenolic compounds, as well as alkaloid xanthenes (Edwards and Bennett, 2005; Palumbo *et al.,* 2009). Principal compounds identified by mass spectrometry are alkaloids and some phenols (Mertens-Talcott *et al.,* 2011). Many of these secondary metabolites likely protect the plant against bacterial and fungal microbial overgrowth.

There are no scientific reports on the health properties of yaupon for humans; but Noratto and colleagues (2011) indicate anti-inflammatory and anti-oxidant activity for the polyphenol (quercetin and kampferol glycosides) extractions of the plant *in vitro*. They demonstrated that yaupon-derived flavanols inhibit human colon cancer cell viability *in vitro* through reduced inflammation by induction of endogenous anti-oxidant systems and through reduced activation of pro-inflammatory genes. While yaupon holly has an intriguing profile of bioactive compounds, when used as a NHP, the anti-tumour, anti-inflammatory, and anti-oxidant properties have yet to be demonstrated in humans.

CELERY FAMILY (APIACEAE)

There are nearly 3,000 members in the Celery family (Apiaceae) worldwide (Bidlack *et al*., 2010). These are mostly temperate plants with soft-hollow stems and the leaves are usually alternate and pinnately or palmately compound with white umbellate inflorescences. The seeds and fruit form below the point of origin of the petals and stamen; they vary in size and shape and many have culinary and/or medicinal uses. Commonly used seeds include: dill (*Anethum graveolens* L.), coriander (*Coriandrum sativum* L.), celery (*Apium* *graveolens* L.), cumin (*Cuminum cyminum* L.), anise (*Pimpinella anisum* L.), caraway (*Carum carvi* L.), parsley (*Petroselinum crispum* (Mill.) Mansf.), and fennel (*Foeniculum vulgare* Mill). The root in many species is edible (e.g., carrot (*Daucus carota* L.), parsnip (*Pastinaca sativa* L.), as well as the stems and leaves of celery, parsley, cilantro, and lovage (*Levisticum officinale* L.). These plants are aromatic due to essential oils rich in bioactive compounds that contribute to their use by people for food and medicine. Caution should be utilized when wild-harvesting members of this family because some are deadly poisonous (e.g., water-hemlock (*Cicuta maculata* L.).

Oshá (Spanish: *chuchupate*)

Oshá (*Ligusticum porteri*, Apiaceae) and other Ligusticum species are herbaceous perennials found from British-Columbia and further south into northern Mexico, at elevations of 500–3,500m. It grows in moist soils on the edge of wooded habitats, as well in drier, rocky soils. The roots are fibrous tubers with 'hairy' root crowns growing from a central rootstock. Below the dark brown outer 'skin', the off-white inner root has a distinctive and aromatic 'celery' aroma. Animals and people consume the leaves, seeds, and roots as food and medicine. Many indigenous and traditional people anecdotally refer to oshá as 'Bear Medicine', because bears utilize the root for food and medicine (Andrews, 1992; Lipske, 1993).

Currently, oshá is widely used by Latin and Native Americans, as well as by mainstream NHP consumers. Cultivation of oshá has been unsuccessful and is currently wild-harvested. Over-harvesting may be a concern, and is being studied by researchers at the Kansas Biological Survey, University of Kansas, USA. Currently, it is sold in Canada, the USA, and Mexico in the form of tinctures, capsules, whole or ground roots, and seeds. The roots and seeds have been infused as traditional and folk medicine, for a variety of ailments; indigenous runners anecdotally chewed the root for stamina and power. Other species of the *Ligusticum* genus, native in Asia, are widely used in Chinese Traditional Medicine.

As a root infusion, oshá is used to treat diabetes (Andrade-Cetto and Heinrich, 2005). Type 2 diabetes is the world's most common endocrine disorder, with an escalating incidence especially amongst the Native and Latin American populations. A recent study reports the hypoglycemic effect of oshá extract in streptozotocin diabetic mice (Brindis *et al.,* 2011). Several compounds isolated from the extract utilized in that study proved to have anti-hyperglycemic activity *in vivo*, with the mechanism of action being undetermined or due to inhibition of intestinal alpha-glucosidase. One compound isolated from the extract has previously been shown to stimulate insulin secretion. Thus, the methanol root extract of oshá represents a normoglycemic agent with bioactive compounds with differing mechanisms of action, worthy of further scientific investigation.

Tincture made from soaking the oshá root in ethanol for months is commonly used as an externally applied liniment for sore muscles. The search for novel analgesics continues, because many common analgesics have adverse side-effects. Botanical anti-nociceptive substances recently discovered include alkaloids, terpenoids, and flavonoids. While chemical analysis of other *Ligusticum* species (e.g., Asian species) has indicated the presence of furano-coumarins, pyrano-coumarins, and phthalides, a composite chemical profile on oshá, reported by Brindis and colleagues (2011), indicates the presence of phenylpropanoids, terpenoids, and phthalides. These phyto-chemicals have yet to be specifically analyzed for anti-nociceptive properties. However, orally administered methanol-choloroform extracts of oshá in mice subjected to the writhing test study resulted in significant decrement of pain-related behavior (Deciga-Campos *et al.,* 2005). These preliminary findings suggest a place for this plant in analgesic discovery research.

GINSENG FAMILY (ARALIACEAE)

Panax species of the Ginseng family Araliaceae are found native in Asia and North America. These perennials have woody or herbaceous species with umbel flowers. The genus name, *Panax* is derived from the Greek word panacea. *Panax* is a part of the subfamily Aralioideae and the 3 species of the genus recognized as medicines are: Asian ginseng (*P. ginseng* C.A.Mey.), Japanese ginseng (*P. japonicas* (T.Nees) C.A.Mey.), and American ginseng (*P. quinquefolius* L.). The most commonly known family member is the Asian ginseng, which is used worldwide as a NHP. The indigenous people in New France used the American root to stimulate appetite and to treat rheumatism and dysentery. Colonists shipped this root to Asia, which proved to be profitable, as the Chinese considered the plant valuable (Messier, 1989). While harvest of wild American ginseng is legal during state-specified periods in the USA, it is illegal in Canada (COSEWIC, 2000).

The English name ginseng derives from its Chinese name, *rénshēn,* meaning "man root" because the roots are often shaped like human legs. *Panax* spp. contain over 150 ginsenosides, the bioactive compounds that are characteristic of true ginseng. Ginsenosides are a subclass of the triterpenoid saponin glycosides (Senchina *et al.,* 2009). Ginseng is commercially available as a NHP in dosage forms suited for oral administration. In a review by Senchina and colleagues (2009), it was found that, along with echinacea, (*Echinacea angustifolia* DC., Compositae), Asian ginseng is the most popular NHP used by athletes, with 3.2–15% of athletes using it. Athletes use NHP for health and performance more than other consumer groups.

Athletes consume members of the genus *Panax* for their alleged increase in energy and physical stamina. Although members of the genus *Panax* have been reported to increase pulmonary function and exercise capacity and to reduce chronic fatigue in patients and elderly people, there is no evidence of these effects in healthy, young athletes (Bahrke *et al.,* 2009). In a review by Bahrke and colleagues (2009), it is also reported that members of the genus *Panax* do not improve performance and recovery of individuals undergoing exhaustive exercise. Asian ginseng supplementation taken one hour prior to exercise tests on a treadmill did not affect the endurance running performance and other selected physiological parameters in recreational runners (Ping *et al.,* 2011). Senchina and colleagues (2009) conclude that the benefits of taking Asian ginseng supplements on athlete immune system remain largely unproven.

Small Spikenard (French: *aralie à tige nue* (Marie-Victorin, 1964); Anishnabe: *jiisens ojiibikan gisēns, wenane*)

Small spikenard (*Aralia nudicaulis* L., Araliaceae), commonly referred to as wild sarsaparilla, is a characteristic feature of parkland groves and wooded ravines of the prairie grasslands except the extreme South and Southwest USA (Vance, 1999). This perennial member of the family Araliaceae, genus *Aralia*, has single leaf stalks, 15–30 cm in length before dividing into 3 parts that then divide again into leaflets. The greenish white flowers are borne on a flowering stalk, which is usually below the level of the leaves. The plant was used as a popular medicine in New France, but it was only during the English-controlled period that the plant was harvested on a large scale. For example, it is reported that several thousands of pounds were sent to London merchants in 1766 (Lessard, 1996).

Indigenous Elders from Saskatchewan often refer to small spikenard as the energy plant, and also as rabbit root. Consistent with other Ginseng family members, the wild sarsparilla root is used as a tonic and stimulant, although not to the same extent as commercial Asian ginseng. The spongy root pith has a sweet balsam aroma and flavour and indigenous people use the root and berries as a stimulating tonic on long journeys (Keane and Howarth, 2009). In Saskatchewan, some pubs still brew sarsaparilla root beer, which is made from natural sarsaparilla flavour (indeterminately of wild sarsaparilla vs. non-native source).

Brussel (2004) also mentions its stimulant effect. Its high carbohydrate level might explain its energetic quality. In a study of 17 species of plants growing in the southern edge of the boreal forest in Ontario, Canada, small spikenard fruits showed the greatest total energy value (73.4 Kcal/100 g) and soluble carbohydrate based upon glucose (16.38%) (Usui *et al.,* 1994); the fat and protein composition of its fruits was 0.28% and 1.34%, respectively. While studies on the role of small spikenard as an energy source have been limited, its ethnobotanical history and nutritional value suggests the need for further examination for its use as a NHP.

There have been several published and ongoing mechanistic and clinical studies of ginseng and NHP. They show promise to be consistent, safe and effective in a variety of health-related areas of research. Regarding wild sarsaparilla, a small spikenard rhizome extract was found to have little anti-mycobacterial activity on its own but appeared to have some synergistic activity with Bacillus Calmette–Guérin (tuberculosis vaccine) and *Mycobacterium avium* when combined with *Symplocarpus foetidus* (Webster *et al.,* 2010). Rhizome extracts (hexane) were effective at eliminating 4 different human cancer cell lines with cellular viability less than 6.8% (Huang *et al.,* 2006). In a companion study, Wang and colleagues (2006) reported that hexane extraction from the rhizome and the fruit of small spikenard were more effective than stem and leaf extraction against human colon cancer, leukemia, and cervix cancer in cell lines.

SUNFLOWER FAMILY (Compositae)

The family Compositae has approximately 20,000 species and is distributed worldwide (Bidlack *et al*., 2010). Well-known members of this family include chicory (*Cichorium intybus* L.), Jerusalem artichoke (*Helianthus tuberosus* L.), Texas tarragon (*Tagetes lucida* Cav.), sunflower (*Helianthus annuus* L.), and prairie thistle (*Cirsium canescens* Nutt.). The edible tubers of Jerusalem artichokes contain a starch comprised of fructose polymers. Roasted dandelion and chicory roots have been used as a coffee substitute. Sunflower, native to America, was widely used by indigenous people for their seeds.

Yarrow (French: *achillée millefeuille*; Anishnabe: *aadjidamowana waabanowashk zhagish kaandawens aanashic*)

Yarrow (*Achillea millefolium* L., Compositae) is one of the most abundant white flowers growing upon the North American prairie. It has white flower heads densely packed in a round-topped terminal cluster. Its woolly leaves are divided into many segments and grow from a branched rhizome. One Elder in Saskatchewan calls this species porridge-on-a-stick and states that an infusion “made using the entire top of the plant helps support the immune system and can be used for chest infection” (Gendron *et al.,* 2009). Indigenous people in Saskatchewan use this plant for regulating body temperature, opening skin pores, stimulating perspiration, and treating colds and fevers. Yarrow is also used to regulate the menstrual cycle, heal tissues, and to reduce inflammation (Keane and Howarth, 2009).

Recently, it was found that methanol extract of yarrow inhibited human neutrophil elastase and matrix metalloproteinases MMP-2 and -9 *in vitro* (Benedek *et al.,* 2007). These enzymes are proteases associated with the inflammatory degradation of the connective tissue and the extracellular matrix proteins. Benedek and colleagues (2007) were unable to identify which flavonoids contributed the most to the neutrophil elastase inhibition. The capacity of yarrow to reduce inflammation may be an interesting avenue to explore in regards to mechanical stress associated with exercise. Yarrow extracts exhibit blood-pressure lowering (*in vivo* & *in situ*), vaso-dilatory (*in vitro*) and broncho-dilatory (*in vitro*) activities (Khan and Gilani, 2011).

Yarrow's high content of flavonoids makes it a potential candidate for chemoprevention research. Dried aerial parts of yarrow contain flavonoids, alkaloids, coumarins, saponins, sterols, tannins, and terpenes. Infusions made with yarrow are a source of the flavonoids rutin, chlorogenic acid, and quercetin (Dadáková *et al.,* 2010). Yarrow has a high amount of apigenin, a flavonoid associated with cancer prevention (Patel *et al.,* 2007). Activities identified for apigenin-mediated cancer prevention and therapy include: estrogenic/anti-estrogenic; anti-proliferative; cell-cycle arrest and apoptosis; anti-oxidation; detoxification enzyme induction; immune-protection; and cell signal modulation (Patel *et al.,* 2007). The *Achillea* genus also shows promising potential at reducing incidence of degenerative diseases, such as atherosclerosis, with its high anti-oxidant activity (Vitalini *et al.,* 2006).

LEGUME FAMILY (LEGUMINOSAE)

The Legume family (also Fabaceae) is the third largest plant family, with over 19,000 species (Bidlack *et al.,* 2010). The family name Fabaceae refers to the fruit, which is also called a legume or pod. This large and economically important family is characterized by having many species that form symbiotic relationships with bacteria to fix atmospheric nitrogen, resulting in plants with rich nitrogen content, and hence in protein. The many important plants in the Legume family world-wide include varieties of beans (*Phaseolus vulgaris* L.), soybeans (*Glycine max* (L.) Merr.), peas (*Pisum sativum* L.), cowpeas (*Vigna unguiculata* (L.) Walp.), peanuts (*Arachis hypogaea* L.), chickpeas (*Cicer arietinum* L.), alfalfa (*Medicago sativa* L.), and carob (*Ceratonia siliqua* L.). The largest genus is *Astragalus* with over 2,000 species; many of which are medicinal while many others are poisonous due to alkaloids, selenium accumulation, or both (Kindscher, 1987).

Prairie Turnip (Lakota: *tipsin*)

The prairie turnip (*Pediomelum esculentum* (Pursh) Rydb.), also called Indian bread root or bread-root scrufpea, is a perennial prairie plant found throughout the grasslands from Alberta to Texas. The scientific name tells one it is the esculent or edible species of the genus. It has a chicken egg-sized swollen root that appears turnip-like, but tastes more like a potato with a hint of peanuts. This was the most important wild plant food collected by indigenous people across the Great Plains of North America (Kindscher, 1987; Nabhan and Kindscher, 2006). The roots are often braided by the tap roots and are still traded and stored by the Lakota and other indigenous bands. The long-lived plants have annual growth rings and are found today only on native prairies.

The plants occur in patches and historically, large prairie turnip patches were places where people went to dig them during the early summer before the tops dried up and blew away as tumbleweeds. The Omaha were known to determine the route of their summer buffalo hunts by where they could camp and harvest an abundance of prairie turnips (Fletcher and La Flesche, 1911). The harvest was an event for the women and children, with the kids seeking new plants as a game while the women used digging sticks to harvest them from the hard prairie soil (Gilmore, 1977). Their abundance was evident as observed in 1858, as the Cree in Saskatchewan were observed to harvest "many bushels" (Mandelbaum, 1940). Lewis and Clark recorded on May 8, 1805 in northern Montana that "this root forms a considerable article of food with the Indians of the Missouri...they are esteemed good at all seasons of the year...are sought and gathered by the provident part of the natives for their winter store, when collected are stripped of their rind and strung on small throngs or chords and exposed to the sun or placed in the smoke of their fires to dry; when well dried they will keep for several years" (Thwaites, 2001).

The native harvesters of these plants came back to their prairie turnip patches repeatedly over the years, but not every year. Fortunately, when the plants are harvested, the seeds are ripe, and traditionally these were scattered across the disturbed soil as the tops of plants were returned to the hole from which they were harvested. Research has shown that disturbance surrounding prairie turnips increases the numbers that are present (Castle, 2006) and helps justify the sustainability of traditional harvest and planting practices.

The nutritional profile of the prairie turnip indicates that in addition to starch, it has high levels of calcium, magnesium, and iron. Also the prairie turnip is a good source of the amino acid lysine and is considered an "exceptionally valuable dietary supplement" (Kaldy *et al.,* 1980). It would seem that the prairie turnip could be suited as a functional food. It has been difficult to cultivate, however, and it is not readily available in the commercial trade.

NIGHTSHADE OR POTATO FAMILY (SOLANACEAE)

The Solanaceae are well known as an important group of plants that are used in food and medicine and contain alkaloids whose toxins range from very mild to very poisonous. Phyto-chemical research has been occurring for approximately 200 years. Members of this family are particularly interesting for their competitive characteristics, high productivity, and a notable presence of secondary metabolites (Eich, 2008). Steroidal alkaloids or alkamines are present such as tomatillidine from *Solanum tomatillo* (Remy) Philippi f. (Eich, 2008). Tropane alkaloids are found in the *Physalis* genera amongst others in the family. Steroidal and tropane alkaloids are non-overlapping in taxa and are thus mutually exclusive (Wink, 2010).

Wild Tomatillos (Zuni: *k'ia'-po-ti-mo'-we*)

The wild tomatillo, or ground-cherry, (*Physalis longifolia* Nutt.) is a low-growing perennial herb of weedy habitats. The papery husk that encloses the fruit of the wild tomatillo is a distinctive characteristic of the genus *Physalis*, which includes cultivated species such as husk-tomato (*P. philadelphica* Lam.) and Chinese lantern (*P. alkekengi* L.). The name *Physalis* is Greek for "a bladder," a reference to the inflated calyx, which forms the husk. The genus *Physalis* is a member of the Nightshade family, Solanaceae, which includes tomatoes (*S. lycopersicum* Lam.), potatoes (*S. tuberosum* L.), and tobacco (*N. tabacum* L.). All nightshades are considered somewhat poisonous and may contain toxins in some parts of the plant, but many fruits in the family Solanaceae are edible, including wild tomatillos (Kindscher, 1987).

The many-seeded berries of the genus range from greenish to yellow to tangerine and are sometimes flushed with purple or red (Whitson and Manos, 2005), thus explaining the use of the common names "ground tomato" and "husk tomato" with reference to *Physalis* (Castetter, 1935). Wild tomatillos occur throughout the continental U.S. and into southern Canada and northern Mexico. Its habitat includes old fields, open woods, and prairies, but it thrives in disturbed sites, including roadsides. Plants form colonies through the spread of underground rhizomes. The widely distributed wild tomatillo is cultivated by Zuni women, who boil the ripe red berries before grinding them with raw onions, chile, and coriander seeds in a mortar. The dish is regarded as a great delicacy (Kindscher *et al.,* 2012; Castetter, 1935). Ethnologist Walter Hough (1898) stated that in the "old times", the berries were eaten by the Hopi. Hough (1898) also reported that the Zuni dried and ground the berries to produce a meal for making bread.

According to Matilda Cox Stevenson (1915) the berries of the ivy-leaf ground-cherry (*P. fendleri* A. Gray, now recognized as *P. hederifolia* A. Gray) had the same Zuni name (*Ke'tsitokia*) as this wild tomatillo (and is named for an insect that feeds upon the plant), indicating that these species may have been used interchangeably. She reported that this plant grows wild on lowlands and is also cultivated in the small gardens worked by women. In Frank Cushing's (1920) *Zuni Breadstuffs*, he states that: "Among the sandy defiles of the upper plains, mesas, and mountains grow abundant low bushes bearing very juicy little yellow berries called *k'ia'-po-*

ti-mo'-we, or the "juice-filled fruitage." These berries were in high favour with the ancient Zuni as food. They were boiled or stewed to make a sweet but acrid sauce, which although not quite so acidic, otherwise resembled the cranberry. The berry is still used as food at the Zuni Reservation. In Rita Edaakie's (1999) "*Idonaphshe*" -let's eat- traditional Zuni foods" she gives a recipe for the use of *K'e:ts'ido'kya K'yalk'osenne* or tomatillo paste in which the store purchased husk-tomatoes or tomatillos (*P. philadelphica* Lam.), are used to make a tasty sauce which includes roasted chilis and green onions, as an adaptation of the previous use of native *Physalis* species.

Physalis seeds, which cannot be identified to specific species, occur commonly in archeological sites in the southwestern USA (Kindscher *et al.,* 2012). In fact, *Physalis* seeds have been found in ruins dating from as early as AD 298 at these archaeological sites in New Mexico: LA 109100 on Ceja Mesa west of Albuquerque (Dello-Russo, 1999); at the Basketmaker III/Pueblo I period (AD 650-900) site at River's Edge west of the Rio Grande River; and north of Corrales (Brandt, 1991). Nutritional data on the native *Physalis* species is lacking, but tomatillos are anecdotally considered nutritious and these plants could provide an important source of additional vitamins and phytochemicals. Tomatillos contain alkaloids, as is common in the Solanaceae family (Whitson and Manos, 2005). *Physalis* species were used medicinally in the past, and now are the subject of much research as our colleagues have discovered 14 new compounds in *P. longifolia* Nutt., including one which has strong and significantly unique anti-cancer properties (Zhang *et al.,* 2011; Zhang *et al.,* 2012).

SUMMARY AND FUTURE DIRECTIONS

North American athletes and other consumer groups use natural health products (NHP) to improve health and performance. Many NHP and dietary supplements are derived from indigenous/traditional knowledge systems. The central region of North American is largely comprised of one of the largest biomes in North America -the grasslands- as well as a variety of physiographic regions rich in ethnomedicine, past and present. For this reason, scientists in Canada and the USA are exploring the bioactive properties of plants from this region. Identified herein are several native and naturalized bioactive North American plants that could help improve the health and performance of athletes, and other consumers, when used as NHP, functional foods, and ergogenic aids. Bioactive plants and their compounds used for dietary supplements and NHP require further study regarding: identification, standardization, mechanism of action, toxicology. Future work should also elucidate plant compound benefits in human physiology, when consumed in a whole food matrix such as a functional food.

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