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Sustainable Goldenberry Production

SCHOOL OF ENVIRONMENTALAND BIOLOGICAL SCIENCES

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CHAPTER 1 – A QUICK LOOK AT GOLDENBERRIES

Goldenberries (*Physalis peruviana* L.) are golden-orange, marble-sized fruit with a unique, exotic citrus-like flavor. They are perennial in their native tropical South America but will produce as annuals in the temperate region if the growing season is long enough. Goldenberries are injured by temperatures < 30°F and have a long growing season, requiring 150 to 180 days to produce ripe fruit from seed (90 – 120 days from transplanting, 60 – 100 days after flowering). To get significant production in the temperate zone, they must be started in the greenhouse then transplanted outdoors as soon as the threat for frost is over. They are productive anywhere tomatoes grow and also grow well in pots and greenhouse culture.

This 'Sustainable Goldenberry Production Guide' is an introduction to this unique, novel fruit which easily fits into vegetable rotations used by CSA and farmer's market growers. It was made possible by a USDA SARE grant 'USDA-NE SARE PROJECT LNE18-362 "Goldenberries (*Physalis peruviana*) : A New Fruit for CSA Farms and Farmers Markets" '.

COMMON NAMES

There are many common names for goldenberries including: aguaymanto, alkekengi, amor en bolsa, apelliefie, Barbados gooseberry, Bladderberry, bolsa de amor, Cape gooseberry, capuli, cereza del Peru, chuchuva, coqueret, golden berry, golden Cape gooseberry, golden husk goldenberry, gooseberry, gooseberry tomato, ground cherry, guchavo, Husk Cherry, incaberry, lobolobohan, love apple, makowi, motojobobo embolsado, Peruvian cherry, Peruvian ground cherry, Peruvian tomato, Pichuberry, Poha Berry, Poha, pompelmoes, strawberry tomato, teparee, tiparee, tomate sylvestre, topotopo, uchuba, uchuva, uvilla, vejigón, wild gooseberry, and winter cherry.

While several noted television food personalities continue to insist that goldenberries are related to gooseberries, they are not. This confusion is likely due to the alternate name for goldenberry, 'cape gooseberry'. Goldenberries are related to ground cherries, tomatillos and tomatoes. They are in the *Solanaceous* family which also includes potatoes, peppers and eggplants. Gooseberries are *Ribes hirtellum* (American) and *Ribes uva-crispa* (European), both in the *Grossulariaceae* family and neither are related to the goldenberry.

HISTORY

Goldenberries were first described by Linnaeus in 1753 and have been cultivated for years in the Andes mountains of South America. The fruit has spread worldwide however it has not become a significant crop in most regions. Localized industries have developed in South America, South Africa, Australia, New Zealand and India but large-scale commercial production is not common.

While 'named' cultivars are sold in a number of seed catalogues, goldenberries are categorized into ecotypes based on their region of geographic utilization. There are three goldenberry ecotypes: Columbian, Kenyan and South African (Almanza & Espinosa, 1995). They are distinguished from each other by size, color and flavor of the fruit as well as flower shape and plant size. The Columbian ecotypes produce smaller, more vividly colored and sweeter fruit than the Kenyan and South African ecotypes, thus they are more desirable to consumers (Fischer, Florez & Sora, 2000). Named cultivars have been developed by South American breeders but seed are not readily available in the US.

Seed purchased from commercial sources are often misidentified as goldenberries (Wolff, 1991), and are tomatillos or ground cherries (personal observation). Even reputable seed companies sell misidentified / mislabeled seed. While 'named' varieties are listed for sale, most of the commercially offered seeds are non-improved lines selected for productivity and flavor from wild land races. As part of this project, we evaluated 21 goldenberry genotypes acquired from 6 of the 7 continents (we couldn't find any sources in Antarctica).

The purpose of this manual is to provide an all-in-one source for goldenberry information. Much of the basic information contained herein was acquired through an extensive literature search and production suggestions were developed via studies at our research farms in New Brunswick and Cream Ridge, NJ. References are provided for those who want to delve more deeply into particular areas.

CHAPTER 2 – GOLDENBERRY BOTANY & HORTICULTURE

GENERAL BOTANY

Plant structure

There are four species of *Physalis* grown for their fruit: *P. ixocarpa* (tomatillos), *P. pruinosa* and *P. pubescens* (ground cherries), and *P. peruviana* (goldenberries). Goldenberries are often confused with ground cherries however, they are easy to differentiate: Goldenberry foliage is extremely pubescent (hairy) while ground cherries are glabrous (smooth).

The plant on the left is a goldenberry while the one on the right is a ground cherry. Note the slightly serrated margins of the younger ground cherry seedling and the smooth margins on the goldenberry. The goldenberry seedling is pubescent while the ground cherry plant is glabrous. The two can be distinguished via inspection of developing fruit since the calyx (husk) of goldenberry has 10 ribs while husks of ground cherries have 5. Mature goldenberry plants are much larger (up to 5 or 6 feet) than ground cherries (up to 3 feet).

Shoots and leaves

Goldenberries are herbaceous perennials in the tropics and annuals in the temperate zone. They are erect shrubs with alternate, often purplish branches with pubescent heart-shaped, pointed, randomly-toothed leaves that are 2-1/2 to 6 inches long and 1 ½ to 4 inches wide appearing nearly opposite along the ribbed stems (Morton, 1984).

Flowers

Flowers are yellow, up to ¾ inch wide, pendulous and bell-shaped with purplish spots in the throat.

Flowers are cupped by a purplish-green, hairy, 5-pointed calyx which expands to form the husk after the flower falls following pollination and fertilization.

Fruit

Fruit are encased in a husk (the calyx of the flower) which starts out soft and green when young but becomes tough, brown and paper-like when the fruit is mature. The husk is much larger than the fruit it encloses and it is inedible. Unlike ground cherries, goldenberries do not abscise (fall off the plant) when ripe and are harvested directly from the plant. If the plant is water-stressed, fruit may abscise, particularly when they are very young or are nearly ripe. Fruit are ½ to 1-inch-wide globe-like berries with smooth, glossy orange skin and juicy pulp containing many very small edible seeds when fully ripe. Fruit has a pleasant tropical flavor, tasting like a mixture of pineapple, strawberry, sour cherry and citrus. Plants generally produce 150 to 300 flowers / fruits per plant.

PRODUCTION

Production practices are well documented for tropical climates (Muniz et al, 2014), however, there is limited information regarding practices for production in the US (Wolff 1991).

SEED SOURCE

Seeds must be from a reliable source. Seeds are not universally available and the companies that carry seed often carry few 'cultivars': Kitizawa Seed Company (1); Johnny's Selected Seeds (1); Southern Exposure Seed Company (2); Reimers Seed Company (3), and Tradewinds Fruit Company (6). Additionally, goldenberries are often mislabeled by seed companies (Wolff, 1991) and are often *P. pruinosa* or *P. pubescens* (both ground cherries) or *P. ixocarpa* (tomatillo)) even when purchased from reputable sources (personal observation). Seeds are easily extracted, dried and saved from superior fruit. Since goldenberries are generally self-pollinating and do not easily cross with other *Physalis*, the seed you save will produce fruit

nearly identical to that from which the seed was extracted. There is only slight variability from generation to generation.

SOWING SEED

Sow seed in flats of sterile seeding mix barely covering the seeds. Keep them moist. Seeds germinate in 14 to 21 days in a moderately warm greenhouse. Germination is usually around 90%.

Seedlings are transplanted into 24 to 50-cell plug trays when they are about 1-inch-tall then grown for at least 6 weeks in the greenhouse before transplanting to the production field. Plants are large enough to transplant outdoors when they are 4 to 6 inches tall and there is no chance for frost. Goldenberries tend to remain rather small when seeded in 50-cell plug trays (3 – 5 inches at transplanting), however, once set in the field, they grow rapidly.

As a side note, if your plants begin to flower in the greenhouse before you can get them moved to the field, you probably have ground cherries and not goldenberries! Ground cherries often flower once the root system fills the plug cell while goldenberries do not. If you want to grow ground cherries and they flower before transplanting, they quickly resume vegetative growth once they are in the field, so there's no need to worry.

Goldenberries can be propagated using stem cuttings. The resulting plants are less vigorous than seedlings, however they flower and fruit earlier. We have not evaluated this potential for shorter season climates, but it is a viable option to investigate.

SOIL PREPARATION

Goldenberries produce best on well-drained soils but need adequate moisture as they are particularly sensitive to water stress and may 'go dormant' during a drought (Deveci and Celik, 2016). Goldenberries are moderately salt tolerant (Miranda et al., 2010). In some of the literature it is suggested that goldenberries produce best when grown in poor soils. We have observed that they benefit from fertilization programs similar to tomato and tend to remain stunted and weak if neglected.

BEDS, MULCH AND TRICKLE IRRIGATION

We recommend planting goldenberries on standard raised beds covered with black plastic mulch with trickle irrigation, just like those used for tomato production. Do not supply any pre-plant fertilizer or any at the time of transplanting as early fertilization may reduce and delay fruit production.

SPACING

Beds can be spaced according to your equipment measurements but should be at least 4 feet on center. From our experience, plants should be spaced 4 to 5 feet apart within the row. Many reports in the literature suggest that much closer within-row spacing can be utilized without compromising productivity. Recommended spacing (in-row x between row) reported include 0.3 x 0.3 m (Ali, 2007), 0.6 x 0.6 m (Girapu

and Kumar, 2006), 0.6 x 0.75 (Gond et al., 2017; 2018), 0.9 x 0.75 m (Ali and Singh, 2015, 2017), 1.0 x 1.0 m (Leila et al., 2016) and 1.00 x 3.00 or 0.50 x 3.00 m (Muniz et al., 2014).

Quality may be reduced with closer in-row spacing as vitamin C, titratable acidity and total soluble solids in fruits were lower with closer spacing comparing 0.5, 0.75 and 1.0 m in-row spacing (Leila et al., 2016)

PRUNING, TRAINING AND SUPPORT

Pruning, training and support are three production practices that must be considered together. Many research studies have evaluated training methods for goldenberry to determine the method of pruning and type of support needed. The majority of training methods have been evaluated in South America where goldenberry is often grown as a perennial. As a perennial, it is pruned heavily after harvest to encourage new shoot growth, usually multiple vigorous shoots arising from the crown. In temperate zones such as ours, goldenberry is grown from seed as an annual and thus has a different growth habit, thus pruning and training must be based on this type of growth rather than perennial production regrowth.

Pruning

There are four kinds of pruning utilized in goldenberry production (Miranda, 2004): formation, maintenance, sanitary and renovation (for perennial production). Formation pruning consists of the removal of axillary shoots up to the first bifurcation. Maintenance pruning through the growing season consists of removing crown suckers every 2 weeks or so as needed. These suckers are extremely vigorous and will soon crowd out your productive branches if they are not removed. In addition, long unproductive shoots may also be removed. Sanitary pruning consists of removal of diseased or insect infested tissue. Renovation pruning is used only in perennial production and consists of severe pruning back of the previous seasons shoots to encourage the formation of new, vigorous shoots from the crown of the plant.

Annual goldenberry plants grow as a single stem for 9 to 15 nodes then bifurcate (branch as a Y). This branching habit continues during subsequent stem growth. All axillary shoots on the main stem up to the first bifurcation as well as suckers arising from the crown should be removed. A trip through the field once every week or two should suffice. Pruning of axillary shoots normally lasts for 3 to 4 weeks, thus labor requirements for pruning are not excessive. Once the plant has branched, minimal sucker removal is required.

Training and support … Single wire with clips

Plants tend to have a sprawling habit and are sensitive to high winds thus they should be supported. A simple 1 wire (at 3 to 4 feet) trellis with main stems clipped or tied to the wire works well. We use T stakes with heavy duty twine and standard tomato clips.

Training and support … The Florida basket weave

An alternative to clipping or tying is to use the Florida weave system similar to that used for tomatoes. For this system make sure the end posts of each row are sturdy with either 4 or 5 ft. wooden stakes or metal t-

stakes to fill out the row. Put a stake between every 3rd or 4th plant. Make sure the stakes are driven about a foot into the ground. Install your stakes early so you can begin weaving when the plants are about a foot tall. You will need either tomato twine (usually nylon) or light to medium weight sisal twine for the weaving.

We used this system with 4 plants between each stake, thus we'll describe how to weave for this setup. Begin weaving by tying your twine at about 8 to 10 inches off the ground to an end post. Standing on one side of the row, weave the twine (use a short piece of pvc pipe with the twine threaded through it as an extension of your arm) out away from you around the first plant, bring the twine between the first and second plant towards you, then out away from you between plants 2 and 3, around plant 3, weaving the twine between plants 3 and 4 towards you. You should now be at the first stake in the row. Pull the twine fairly tight (it will stretch with time) and wrap it around the stake several times locking it in place. Now continue down the row weaving in and out of plants as just described, making sure the twine is tight and wrapped around each stake as you go down the row. When you reach the end of the row, turn around and weave the twine between your plants on the opposite side of the row so that when you reach the other end of the row, your plants will be sandwiched with twine. When plants grow another foot or so, weave another level of twine about 8 to 10 inches above the first level. Continue the process through the growing season as needed to keep plants supported.

Other options

Many different variations for training have been reported in the literature including espalier, two, four, six and eight stemmed plants, X, Y and V trellising, etc. We evaluated whether or not pruning is needed and whether or not plants need to be supported. We determined that pruning and training facilitates management and is worth the effort. We have kept the process as simple as possible and anything more than simple pruning is not recommended at this time. If pruning and training are not possible for your situation, remember that when left un-pruned, plants are huge and sprawling, often 10 feet or more in diameter, hindering harvest and worker movement in the field.

Keep in mind that our objectives are different than those of South American growers. They must manage their crop as a renewable perennial for fruit production lasting 4 to 6 months per season. We are managing an annual crop for 1 or 2 months of fruit production.

FLOWERING

One publication (Heinze and Midasch, 1991) suggests that goldenberry is a quantitative short day plant (i.e. flowering results from exposure to days shorter than a critical photoperiod (which was not determined)). There are no other reports on the photoperiod requirements for flowering in goldenberry.

Seven-week old seedlings (from time of seeding) flower about 30 days after field planting with mature fruits (harvested weekly) about 60 days after flowering (Tulukcu, 2012). The first flower appears at the node of bifurcation (approximately a month or so after transplanting) and flowering will continue until frost in the fall. Flowers are wind and insect pollinated and are self-pollinating. The importance of cross-pollination with other goldenberry strains or related species in keeping a particular goldenberry variety true from year

to year is not yet known. There is evidence in the literature that cross pollination within goldenberry is rare and cross pollination between species (i.e. goldenberry with ground cherries or tomatillos) is even rarer (Menzel, 1951).

FRUITING

Goldenberries typically produce 150 to 300 fruit per plant, beginning in late August or early September continuing until the first fall frost.

Two different fruit sizes are often observed: small (average fruit weight with calyx of 1.96 g) and large (average fruit weight with calyx 6.55 g) (Tulukcu, 2012). Large fruited plants (48 cm tall) produce an average of 30 fruit (197 g) per plant. Small fruited plants (76 cm tall) produce an average of 75 fruit (147 g) per plant.

Reported average productivity per plant varies greatly with spacing, fertility, genotype, length of fruiting season and country of production. Reported yields range from less than 100 g plant^{-1} to well over 1500 g plant^{-1}. Comparisons of productivity of our system with that in the literature is not wise since we are working with a drastically different production system than most systems reported in the literature.

FERTILIZATION

Recommendations for goldenberry fertilization are rather limited. Most fertility studies have been conducted in India or South America. Even though both have climates quite different from the Northeast US, some useful information can be gleaned from these reports.

N fertilization often delays flowering and fruiting but increases total productivity (Ali, 2007; Girapu and Kumar, 2006). Since growers in the Northeast need their goldenberries to flower as early as possible, it might be wise to delay any fertilization until after flowering has begun and applying it as several split applications.

Inorganic sources

Recommendations are often based solely on N requirements and range from 70 kg N ha^{-1} (Panayotov and Popova, 2015) to 200 kg N ha^{-1} as split applications on sandy soils (El-Tohamy et al., 2009). Other recommendations include 90 kg N ha^{-1} (Girapu and Kumar, 2006), 140 kg N ha^{-1} (Panayotov et al., 2016), and 113 kg N ha^{-1} supplied as ammonium sulphate (Albayrak et al., 2014).

A report regarding ripening of green fruit after harvest might be of interest to some growers in the Northeast where a significant number of green fruit may be on the plant just when the first frost of the season is forecast. Panayotov and Popova (2015) reported that 70 – 140 kg N ha^{-1} was optimum for mature fruit production and production of green fruit for post-harvest ripening since a greater percentage of green fruit ripened after harvest from these rates compared to other rates tested.

Several recommendations consider P and K rates as well as N and include 100:80:80 kg N:P:K ha^{-1} (Ali, 2007) and 100:80:80 kg N:P:K ha^{-1} one-third pre-plant and the rest as split applications (45 and 75 days after

transplanting) (Ali and Singh, 2015, 2017). Patidar et al. (2018) recommend 200:130:180 kg N:P:K ha^{-1}, 75 to 100% derived from farmyard manure. This approach might be problematic given the variations in N, P and K levels in different sources of manure.

Organic / Manure sources

A number of recommendations have been published with respect to application of manures. Recommendations include 300 kg N / ha^{-1} from poultry manure (Ariati et al., 2017), 20 t ha^{-1} farmyard manure (Gond et al., 2017), 10 - 20 t ha^{-1} of vermicompost (Gond et al., 2017; 2018), and 15 t ha^{-1} vermicompost (Leila et al., 2016).

Verma et al. (2017) recommends the application of 50% vermicompost + 50% recommended NPK however, they did not indicate rates of NPK.

Sandhu and Gill (2011) recommend inoculating seedlings with Azotobacter (a free living, nitrogen fixing bacterium found in many soils) and fertilizing with 75-100% of the 'standard dose' of NPK (10, 10 and 5 g $plant^{-1}$ from calcium ammonium nitrate (N 25%), single super phosphate (P 16%) and muriate of potash (K 60%) plus farm yard manure (1 kg $plant^{-1}$).

Hydroponic production

For hydroponic production of goldenberries, 100 to 150 ppm N is recommended (Gastelum-Osorio et al., 2013). Torres Rubio et al. (2015) determined that N extraction from soilless media is similar for different solanaceous species (264 kg N·ha^{-1} for cape gooseberry, 293 kg N·ha^{-1} for pepper, 266 kg N·ha^{-1} for pepino, and 242 kg N·ha^{-1} for tomato). Goldenberry extracted significantly more K (463 kg K·ha^{-1}) than pepper (382 kg K·ha^{-1}), tomato (350 kg K·ha^{-1}) and pepino (374 kg K·ha^{-1}). P extraction is low and similar for all species (28, 33, 30 and 28 kg P·ha^{-1}, for goldenberry, pepper, tomato and pepino, respectively). Ca extracted by goldenberry (52 kg·ha^{-1}) was lower than pepper (101 kg·ha^{-1}) and pepino (256 kg·ha^{-1}). Mg extracted by goldenberry (42 kg·ha^{-1}) was lower than pepper (63 kg·ha^{-1}) but similar to tomato (45 kg·ha^{-1}) and pepino (40 kg·ha^{-1}). This suggests that fertility programs for goldenberry should be similar to those for other solanaceous crops with the exception that goldenberry requires more K than other solanaceous crops. Given this information, a standard solanaceous hydroponic solution might be considered for goldenberry, keeping an eye out for possible problems with K deficiency (see next section for symptoms).

Foliar application of nutrients

Bi-weekly foliar application of a nutrient solution consisting of (1ml L^{-1} Torped® foliar fertilizer, providing 71.0 ppm N, 113.6 ppm P, 113.6 ppm K, 14.2 ppm Ca, 7.1 ppm Mg, 35.5 ppm S, 14.2 ppm Zn, 7.1 ppm B, 7.1 ppm Mn, 2.8 ppm Cu, 1.4 ppm Fe, 1.4 ppm Mo, The Zn, Cu, Mn and Fe were complexed by 7% amino acids) beginning when plants had 15 leaves significantly increase fruit productivity per plant (179 and 269 fruit $plant^{-1}$ for controls and treated plants, respectively) and average fruit size (3.2 and 4.2 g $fruit^{-1}$ for control and treated plants, respectively) (Pedó et al., 2019). Foliar application also increased the pH, total

soluble solids (°Brix) and the antioxidant activity of ripe fruit, improving overall fruit quality compared to the controls.

Source of inorganic N

The source of N can also be important for goldenberry production. Yield was enhanced when 25% of the total nitrogen was supplied as ammonium compared to 0 or 50% ammonium (Antúnez-Ocampo et al., 2014).

NUTRIENT DEFICIENCIES

Deficiency symptoms (N, P, K, Mg, Ca, B) in goldenberry were described by a number of researchers (Martinez et al., 2009; Silva et al., 2017). Generalized descriptions are adapted from their publications and are presented here for convenience, however the reader is encouraged to access the original articles (some in Spanish) online to view photos of the symptoms:

Martinez et al., 2009: http://www.scielo.org.co/pdf/agc/v27n2/v27n2a05.pdf

Silva et al., 2017: http://www.seer.ufu.br/index.php/biosciencejournal/article/download/32746/19755/

Nitrogen (N) deficiency

N deficient plants are about half the size of non-deficient plants. Plants tend to be etiolated with thin stems and shortened internodes. Leaves are small and thin and are generally a lighter shade of green compared to leaves of non-deficient plants. Both leaf blades and petioles exhibit a marked interveinal purple color. Older leaves turn yellow, become necrotic and eventually abscise. Branching, flowering and fruiting are often delayed by a week or two. The calyces are pale with a purple coloration near the peduncle. Veins of the calyx are reddish and fruit are lighter orange.

Phosphorus (P) deficiency

P deficient leaves are significantly darker green than leaves of non-deficient plants. Younger leaves have rippled edges and older leaves are mottled with spots appearing waxy. Older leaves have a purple to brown color in the main veins which starts at the leaf apex and leaves are thick and brittle. Premature abscission is often observed in older leaves. P deficient plants are slightly smaller than non-deficient plants.

Potassium (K) deficiency

Potassium deficient plants have shorter internodes on the main stem with slightly elongated branches. Plants exhibit severe foliar symptoms particularly on older leaves which begin as irregular, interveinal water soaked spots which eventually become necrotic with a chlorotic, orange halo surrounding it. Symptoms begin at the leaf margins gradually overtaking the entire blade. All leaves may exhibit epinasty, looking as though they are wilting from lack of water. Leaf blades of older leaves often appear corrugated. Second order branches often become dried and brown, eventually dying. Similar damage is observed in the calyx.

Small irregular spots appear in the middle third of the calyx eventually expanding towards the apex. Eventually the entire husk, including peduncle, becomes dry and 'crispy'.

Magnesium (Mg) deficiency

Magnesium deficiency is readily observed in the middle third of the plant after the second bifurcation as a mottled interveinal chlorosis with a netlike appearance which begins towards the apex or middle of the leaf then moves along the edge of the blade. As the deficiency worsens, a purple or brownish color develops along the margins and between the veins in leaves and calyces. General plant growth is not affected by Mg deficiency.

Calcium (Ca) deficiency

Calcium deficiency is mostly observed in lower and middle leaves after the second bifurcation even though some Ca deficiency symptoms appear in younger leaves. New leaves are crinkled and shriveled and older leaves eventually exhibit similar characteristics. Deficient leaves show strong chlorosis or orange coloration beginning at the base of the leaf. In addition, small, necrotic spots are observed in the leaf margins. Eventually shoot tips become necrotic. Fruit occasionally exhibit elongated whitish spots. Deformed calyces that do not cover the fruit may be observed with Ca deficiency.

Sulfur (S) deficiency

S deficient causes a significant reduction in plant growth and size. Leaves are generally light green and as the deficiency worsens, younger leaves become chlorotic followed by older leaves. Symptoms progress to where leaves are chlorotic almost white with green veins. In younger leaves, the apex and margins become necrotic as well.

Boron (B) deficiency

Boron deficiency severely affects plant architecture resulting in a severe rosette form with corrugated, brittle tissue where leaves became curled with the appearance of a cone. There is also general leaf chlorosis and a purple mosaic appearance of veins beginning at the apex ultimately covering the entire blade. Interveinal necrosis also occurs. New leaves are extremely deformed, often dark green with a waxy appearance, with excessive sprouting of deformed stems. Flower and fruit abortion is excessive.

Boron toxicity in goldenberry may be somewhat alleviated with K fertilization (Cikili and Samet, 2016).

Copper (Cu) deficiency

While most nutrient deficiencies cause a general reduction in plant growth, copper deficiency does not. No symptoms of Cu deficiency in goldenberry have been reported or described.

Iron (Fe) deficiency

Fe deficiency is recognized as a mosaic chlorosis observed in young leaves that develops at the base of the leaf and progresses towards the middle. When severe enough, newly expanding leaves are totally chlorotic, eventually turning white. Necrosis develops from the inside towards the outside of the leaf. Eventually the plant apex dies.

Manganese (Mn) deficiency

Mn deficiency appears as interveinal chlorosis on young leaves, eventually spreading to older leaves. Veins remain green and the chlorosis is not as severe as that seen with S deficiency.

Zinc (Zn) deficiency

Zn deficiency causes smaller leaves on thinner stems with more branching than normal. Chlorosis is also observed on older leaves.

PESTS

We have seen three significant insect pests during our trials. One which is usually early in the season is the three lined potato beetle (*Lema daturaphila*). The larvae of this pest are particularly troublesome as they defecate on themselves to discourage predation. Tobacco and tomato hornworms (*Manduca sexta* and *Manduca quinquemaculata*, respectively) are often problematic later in the season on mature plants. The tobacco hornworm is more common than the tomato hornworm and can be distinguished from the tomato hornworm by its seven diagonal white stripes and its usually red 'horn' while the tomato hornworm horn is bluish-black. The third most damaging pest is an unidentified *Lepidoptera* species which pokes a hole in the young husks and lays eggs which later hatch into fruit burrowing worms that are not observed until harvest. The fruit of such infested husks is rendered useless. We try to hand-pick the potato beetles and hornworms as there are no pesticides labelled specifically for goldenberry and we like to use as few chemicals (even those approved by OMRI) as possible.

HARVESTING

Fruit are ripe when they turn a golden color which is often easily seen through the husk, which has faded and turned yellowish brown and translucent. Green fruit are not ripe and will only ripen if mature at harvest. If green fruit are immature at harvest, they will not ripen once removed from the plant. Mature fruit tend to be lighter green in color and are encased in a calyx which has begun to turn yellow. Immature fruit are darker green and encased in a green calyx. Ripe fruit do not easily abscise from the plant like ground cherries and are harvested by hand. Fruit should be harvested when they are dry; if they are moist from dew or rain they are likely to mold. Fruit is normally left in the husk for sale in pint containers, but sometimes the husk is removed and the goldenberries displayed in half-pint containers for sale. Many chefs prefer fruit with the husk intact as it is often used for decoration. Additionally, fruit will keep at room temperature for up to 3 months if they are left in the husk.

POST-HARVEST HANDLING

Goldenberry is a climacteric fruit and will continue to ripen after harvest (Novoa et al., 2006). The degree of after harvest ripening is dependent on the stage of maturity at harvest. Stages of maturity are IG: immature green berry, fresh calyx; MG: mature yellowish green berry, greenish to pale yellow calyx; stage Y: dark yellow berry, calyx not completely dry; stage OR: orange ripe berry, light brown, dry and paper-like calyx (Baumann and Meir, 1993; Gutierrez, et al., 2008). Immature fruit will not ripen after harvest.

After harvest ripening is important since with such a long season crop, many green fruit may still be on the plant when the first fall frost or freeze is forecast. If these fruit can be harvested in time, they may ripen after harvesting if mature enough when harvested.

A report regarding ripening of green fruit after harvest might be of interest to some growers in the Northeast where a significant number of green fruit may be on the plant just when the first frost of the season is forecast. Panayotov and Popova (2015) reported that 70 – 140 kg N ha^{-1} was optimum for mature fruit production and production of green fruit for post-harvest ripening since a greater percentage of green fruit ripened after harvest from these rates compared to other nitrogen rates tested.

Fruit can be stored at room temperature for up to 3 months from harvest as long as they are kept dry with sufficient air circulation to prevent mold growth. Fruit should be inspected on a regular basis to remove fruit that have become moldy or soft. The husks should not be removed for storage, as fruit only last for 4 or 5 days once the husk is removed.

FRUIT QUALITY

Fruit quality is a subjective trait. Fruit from different genotypes vary in size and taste. We have selected two genotypes that we prefer from many that we have trialed on our research farms. We are continuing to screen new accessions as they become available.

Goldenberries are about 17% seeds and 83% pulp and peel. Juice yield from goldenberry is about 72.6 % of the total berry weight.

Quality is often quantified with measurements of sugar, acid and color attributes. Goldenberries have a soluble solids content of about 10-15%, mainly sugars, mostly sucrose with a pH of about 3.9 and a total acid content of about 1%.

CHAPTER 3 - THE BBCH PHENOLOGICAL SCALE

Mathematical models are often developed to describe stages of growth and development in crop plants. These models are then used to indicate at which stage various horticultural practices such as pruning, staking or fertilization should be performed. One type of mathematical model widely used in plant science is the BBCH scale.

WHAT IS THE BBCH PHENOLOGICAL SCALE?

The BBCH phenological scale is a code describing the stages of development in flowering plants. The life cycle of a plant is subdivided into ten easy to recognize growth stages that usually proceed in sequence but that may proceed in parallel in some cases. Each stage is described in detail so that others working with the same species can easily use and interpret the scale. If a specific growth stage is lacking in a particular species, it is omitted from the scale. The primary growth stages are described and assigned a number from 0 to 9 (Table 1).

TABLE 1. PRIMARY GROWTH STAGES INCLUDED IN THE BBCH PHENOLOGICAL SCALE.

STAGE	Description
0	Germination
1	Main shoot leaf development
2	Formation of side shoots
3	Stem elongation or rosette development
4	Development of vegetatively propagated organs or harvestable vegetative plant parts
5	Inflorescence emergence
6	Flowering
7	Fruit development
8	Ripening or maturity of fruit and seed
9	Senescence, start of dormancy

SIMPLE OR COMPLEX?

For most species, a single digit describing each primary growth stage is insufficient. The single digit is complimented with a second digit to indicate secondary growth stages. As an example, the germination

stage (0) might include a second digit to indicate a sub-stage of germination: 00 indicates a dry seed, 01 indicates a fully imbibed seed, 02 indicates radicle emergence, 03 indicates cotyledon(s) breaking through seed coat and 04 indicates cotyledon(s) emerging through the soil surface. Sometimes, a third digit describes a sub-stage of a secondary stage, but most BBCH scales do not include a third digit.

When two or more primary stages proceed in parallel, both may be indicated using a diagonal stroke, i.e., 22/31. If only one stage will be indicated, the more advanced stage is used.

SOME GENERAL CONCEPTS

There are a number of generalities among all published BBCH scales:

1. Similar phenological stages among all species have the same code, i.e., all dry seeds have the code 00 regardless of species.

2. Stages are described and illustrated via publication of an official BBCH scale. The official BBCH scale for goldenberries is:

   > Ramirez, F., G. Fischer, T. Davenport, J. Pinzon and C. Ulrichs, (2013) Cape Gooseberry (*Physalis peruviana* L.) phenology according to the BBCH phenological scale. *Scientia Horticulturae* 162:39-42.

3. Descriptions of clear and easy to identify external morphological characteristics make the codes easy to use.

4. Only the development of the main stem is considered unless otherwise indicated in the reference.

5. Growth stages indicate development of a single representative plant within the species. In some cases, a generalization for a group of plants characterize field, greenhouse or high tunnel production. In these cases, the scale must represent the stage of at least 50% of the population of plants in question.

6. Sizes in the descriptions relate to the species in question or of specific varieties within the species.

7. The secondary stages 0 to 8 represent ordinal numbers or percentages. For example, a secondary stage of 3 may indicate the third flower or that 30% of the total number of flowers on the plant are open. The description of the stage indicates what the digit means.

8. Post-harvest is always stage 99.

9. Seed treatment before planting is always stage 00.

WHERE DID THE BBCH SCALE COME FROM?

The BBCH scale is a team effort of the German Federal Biological Research Centre for Agriculture and Forestry (BBA), the German Federal Office of Plant Varieties (BSA), the German Agrochemical Association (IVA) and the Institute for Vegetables and Ornamentals in Grossbeeren/Erfurt, Germany (IGZ). The scale is based on the work with cereal crops by Zadoks et al., (1974). The abbreviation BBCH comes from Biologische Bundesanstalt, Bundessortenamt and Chemical industry.

When there is no BBCH scale for a particular species, an individual or group of researchers develop one through careful observation of growth over the life cycle of the species in question. The proposed BBCH scale is submitted for consideration of publication in a reputable scientific journal, where it would be peer reviewed, and if acceptable, published as the official BBCH scale for that species. Once published, the scale is then used or modified by other researchers in their work.

WHY DO WE NEED IT?

The Goldenberry is an indeterminate, perennial herbaceous shrub in the Solanaceae family reaching 1.0 to 1.5 m in height. Since it is indeterminate, it continues to grow indefinitely, producing shoots, flowers and fruit at the same time. In order to accurately describe when, how and why to perform specific management tasks, we need an accurate mark of development to indicate the stage appropriate for action. In addition, since goldenberries are grown worldwide in various climatic conditions, using measures such as days after seeding or days after transplanting may not be useful for identifying specific stages of development for specific production practices. With goldenberries becoming more widespread, it would be useful to begin using the BBCH scale now rather than later when describing production. Information will then be useful to a much larger audience.

GENERAL SHOOT GROWTH REVISITED

The basal section of the main stem is vegetative for 8 to 12 nodes. Internodes normally average 5cm (~2”). The juvenile vegetative stage of the goldenberry is characterized by a main stem with single, simple, petiolated, alternate, heart-shaped, highly-pubescent leaves that are 5 to 15 cm (2 to 6”) long and 4 to 10 cm (2 to 4“) wide. Each node’s leaf has an axillary bud that is often removed as soon as it is visible to prevent an excessive number of shoots from developing before the first bifurcation of the main stem (Figure 1).

Once the main stem reaches 8 to 12 nodes, it bifurcates, producing a flower at the bifurcation and two shoots. With the first bifurcation, the plant is considered mature and fruitful. Fruiting branches generally produce 2 leaves per node compared to the single leafed nodes of the vegetative main stem. Each node on the fruiting branch bears one flower bud, two petiolate leaves and sometimes especially in the lower part of the plant, a lateral shoot.

When the first flower appears at the site of the first bifurcation, the two new shoots that develop are shoots developing from the axillary bud of each of the two leaves located at the node of bifurcation. These elongate and form a node where another flower bud develops with two leaves and subsequent growth of

their axillary buds, forming the second bifurcation of each of the original two shoots off the main stem. This process occurs indefinitely.

It takes 70 to 80 days from germination for the first flowers to appear. The calyx of the flower grows into a bladder (husk) surrounding the ripening fruit which remains green during fruit development. As the fruit ripen, the husk turns from green to a light tannish color. Fruit are generally around 2cm (3/4“) in diameter, turn golden when ripe and are easily seen through the tan colored husk surrounding it.

THE BBCH SCALE FOR GOLDENBERRIES

The BBCH scale published by Ramirez et al. (2013) has seven of the ten possible primary growth stages. Most solanaceous species have 9. Stages 3 (stem elongation or rosette development) and 4 (development of vegetatively propagated organs or harvestable vegetative plant parts) of the ‘standard’ scale do not apply to goldenberry and stage 9 (fruit senescence) was omitted since fruit would be harvested from the plant before senescence occurred. The Basic BBCH scale includes 2 digits indicating the primary and secondary stages, however, since 2 digits will not suffice for describing different stages in the goldenberry life cycle (i.e. when there are 14 leaves on a shoot), an extended BBCH scale using 3 digits is employed.

Stage 0 – Germination

3-digit code	Description
000	Dry seeds
001	Beginning of seed imbibition
003	Seed imbibition complete
005	Radicle emerges from seed
007	Hypocotyl with cotyledons breaking through seed coat
009	Emergence: cotyledons break through soil surface

Stage 1 – Leaf development

3-digit code	Description
100	Cotyledons completely unfolded
101	First true leaf on main stem fully unfolded
102	Second leaf on main shoot unfolded
10.	Continue numbering as needed (maximum number of leaves using a 3 digit code is 99)
199	99th leaf on main stem

Stage 2 – Side shoot formation

3-digit code	Description
201	First bifurcation two apical shoots visible
202	Second bifurcation two apical side shoots visible
20.	Continue numbering as needed (maximum number of bifurcations using a 3 digit code is 99)
299	99th apical bifurcation visible

No Stage 3 or 4

Stage 5 – Inflorescence emergence

3-digit code	Description
501	First flower bud visible at first bifurcation
502	Second flower bud visible at second bifurcation
503	Third flower bud visible at third bifurcation
50.	Continue numbering as needed (maximum number of flower buds using a 3 digit code is 99)
599	99th flower bud visible

Stage 6 – Flowering

3-digit code	Description
601	First flower opens
602	Second flower opens
603	Third flower opens
60.	Continue numbering as needed (maximum number of flowers using a 3 digit code is 99)
699	99th flower opens

Stage 7 – Fruiting

3-digit code	Description
701	First fruit reaches typical size and form
702	Second fruit reaches typical size and form
703	Third fruit reaches typical size and form
70.	Continue numbering as needed (maximum number of fruit using a 3 digit code is 99)
799	99th fruit reaches typical size

Stage 8 – Fruit ripening

3-digit code	Description
801	10% of fruit show typical fully ripe yellow color
802	20% of fruit show typical fully ripe yellow color
803	30% of fruit show typical fully ripe yellow color
804	40% of fruit show typical fully ripe yellow color
805	50% of fruit show typical fully ripe yellow color
806	60% of fruit show typical fully ripe yellow color
807	70% of fruit show typical fully ripe yellow color
808	80% of fruit show typical fully ripe yellow color
809	Fully ripe, fruit show typical fully ripe orange color

Now we can merge all seven tables and add a column describing important management steps that need to take place at particular stages of development. Some stages have been eliminated from the table since they are not considered in management decisions.

BBCH Stages of Goldenberry (*Physalis peruviana*) Development and Management Practices

Stage	Code	Description	Activity
0-Germination	000	Dry seeds	Lightly cover seed with soil / planting mix upon sowing and keep moist until seedling emergence.
	009	Emergence: cotyledons break through soil surface	
1-Leaf development	100	Cotyledons completely unfolded	Keep seedlings watered; Be on the look-out for damping off.
	101	First true leaf on main stem fully unfolded	Verify that specimen is *P. peruviana* presence of significant leaf and stem pubescence.
	102	Second leaf on main shoot unfolded	
	10.	Stages continuous till	Plants ready for transplanting to production field at stages 104 – 106.
	109	Nine or more leaves on the main shoots unfold	Remove axillary shoots as they appear in all axils of leaves formed preceding first bifurcation.
2-Side shoot formation	201	First bifurcation two apical shoots visible	Make note of first flower at node of first bifurcation. Begin training. Continue formation pruning.
	202	Second bifurcation two apical side shoots visible	
	20.	Stages continuous till	Continue trellising activity if needed.
5-Inflorescence emergence	501	First flower bud visible at first bifurcation	
6-Flowering	601	First flower opens	
7-Fruiting	701	First fruit reaches typical size and form	
8 - Fruit ripening	801	10% of fruit show typical fully ripe yellow color	Begin harvesting

Figure 1. Goldenberry plant on the left has eighth leaf on main stem tagged (Stage 108). Note that all axillary shoots below this leaf have been removed. The plant on the right has not been pruned or tagged.

CHAPTER 4 – GENETICS, CULTIVARS AND OTHER GERMPLASM

BASIC GENETICS

Goldenberries are tetraploid with n=12 (Nohra et al., 2006). Most flowers are cross-pollinated (Santana and Angarita, 1999) but some selfing can occur (Fischer et al., 2014).

Margaret Menzel, a graduate student at the University of Virginia in the late 1940's and early 1950's, provided a cytotaxonomic and genetic study to help clarify confusion among the different species within the genus *Physalis* (Menzel, 1951). She reported very little success with interspecific crosses, indicating that trying to combine desirable characteristics from ground cherry (flavor) or tomatillo (larger fruit size) via hybridization would be in vain.

The Pubescentes section of *Physalis* includes *P. pruinosa* and *P. pubescens*, both diploids 2n = 24, which are both considered ground cherries. *P. pruinosa* is the ground cherry familiar to most growers as *P. pubescens* is often misidentified by seed sellers. The tomatillo (*P. ixocarpa*) is a diploid 2n = 24 in the Philadelphicae section. The goldenberry (*P. peruviana*) is a tetraploid 2n = 48 in the Heterophyllae section (Menzel, 1951). When evaluating 10 different lines of *P. peruviana*, Menzel (1951) detected vary little variability among them, suggesting little potential improvement with controlled crosses.

Sullivan (2004) published the keys with descriptions of the 16 species of *Physalis* commonly found growing in the Southeastern United States. *P. peruviana* was not included in this publication because it was never found growing wild indicating that it either does not escape garden plantings or cannot persist in the wild.

While most crops are identified as cultivars, goldenberries are somewhat different in that few reliably named cultivars exist. Most goldenberries are open-pollinated accessions from local variants of the crop that performs well in particular climates. Available germplasm comes from different areas of domestication, each with its own unique genetic lines with qualities desired by regional growers and markets.

The general regions of domestication include South America, India, Africa, Australia and New Zealand.

POTENTIAL FOR HYBRIDIZATION

The genetic potential for crop improvement via hybridization largely depends on an abundance of genetic variability in the species under consideration. Traits in *Physalis peruviana* with high variability are fruit weight and fruit diameter (Singth, et al., 2013; Trevesani, et al., 2016), fruits per plant, acidity, juice content, ascorbic acid content and soluble solids (Singh, et al. 2013). The characteristics most important for goldenberry improvement have been identified as fruit weight (Anzanello, et al., 2013; Bonilla and Espinosa, 2005) and diameter (Bonilla and Espinosa, 2005). Appearance, fruit size and post-harvest quality are also important to consider for commercial value (Tavarini et al., 2008).

PERFORMANCE OF HYBRIDS

Even though Menzel (1951) determined that hybridization of *P. peruviana* with other Physalis species was not likely, hybridization among *P. peruviana* genotypes has been achieved. It is an expensive and time consuming process. In order to justify the expense and effort of hybridization, documentation of hybrid superiority is needed. Reports describing performance of goldenberry hybrids are limited. Researchers in Spain documented superiority of *P. peruviana* hybrids with respect to yield and quality characteristics (yield, fruit weight, fruit shape, soluble solids, titratable acidity and ascorbic acid content) compared to their parents in both field and greenhouse production (Leiva-Brondo, et al., 2001). The broad sense heritability of all parameters studied was high to medium (0.48 to 0.91) indicating that selection response would be high in any attempt to improve yield with hybridization. Selection of hybrid offspring has led to improved varieties with higher yield and improved fruit size (Prohens, et al., 2004).

ACCESSIONS TESTED AT RUTGERS 2018-2019

A study evaluating 21 goldenberry accessions was conducted in 2018 and repeated in 2019. Multiple generations of the same germplasm were included to evaluate the stability of open pollinated seed collected on our research farm. We also trialed other accessions that were sold as *P. peruviana*, but they turned out to be either *P. pruinosa* (ground cherry) or *P. ixocarpa* (tomatillo). These are listed after the *P. peruviana* accessions, not as a critique of the seller, but rather, for your information.

The accessions we trialed are listed below along with their year of accession, source of seed, country or continent of origin and pedigree. A photo of fruit sampled (2018) from each accession is also provided. Note the differences in size and color among the accessions.

Accessions tested at Rutgers in 2018 that were not *P. peruviana* included: Tomatillo Ground Cherry from Seed Needs in North America; Giant Poha Berry from Caribbean Garden Seed (located in North America); Cape Gooseberry from Chiltern Seeds in the United Kingdom.

Among the genotypes we evaluated in 2018, there are essentially two major "types" of goldenberry: a large fruited type (8-10 g/berry) and a smaller fruited (3-5 g/berry) type. The larger fruited type such as 'Schoenbrunn Gold' tastes fruitier with less of a bitter aftertaste than many of the smaller fruited lines such as 'Cape Gooseberry 10008' from Trade Winds fruit. In general, the larger fruited lines produce fewer berries per plant (50 - 100 berries/plant) compared to the smaller fruited lines (150 - 300 berries/plant).

While controlled taste tests were not conducted in 2018, the differences in flavor among the smaller fruited lines seemed negligible.

A large difference in appearance among all genotypes tested was observed.

Fruit from the genotype (#23, GRS-16-OP16) from The Rare Vegetable Seed Consortium in North America and #24 Cape Gooseberry (RES-16-OP16) from Rare Exotic Seeds in North America were consistently of excellent color and overall appearance. Unfortunately, seed of #23 is no longer available for purchase.

Rare Exotic Seeds - Cape Gooseberry

Fruit from the genotypes (#12 PI232077 64GI1 South Africa USDA ARS GRIN Geneva 2015 (S15 OP15 OP16)), #14 Giant Cape Gooseberry from Baker Creek Heirloom Seeds in North America (S16 OP16) and #52 Cape Gooseberry from Herbs4Health) rated good in color and overall appearance. Number 12 is available for research only and 14 is no longer available for purchase.

Herbs4Health - Cape Gooseberry

Most other genotypes had inconsistent coloring, which was often a somewhat unattractive, muddled greenish-yellow color.

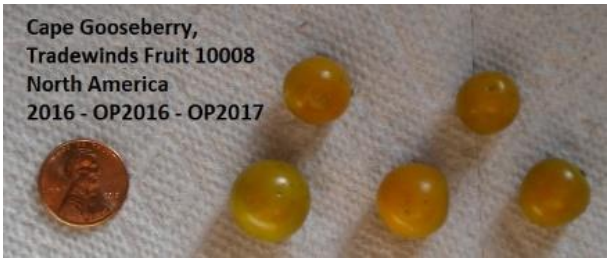
Chiltern Seeds - Giant Goldenberry

Fedco Seeds - Ambrosia Husk Cherry

Maui Seeds - Poha Berry

Floral Encounters - Cape Gooseberry

Turtle Tree Seeds - Schoenbrunn Gold



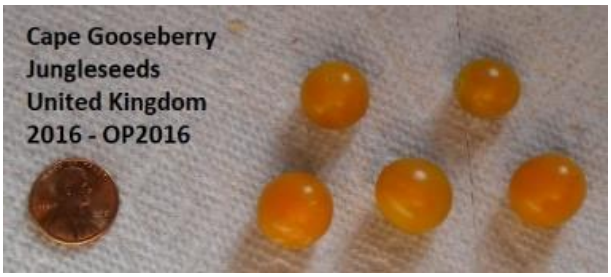
Tradewinds Fruit - Cape Gooseberry

Redwood Organic Seeds - Goldenberry

Plant World Seeds - Golden Berry Gigante

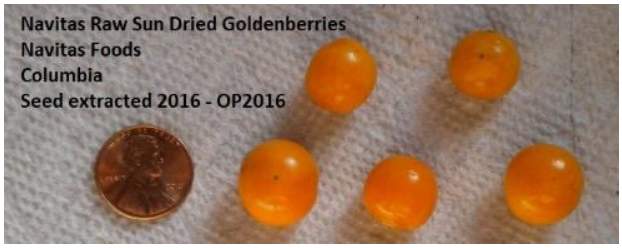
Solana Seeds - Cape Gooseberry

Strictly Medicinal Seeds - Goldenberry



Jungleseeds - Cape Gooseberry

Jakes Seeds - Giant Cape Gooseberry



Navitas Sun Dried Goldenberry

Number of fruit, average fruit weight and estimated production per plant for goldenberry genotypes evaluated at Rutgers University during the 2018 and 2019 growing seasons. Data from 2018 are presented for comparison.

	2018			***2019***		
	Fruit / plant	***Fruit size***	***Estimated yield / plant***	***Fruit / plant***	***Fruit size***	***Estimated yield / plant***
Genotype	(number)	(g)	(g)	(number)	(g)	(kg)
Cape Gooseberry - Tradewinds Fruit 2018	79 abc[z]	----[y]	----[y]	530	3.1	1.6
Schoenbrunn Gold - Turtle Tree Seed 2018	54 abc	----[y]	----[y]	269	8.1	1.9
Giant - Chiltern Seeds 2018	80 abc	2.1 defgh	167 abcde	402	2.9	1.1
Ambrosia Husk Cherry - Fedco Seeds 2018	29 abc	2.5 def	73 bcde	620	3.5	2.2
Poha Berry - Maui Seed Company 2018	66 abc	2.3 defgh	152 bcde	399	3.7	1.5
Cape Gooseberry - Floral Encounters 2018	70 abc	2.2 defgh	155 abcde	-	-	-
Cape Gooseberry - Herbs4Health 2018	18 bc	4.8 abc	85 bcde	299	5.8	1.6
Schoenbrunn Gold Turtle Tree Seed 2016 OP 2016	48 abc	5.5 ab	262 abc	-	-	-
OP PI232077 64GI1 SD - USDA ARS GRIN 2015-OP 2015 - OP 2016	134 a	3.0 bcd	402 ab	742	2.5	1.8
OP PI291561 95GI1 SD - USDA ARS GRIN 2015-OP 2015 - OP 2016	81 abc	3.1 bcd	252 abcd	240	4.8	1.6
Giant Cape Gooseberry - Baker Creek Heirloom Seeds 2016 - OP 2016	84 abc	2.2 defgh	186 abcde	557	2.9	1.5
Goldenberry - Redwood Organic Seeds 2016 - OP 2016	50 abc	2.4 defgh	119 bcde	-	-	-
Golden Nugget - Cornucopia Seeds 2016 - OP 2016	66 abc	2.7 cde	179 abcde	525	3.6	1.9
Golden Berry Gigante - Plant World Seeds 2016 - OP 2016	44 abc	2.4 def	105 bcde	492	3.6	1.8
Cape Gooseberry -Solana Seeds 2016 - OP 2016	110 a	6.9 a	755 a	315	7.2	2.1
Schoenbrunn Gold -Turtle Tree Seed 2017	38 abc	5.2 ab	195 abcd	-	-	-
Goldenberry -Strictly Medicinal 2015 - OP 2015 - OP 2016	60 abc	1.9 defgh	113 bcde	447	2.7	1.2
Cape Gooseberry -Jungleseeds 2016 - OP 2016	82 ab	2.1 defgh	173 abcd	392	3.0	1.2
Cape Gooseberry -Tree and Twig 2016 - OP 2016	105 ab	2.0 defgh	209 abcd	-	-	-
Golden Inca Berry - The Rare Vegetable Seed Consortium 2016 - OP 2016	106 ab	2.4 defg	254 abc	518	3.3	1.7
Cape Gooseberry - Rare Exotic Seeds 2016 - OP 2016	107 a	2.1 defgh	224 abc	598	3.0	1.8
Giant Cape Gooseberry - Jakes Seeds 2016 - OP 2016	105 a	2.5 def	263 abc	-	-	-
Cape Gooseberry - Tradewinds Fruit 2016 - OP 2016	38 abc	1.6 fgh	61 cde	-	-	-
Navitas Raw Sun Dried Goldenberries Extracted 2016 - OP 2016	64 abc	1.7 efgh	108 bcde	311	2.6	0.9
Navitas Raw Sun Dried Goldenberries Extracted 2016	108 ab	2.4 def	259 abcd	-	-	-
Goldenberry - Redwood Organic Seeds 2016 - OP 2016 - OP 2017	9 c	1.3 gh	12 e	568	3.1	1.8
Cape Gooseberry - Tradewinds Fruit 2016 - OP 2016 - OP 2017	26 abc	1.3 h	34 de	-	-	-

[z]Mean separation via REGWQ test, $\propto = 0.05$. Lack of letters indicates not significant at 0.05 level. [z]Mean separation via REGWQ test, $\propto = 0.05$. Lack of letters indicates not significant at 0.05 level. [y]Fruit size not measured in Experiment 1 / yield not estimated. [x]Not goldenberry.

CHAPTER 5 - HEALTH BENEFITS OF GOLDENBERRIES

Goldenberries are a nutritive powerhouse (Puente et al, 2011) with many potential health benefits. They are commonly used in the traditional medicines of South America, Africa and India and are used to treat dermatitis, cough, sore throat, parasites, hepatitis, gout, malaria, rheumatism, asthma and cancer (Adams et al, 2009; Maldonado et al, 2010; Hseu, et al., 2011). Recent studies have revealed the nutritional composition of goldenberries and identified some of the compounds that likely play a role in their pharmacological properties.

This chapter is a review of information available regarding the potential health benefits of goldenberries.

Disclaimer: We're not medical doctors. This information is provided for your information only and is not meant to suggest that you fix your health issues by eating goldenberries.

TOXICITY ??

There are numerous internet reports suggesting that since goldenberries are in the nightshade family, plant tissues and green fruit are poisonous. Green tissues including unripe fruit do contain solanine (Lampe and McCann, 1985) which can cause gastroenteritis and diarrhea, thus consumption of unripe fruit should be avoided.

There is evidence that excessive consumption of freeze-dried goldenberry juice can lead to cardiac abnormalities in males (Perk et al., 2013). Excessive goldenberry fruit consumption has been implicated in a few cases of hypertension (Gunaydin et al., 2013), ventricular tachycardia (Simsek et al., 2011) and mania (Yanartes et al., 2012).

BASIC NUTRITIONAL / CHEMICAL PROFILE

A ¾ cup serving of goldenberries supplies 60 calories, less than a gram of fat, a little protein (1.3 g), 14 g carbohydrates and 3 g of fiber. They are low in sodium and high in zinc, and potassium and also provide some calcium, phosphorus and magnesium. Goldenberries are about 82% water (apples and strawberries are 83 and 91% water, respectively).

The bulk density of fresh goldenberry fruit is estimated at 1.038 g/cm^3 with water activity of 0.988 (Marin, 2009). Water activity gives a general idea of which direction water travels in a system with components having differing water contents. It's important in the processing industry. Water moves from a component with a higher water activity to a component with lower water activity. Distilled water has a value of 1.00.

Ripe goldenberries (level 4 (yellowish-green) according to color specifications of the Colombian Technical Standard NTC 4580 (Instituto Colombiano de Normas Técnicas y Certificación (ICONTEC), 1999) have a pH of 3.7, 1.6 - 2.0 percent acidity and 13 - 15 °Brix. (Osorio & Roldan, 2003; Salazar, Jones, Chaves, & Cooman,

2008; Marín, 2009; Restrepo, 2008; Botero, 2008). °Brix and pH decrease with further ripening while percent acidity increases.

Citric acid is the predominate organic acid followed by malic, ascorbic, tartaric and oxalic acids (Novoa et al., 2006).

The average basic nutritional profile of 100 g (about ¾ cup) of ripe goldenberries is presented in Table 1.

Table 1. Average nutritional content of 100 g fresh, raw goldenberry fruit, calyx removed. Values are averages of the values from listed reference(s). RDA obtained from https://health.gov/dietaryguidelines/2015/guidelines/appendix-7/ for average adult males and females are provided as reference only.

Component	Value	RDA (Adult Male)	RDA (Adult Female)	Reference(s)
Energy (cal)	60	2000 – 3000	1600 – 2000	National Research Council (NRC) (1989); Fischer et al. (2000); CCI (2001); Osorio and Roldan (2003); Repo de Carrasco and Zelada (2008)
Water	81%	3.7 liter	2.7 liter	National Research Council (NRC) (1989); Fischer et al. (2000); CCI (2001); Osorio and Roldan (2003); Repo de Carrasco and Zelada (2008)
Protein (g)	1.3	56 g	46 g	National Research Council (NRC) (1989); Fischer et al. (2000); CCI (2001); Osorio and Roldan (2003); Repo de Carrasco and Zelada (2008)
Fats (g)	0.3	20 – 35% cal	20 – 35% cal	National Research Council (NRC) (1989); Fischer et al. (2000); CCI (2001); Osorio and Roldan (2003); Repo de Carrasco and Zelada (2008)
Carbohydrates (g)	14	130 g	130 g	National Research Council (NRC) (1989); Fischer et al. (2000); CCI (2001); Osorio and Roldan (2003); Repo de Carrasco and Zelada (2008)
Fiber (g)	3	28 - 34 g	22 -28 g	National Research Council (NRC) (1989); Fischer et al. (2000); CCI (2001); Osorio and Roldan (2003); Repo de Carrasco and Zelada (2008)

Sodium (mg)	3	2300 mg	2300 mg	National Research Council (NRC) (1989); Leterme et al. (2006); Musinguzi et al. (2007);
Potassium (mg)	322	4700 mg	4700 mg	National Research Council (NRC) (1989); Leterme et al. (2006); Musinguzi et al. (2007); Repo de Carrasco et al. (2008)
Calcium (mg)	17	1000 mg	1000 – 1200 mg	National Research Council (NRC) (1989); Leterme et al. (2006); Musinguzi et al. (2007); Repo de Carrasco et al. (2008)
Magnesium (mg)	13	400 – 420 mg	310 - 320 mg	Leterme et al. (2006); Musinguzi et al. (2007)
Phosphorus (mg)	39	700 mg	700 mg	National Research Council (NRC) (1989); Leterme et al. (2006); Musinguzi et al. (2007); Repo de Carrasco et al. (2008)
Iron (mg)	1	8 mg	8 - 18 mg	National Research Council (NRC) (1989); Leterme et al. (2006); Musinguzi et al. (2007); Repo de Carrasco et al. (2008)
Zinc (mg)	34	11 mg	8 mg	Leterme et al. (2006); Repo de Carrasco et al. (2008)
Beta-carotene (Vitamin A) (mg)	1460	900 mg	700 mg	National Research Council (NRC) (1989)
Thiamin (Vitamin B1) (mg)	0.1	1.2 mg	1.1 mg	National Research Council (NRC) (1989); CCI (1994); Fischer et al. (2000); Osorio and Roldan (2003)
Riboflavin (Vitamin B2) (mg)	0.8	1.3 mg	1.1 mg	National Research Council (NRC) (1989); CCI (1994); Fischer et al. (2000); Osorio and Roldan (2003)
Niacin (Vitamin B3) (mg)	1.3	16 mg	14 mg	National Research Council (NRC) (1989); CCI (1994); Fischer et al. (2000); Osorio and Roldan (2003)
Ascorbic acid (Vitamin C) (mg)	30	90 mg	75 mg	National Research Council (NRC) (1989); CCI (1994);

				Fischer et al. (2000); Osorio and Roldan (2003)
Vitamin K_1 (mg)	224	120 ug	90 ug	Ramadan et al. (2003)
Vitamin E (mg)	8,630	15 mg	15 mg	Ramadan et al. (2003)

BASIC NUTRITION

While this book is not intended to provide health advice, it is appropriate to provide some basic information regarding plants and human health. Much of the information is fairly common knowledge and is likely a review for many. However, rather than having to look up basic information from another source while reading this manual, it is provided here. Much of the basic material is adapted from Chapter 17 'Human Nutrition, Phytonutrients, Nutraceuticals, and Horticulture', in the textbook 'Principles of Horticultural Physiology' by Durner (2013).

GENERAL RECOMMENDATIONS

Basic human nutrition describes a well-balanced diet that provides carbohydrates, protein, fat, fiber, vitamins and minerals at levels that promote good health. Even with the tremendous amount of literature available regarding nutrition, and the recently released guidelines jointly published by the US Department of Agriculture and Department of Health and Human Services (2010), what constitutes an acceptable balance of nutrients remains controversial (Hite et al., 2010).

Even with the varied opinions regarding the appropriate balance of nutrients needed for good health, we need some source as a reference for our discussion. To that end, the 2011 recommendations of the US Departments of Agriculture and Health and Human Services serve as our reference. Following are the opinions of experts in the fields of health and human nutrition. You decide what is right for you.

General recommendations for good health include the following:

1. Maintain an age and gender appropriate weight by balancing caloric intake with physical activity.
2. Reduce obesity by increasing physical activity and reducing caloric intake.
3. Limit sodium intake to 1500 mg per day.
4. Limit daily caloric intake from saturated fats to less than 10% per day.
5. Limit cholesterol consumption to less than 300 mg per day.
6. Avoid trans fats.

7. Avoid refined and processed foods.

8. Eat nutrient dense foods such as dark-green, red and orange vegetables, whole grains, beans and peas, fruit, unsalted nuts and seeds, with small amounts of low or no fat dairy products, lean meat, poultry and seafood.

One of the main areas of controversy in the literature is regarding the balance of carbohydrates, fats and proteins in the diet that should be maintained for good health. You're on your own to investigate that area.

CARBOHYDRATES

Carbohydrates are direct products of photosynthesis. Solar energy captured during photosynthesis is released when we consume plant based foods. Much of the energy derived from that food comes from carbohydrates. There are a few exceptions such as avocado (most of the solar energy stored in fats) or soybeans (most of the energy stored as protein).

One of the main nutritional properties of carbohydrates is their glycemic index, a measure of whether or not they are hydrolyzed and absorbed in the small intestine and the relative glycemic response humans have to it. The glycemic index (GI) is a number from 1 to 100 that indicates how particular food impacts blood glucose levels (Porter, 2010). Foods with a low GI cause a slight to moderate rise in blood glucose while foods with a high GI cause a large and rapid rise in blood glucose levels that may be harmful for certain individuals, particularly those with diabetes. Diets which include a large portion of carbohydrates with high GIs is generally considered unhealthy. High carbohydrate diets may also negatively affect blood triglyceride levels and jeopardize cardiovascular health (Acheson, 2010).

AN AVERAGE ¾ CUP SERVING OF GOLDENBERRIES PROVIDES 14 G OF CARBOHYDRATES AND 3 G OF FIBER.

Carbohydrates are most often categorized as simple sugars, sugar alcohols, starch and non-starch polysaccharides. Simple sugars include mono and di-saccharides. Monosaccharides are the true simple sugars, single molecules that do not need to by broken down in the body before being absorbed into the blood stream. The major monosaccharide consumed by humans is glucose (dextrose). It provides quick energy, however, it is not sustained and once metabolized, a rapid drop in blood and energy occurs. Another negative aspect of glucose is that it is converted into fatty acids and cholesterol in the liver then transported for deposition in adipose tissue (Vanderhoof, 1998). Some other monosaccharides are fructose (levulose), galactose, xylose and ribose.

Disaccharides are two molecules of the same or different sugars joined together. Some common disaccharides include sucrose (glucose + fructose), and maltose (glucose + glucose), and lactose (glucose + galactose), the only non-plant sugar in the human diet. Disaccharides must be broken down into monosaccharides before they can be absorbed into the bloodstream. This occurs quickly after ingestion, particularly with sucrose and maltose, thus they provide quick energy but may be followed by a large drop in blood sugar levels relatively soon after eating.

THE MOST PREVALENT SUGAR IN GOLDENBERRIES IS SUCROSE (NOVOA ET AL., 2006)

Sugar alcohols are carbohydrates where the carbonyl group of a sugar has been hydrogenated forming a hydroxyl group, thus the classification as an alcohol. The simplest sugar alcohols, ethylene glycol and methanol are sweet tasting but toxic. The other sugar alcohols are generally sweet but non-toxic. Most sugar alcohols we eat are from food additives rather than from plant products containing sugar alcohols. Some common sugar alcohols used as food additives include glycerol, erythritol, xylitol, mannitol, sorbitol, inositol, isomalt, and maltitol. They are not absorbed well and may be excreted in the urine (Englyst and Hudson, 1996). Since sugar alcohols are not metabolized by oral bacteria, they do not promote tooth decay. When cooked, they do not caramelize. Many plants in the Rosacea produce significant amounts of sorbitol, celery (*Apium graveolens*) produces significant amounts of mannitol, and many seaweeds are rich in galactitol.

Polysaccharides are chains of many monosaccharide units. Starch (many molecules of glucose) is a very common polysaccharide. The glucose produced as a product of photosynthesis is often converted into starch for long term storage in seeds, roots, stems and fruit in many plants. When needed for metabolism, the starch is broken down into glucose, thus starchy foods provide a longer, slower release of energy than either mono or disaccharides, thus blood sugar levels are less likely to fluctuate wildly with consumption of starch compared to mono or disaccharides.

There are two main types of digestible starch in food: amylose and amylopectin. Amylopectin is broken down more easily than amylose thus it provides energy more rapidly than amylose. The rate of digestion and energy release depends not only on the starch, but how it is combined with other nutrients in the consumed food. For example, starch in whole foods are normally ingested with large quantities of fiber. The starch is more slowly digested compared to when it is consumed from refined foods where much of the fiber has been removed. The physical form of the starch also influences its rate of digestion and energy release. Starch in raw potatoes or a banana is present as granules that are resistant to degradation and digestion. When cooked, granular starch gelatinizes and becomes readily digestible.

Resistant starch is a polysaccharide that behaves like fiber in the gastrointestinal tract, and is resistant to digestion in the small intestine. It may be fermented in the large intestine by beneficial bacteria, producing small chain fatty acids associated with health benefits. Sources of resistant starch include brown rice (*Oryza sativa*), barley (*Hordeum vulgare*), whole wheat (*Triticum aestivum*) and buckwheat (*Fagopyrum esculentum*).

DIETARY FIBER

Dietary fiber is an increasingly important component of healthy diets. Most of the dietary fibers we eat are plant-based carbohydrates that resist digestion in the small intestine. (Lignin, which is found extensively in cell walls and often associated with fiber, is not a carbohydrate, but rather, a polyphenol. It seems to have benefits to human health due to its high antioxidant activity.) Whether or not a carbohydrate is digestible or non-digestible by humans depends on the chemical bonds connecting the sugar molecules. When glucose molecules are bonded to each other with one type of chemical bond (alpha-1,4 glycosidic) we have amylose (starch) which we can easily digest. Change the bond between glucose molecules to beta-1,4 glycosidic bonds and we have cellulose, which we cannot digest.

A group of experts from the Institute of Medicine affiliated with the National Academies of Science gathered in 2001 to establish definitions for fiber naturally occurring in plants (dietary fiber) and isolated fiber that might be used as an additive or supplement (functional fiber). Total fiber is the sum of dietary and functional fiber. Most adults need between 25 and 50 g of total fiber a day depending on age and gender.

Dietary fiber includes lignin, cellulose, beta-glucans, hemicelluloses, pectins, gums, inulin and oligofructose, and resistant starch. Lignin is a complex polyphenol found in plant cell walls and seeds. Cellulose is a non-digestible (by humans) polymer of glucose found in plant cell walls. Beta-glucans are mixed glucose polymers. Oats and barley are particularly rich in beta-glucans. Hemicellusoses are polysaccharides found especially in plant cell walls. Pectins and gums are viscous polysaccharides found primarily in fruits and seeds, respectively. Inulin and oligofructose are mixtures of fructose polymers. Plants that store inulin do not store starch. Some plants that have high levels of inulin include Agave (*Agave* spp.), Banana (*Musa* spp.), Chicory (*Cichorium intybus*), Dandelion (*Taraxacum officinale*), Garlic (*Allium sativum*), Jerusalem artichoke (*Helianthus tuberosus*), Jicama (*Pachyrhizus erosus*), and Onion (*Allium cepa*). Inulins contain only 25 to 35% of the calories of starch and have a minimal effect on blood sugar levels. Resistant starch is starch that is isolated within plant cells and is inaccessible to digestive enzymes. Bananas and many legumes contain significant resistant starch.

Functional fiber is composed of isolated, non-digestible carbohydrates that have either been extracted from plant material or manufactured. They benefit human physiology and are added to food or taken as a supplement (Institute of Medicine, 2002). Functional fiber includes isolated forms of dietary fiber, psyllium, chitin or chitosan, fructooligosaccharides, polydextrose and polyols and resistant dextrins (Institute of Medicine, 2002; Niness, 1999; Hendler and Rorvik, 2008). Psyllium is a viscous mucilage extracted from the husks of psyllium (*Plantago ovata*) seeds. Chitin is a non-digestible carbohydrate isolated from the shells of crustaceans such as crabs and lobsters. Fructooligosaccharides are food additives composed of synthetic fructose polymers. Polydextrose and polyols are synthetic polysaccharides added to processed foods for bulk or as a sugar substitute. Resistant dextrins (also called resistant maltodextrins) are indigestible polysaccharides synthesized by heating starch with certain enzymes. They are used as food additives.

Fiber can be categorized as viscous vs non-viscous. Viscous fiber is one that will form a viscous solution or gel with water to produce bulk which tends to delay emptying of the stomach (Lupton and Turner, 2000; Gallaher and Schneeman, 2001). Viscous fibers include pectins, beta-glucans, some gums, and mucilages (psyllium). Increasing viscous fiber intake can significantly lower total serum and LDL cholesterol (Brown et al., 1999) and improve blood sugar control (Wolever and Jenkins, 2001). both factors playing a role in the reduced risk of cardiovascular disease associated with increased fiber intake (Liu and Willett, 2002).

Fibers may also be categorized as fermentable or non-fermentable by bacteria in the gut. Fermentation products often include gas and short chain fatty acids. Short chain fatty acids can be used as an energy source and may help prevent cardiovascular disease. Many fruits and vegetable are high in fermentable fiber. Fiber rich in cellulose is not fermentable.

Fiber is also categorized as soluble or insoluble based on its solubility in water. Over time, the term 'soluble fiber' has been used to describe the potential for bacterial fermentation and the associated health benefits,

even though the association is somewhat misleading (Marlett, 1992). Other fibers beside soluble fibers have health benefits. When considering fiber as beneficial to health, specific fibers should be considered.

PROTEIN

Proteins are important in human nutrition for a number of reasons. They are the main structural component of the human body and they form enzymes which orchestrate nearly all metabolic activity in our bodies. Proteins also regulate movement of substances into and out of our cells via channels formed in cell membranes. Our bodies are constantly synthesizing new proteins to replace those lost to senescence or injury or those needed for maintenance and growth. In order to make new proteins, we need amino

AN AVERAGE ¾ CUP SERVING OF GOLDENBERRIES PROVIDES 1.3 G OF PROTEIN.

acids, the basic building blocks of protein. There are 20 different amino acids and their specific combination and arrangement in a protein give the protein its unique structure and function.

The protein content for the juice of a relative of goldenberry, the ground cherry (Physalis pubescens L.), was particularly high in the essential amino acids leucine, lysine and isoleucine (El Sheikha, Zaki, Bakr, El Habashy, and Montet, 2010), however no similar studies have been reported indicating the protein composition of goldenberry.

Proteins we eat are digested and broken down into amino acids before being absorbed into the bloodstream to be transported to cells throughout our bodies. In general, we require between 40 and 65 g of protein each day, or about 0.8 g per kilogram of body weight (Porter, 2010). If we don't get enough protein in our diet each day, our body begins to break down its own muscles for it. If we consume too much protein each day, our bodies will break it down and store it as fat. While we need 20 different amino acids to build the different proteins we need, our bodies only contain the ingredients to synthesize 11 of them. The other 9 amino acids must come from the food we eat. They are called essential amino acids and are: isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine and histidine. Only infants need the 9th one, histidine (Porter, 2010).

The proportion of specific amino acids in the foods we eat is important for good health. In addition, protein from different sources varies as to how well our bodies can utilize the amino acids in them. Protein from animals has a balance of the different amino acids very similar to our own tissues, thus animal protein is often called complete. Many plant derived proteins lack or are low in one or more of the essential amino acids, thus many people may consider plant proteins incomplete or of lower quality. However, if plant based proteins from various sources are correctly combined, the protein profile is complete.

FAT

Fats are energy dense molecules of glycerol with attached fatty acids. Our bodies can manufacture many of the fatty acids we need while others must be obtained from the food we eat and are called essential fatty acids. The essential fatty acids are: alpha-linolenic acid (an omega-3 fatty acid) and linoleic acid (an omega-6 fatty acid). Good sources of omega-3-fatty acids, which may reduce the risk of coronary artery disease, include flaxseed, lake trout, mackerel, salmon, herring, tuna, green leafy vegetables and walnuts. Omega-6-fatty acids can be found in vegetable oils such as sunflower, safflower, corn, cottonseed, and soybean oils, fish oils and egg yolks (Porter, 2010). Though fats are often perceived negatively, they are required for growth, energy, and overall good health.

Goldenberries are low in fat, about 0.3 g per ¾ cup serving!

The type(s) of fatty acid(s) in the fat determines whether the fat is nutritionally considered a 'good' fat or a 'bad' fat. Saturated fatty acids are those where the double bonds within it are saturated with H atoms. If the double bonds are not saturated, the fatty acids are called unsaturated fatty acids. The degree of saturation is important in determining the health benefits or lack thereof for the fats we consume. Most fat from animal sources is saturated while most from plant sources are unsaturated. The exceptions are

Even though they are relatively low in fat, goldenberries are a rich source of oils (2% by fresh weight, 1.8% from the seeds and 0.2% from the skin and pulp. (Ramadan and Morsel, 2003; Rodrigues et al., 2009).

The fatty acids are predominantly linoleic (72%), oleic (10%), palmitic (9%) and stearic (2.5%). Overall, goldenberry oil contains 12.8% saturated, 10.7% mono-unsaturated and 73.8 poly-unsaturated fatty acids.

the highly saturated palm and coconut oils. Trans fats are completely man-made by hydrogenating unsaturated fats, often vegetable oils. Saturated and trans fats are associated with increased blood cholesterol levels and increased risk of heart disease. Generally, it is recommended that we limit our fat consumption to less than 30% of our daily caloric intake (< about 90 g per day) and that we limit saturated fat consumption to less than 10% (about 30 g per day).

VITAMINS

Vitamins are organic compounds that are essential for our metabolism. Our bodies cannot synthesize vitamins thus we must get them from our food or take a supplement. In order for a substance to be considered a vitamin, a lack of it must produce clear and unmistakable symptoms of deficiency. If the substance is supplied or replenished, the symptoms go away. Vitamins are either water soluble (vitamin C, the vitamin B complex (biotin, folate (folic acid), niacin, pantothenic acid, riboflavin (vitamin B2), thiamin

(vitamin B1), vitamins B6 (pyridoxine) and B12 (cobalamins)) or fat soluble (vitamins A, D, E, and K) (Porter, 2010). Fat soluble vitamins and the water soluble vitamin B12 are stored in the liver and fatty tissue. Low fat diets might lead to a deficiency of these vitamins and disorders that interfere with fat absorption such as Crohn's disease, cystic fibrosis, and pancreatitis may also lead to a deficiency. Water soluble vitamins are not stored in the body and are often eliminated in urine.

Since much of the food we eat is cooked, cooking's effect on vitamins is important. Cooking temperature, length of cooking, light exposure, and pH can all affect vitamin stability, thus a blanket statement regarding vitamin stability during cooking is impossible. Brief to moderate cooking generally does not destroy fat soluble vitamins (A, D, E and K). Cooking foods with water soluble vitamins tend to leach the vitamins into the cooking liquid and if the liquid is discarded, so are the vitamins.

Biotin (B7)

Biotin is a non-toxic, heat stable, water soluble vitamin (Higdon et al., 2012) that is important in fatty acid metabolism, gluconeogenesis (the production of glucose from protein or fat), leucine catabolism, and DNA replication and transcription. Deficiency is rare but may occur in patients that have been fed intravenously without biotin supplementation or in individuals who have consumed raw egg whites for a prolonged period, as biotin binds to a protein in raw egg whites called avidin, preventing biotin absorption. Good sources of biotin include yeast, egg yolks and liver. The best plant based source of biotin is Swiss chard (*Beta vulgaris* subsp. *cicla*), containing about 10mcg biotin per 1 cup serving. Intestinal bacteria can synthesize biotin and this biotin may be absorbed by the body providing another source of the vitamin.

Folic Acid (B9)

Folic acid, a water-soluble B vitamin, is the form of this B vitamin normally found in supplements, however, it rarely occurs in this form in the human body or in foods (Higdon et al., 2012). Folates are the forms found in food or our bodies and they occur in many chemical configurations. They are non-toxic however large doses of folic acid may mask a B12 deficiency which can cause serious neurologic damage. Folates are important for nucleic acid and amino acid metabolism. DNA synthesis depends on synthesis of methionine which requires folates. Methionine is important for DNA methylation and methylation of DNA may help prevent cancer. A folate deficiency may lead to a buildup of homosysteine which has been implicated as a risk factor for heart disease.

Folate deficiency may be due to a dietary insufficiency or induced by alcohol consumption, pregnancy, cancer or when nonsteroidal anti-inflammatory drugs (NSAIDs), such as aspirin or ibuprofen, are taken in large therapeutic dosages. Folates are particularly important in fetal nervous system development, and deficiency can lead to birth defects. Since nervous system development occurs during the first month of pregnancy and many women may not know they are pregnant during the first month, folate nutrition is particularly important for women of child bearing age.

Green leafy vegetables are an excellent source of folates (hence the name, folate). Other plant-based foods rich in folate include lentils, garbanzo beans, lima beans, pinto beans, black beans, kidney beans, orange juice, and asparagus. Prolonged cooking can reduce the folate content of foods significantly.

Niacin (B3)

Niacin (Vitamin B3, nicotinic acid) is a water soluble vitamin extremely important in energy metabolism (Higdon et al., 2012), cell signaling, transcription, aptosis (controlled cell death), DNA repair and stress responses. Niacin deficiency was prevalent in Europe in the 1700's and in the southern US in the 1900's, causing the problem known as pellagra. The commonality of both locations and times was widespread consumption of corn and its products as the main dietary staple. Corn contains significant amounts of niacin, however, it is relatively unavailable. Even though corn is a major staple in Mexico, pellagra is rare. The reason is that cooking corn in an alkaline solution releases the niacin making it available and much of the corn consumed in Mexico is soaked in a calcium oxide solution prior to cooking, greatly increasing niacin's bioavailability.

Good sources of niacin include yeast, meat, poultry and red fishes. Good plant sources of niacin include legumes and seeds, and to a lesser degree, green leafy vegetables, coffee and tea. In some plant products, the niacin is bound to a carbohydrate, greatly reducing its bioavailability. Niacin is not easily destroyed by heat, however it is water soluble, thus when foods are cooked in a liquid, the liquid and the food should both be consumed.

Pantothenic Acid (B5)

Pantothenic acid (Vitamin B5) is found in all cells. It is a component of coenzyme A (CoA), vital for all life (Higdon et al., 2012). CoA is important in energy metabolism and in the synthesis of essential fats, cholesterol, steroid hormones, acetylcholine, hemoglobin and melatonin. Pantothenic acid deficiency is very rare.

Good sources of pantothenic acid include yeast, egg yolks, yogurt, milk, liver and kidney. Good plant sources include broccoli, legumes, mushrooms, avocado, sweet potatoes and non-processed whole grains. Processing, freezing or canning of food products may result in a 35 to 75% loss of pantothenic acid (Food and Nutrition Board, 1998).

Riboflavin (B2)

Riboflavin (Vitamin B2) is a water soluble vitamin important for energy metabolism, the metabolism of drugs and toxins, and the absorption of other B vitamins and iron. The production of the potent antioxidant uric acid also depends on riboflavin (Higdon et al., 2012). Riboflavin deficiency is rare. Plant sources particularly rich in riboflavin are almonds, broccoli, asparagus and spinach.

Thiamin (B1)

Thiamin (thiamine, vitamin B1) is a water soluble vitamin important in energy generation from food and for the synthesis of nucleic acids. Severe thiamin deficiency leads to Beriberi which affects the nervous, muscular, gastrointestinal and cardiovascular systems. Thiamin deficiency may be due to inadequate intake, alcoholism, an increased thiamin requirement brought on by strenuous physical activity, pregnancy or growth spurts during adolescence or excessive loss from the body due to excessive urination. Consumption of anti-thiamin factors which create an inactive form of thiamin can also lead to deficiency. Anti-thiamin factors are particularly present in coffee and tea (Higdon et al., 2012). Individuals who consume large quantities of raw thiaminase-containing foods could suffer a thiamin deficiency. Thiaminases are enzymes, normally destroyed during cooking, that are present in certain raw foods (freshwater fish, shellfish and ferns) that break down thiamin. Good plant sources of thiamin include whole grains, beans and lentils, nuts, spinach, orange and cantaloupe.

Vitamin A

Vitamin A is a general term for a large number of related compounds. It is not a single substance. The major compounds of 'vitamin A' are retinoids and include retinol (an alcohol), retinal (an aldehyde) and retenoic acid, an oxidized form of retinol (Higdon et al., 2012). Retinol is very important for night vision and retinoic acid is important for gene expression and cellular differentiation. Both are crucially important for proper differentiation and development of white blood cells that are so important in immune responses. The differentiation of red blood cells and release of iron from cellular storage sites for incorporation into hemoglobin are both regulated by retinoids. Vitamin A is also important for normal heart, eye and ear development in the fetus. Retinol in its free form is not normally found in foods. Plant-based foods contain many carotenoids but only four (beta-carotene, alpha-carotene, gamma-carotene and the xanthophyll beta-cryptoxanthin) can be converted into vitamin A by the body. Good plant sources of 'vitamin A' include carrots, sweet potato, pumpkin, cantaloupe, mango, spinach, kale, collards and butternut squash. Since vitamin A and its precursors are fat soluble, maximum nutritional benefit is obtained by consuming cooked vegetables with a little bit of fat or oil.

Vitamin B6

Vitamin B6 is a water soluble vitamin that exists in three forms: pyridoxal (PL), pyridoxine (PN) and pyridoxamine (PM) (Higdon et al., 2012). Humans cannot synthesize vitamin B6. The most nutritionally important form of vitamin B6 is the coenzyme pyridoxal 5'-phosphate (PLP). PLP is particularly important in the release of glucose from glycogen stored in muscle tissue and for the synthesis of glucose from amino acids. Synthesis of the neurotransmitters such as serotonin, dopamine, norepinephrine and gamma-aminobutyric acid requires PLP. PLP is also required for the production of the iron containing portion of hemoglobin, for the conversion of tryptophan into niacin and the synthesis of nucleic acids. PLP also regulates the function of steroid hormones such as testosterone and estrogen. Salmon, chicken and turkey are fairly high in vitamin B6. Plant-based foods particularly high in vitamin B6 include bananas, baked russet potato, spinach and hazelnuts.

Vitamin B12

Vitamin B12, unique in that it contains the metal cobalt, is largest in size of the vitamins and has a complex structure (Higdon et al., 2012). Methylcobalamin and 5-deoxyadenosyl cobalamin are two forms of vitamin B12 used by the human body. Methylcobalamin is important for methylation of DNA, which has been associated with cancer prevention. Homocysteine accumulation, which has been linked to increased risk for heart disease, occurs with vitamin B12 deficiency. Vitamin B12 is also needed for energy production from fats and proteins and for hemoglobin synthesis. Vitamin B12 is generally not present in plant-based foods, thus all dietary requirements must be met through animal-based foods such as fish, seafood, meat or dairy or from supplements.

Vitamin C

Vitamin C (ascorbic acid), a water soluble vitamin, cannot be synthesized by humans (Higdon et al., 2012). It is required for synthesis of the structural component collagen, the neurotransmitter norepinephrine and the synthesis of carnitine, a molecule essential for transporting fat into mitochondria for energy production. Vitamin C is also a powerful antioxidant. Many plant-based foods are high in vitamin C including: citrus fruits, strawberries, sweet red pepper, and broccoli.

Vitamin D

Vitamin D is a fat soluble vitamin needed for calcium metabolism (Higdon et al., 2012). Humans can synthesize vitamin D3 (cholecalciferol) upon skin exposure to ultraviolet B radiation in sunlight. The generic term 'vitamin D' refers to either or both vitamin D3 and D2. In order to be metabolically useful, vitamin D must be converted to 25-hydroxyvitamin D (calcidiol) in the liver followed by conversion to 1,25-dihydroxyvitamin D (the most potent form of vitamin D) in the kidney.

Vitamin D is important for balancing calcium levels in the blood, reducing cell proliferation while inducing differentiation, may enhance the immune system, helps regulate insulin secretion by the pancreas especially in type II diabetics, and may help decrease the risk for hypertension. Vitamin D deficiency may lead to rickets, bowing of weight bearing limbs, especially in infants and children. It may also lead to bone weakness and softening in older individuals as well as muscle weakness and pain. Most people can get their vitamin D requirement from 5 to 10 minutes of sun exposure each day. Most foods contain very little vitamin D unless they are fortified, thus supplements may be required if adequate sun exposure is not available.

Vitamin E

Alpha-tocopherol is the only antioxidant of 8 that belong to the vitamin E family that is maintained at appreciable levels in the human body (Higdon et al, 2012). Gamma-tocopherol is the vitamin E family antioxidant found in most of our food, yet blood serum gamma-tocopherol levels are much lower than alpha-tocopherol levels. The main function of vitamin E is to remove free radicals from the human body, primarily to protect fat molecules in membranes and low density lipoproteins from oxidation. When membrane lipids are oxidized, their integrity is compromised and oxidized low density lipoproteins are implicated in cardiovascular disease. The antioxidant capacity of an alpha-tocopherol molecule is lost once

it has been oxidized by a free radical, however, the antioxidant capacity can be regenerated by other antioxidants such as vitamin C. Vitamin E is also important in cell signaling, immune system function, blood platelet aggregation and vasodilation. Good sources of vitamin E include olive, corn, canola, soy, safflower, and sunflower oils, almonds, hazelnuts and peanuts.

Vitamin K

Vitamin K is a fat soluble vitamin vital to blood coagulation (Higdon et al., 2012). The two forms of vitamin K are K1 (phylloquinone), the predominant form in our diet, produced by plants and vitamin K2 (many forms of menaquinones) which is produced by bacteria in the intestines of animals. Vitamin K1 is the predominant form of dietary vitamin K and foods rich in vitamin K include kale, broccoli, Swiss chard and parsley.

MINERALS

Minerals are elements no living organism can synthesize and are obtained primarily from the earth, mostly by bacteria, fungi or plants. Most of the minerals in our diet are derived from plants that have absorbed them from the soil. We eat the plants directly, or consume animals (or their products) that have eaten the plants. We also obtain some minerals from the water we drink. The two classes of minerals are: (1) macro minerals, those we require in large quantities for good health (calcium, chloride, magnesium, phosphate, potassium and sodium) and (2) micro minerals, no less important, but required in much lower amounts (chromium, copper, fluoride, iodine, iron, manganese, molybdenum, selenium and zinc) (Porter, 2010). Trace minerals such as arsenic, cobalt, fluoride, nickel, silicon and vanadium which seem to be essential in animal nutrition have not been established as essential in human nutrition.

Calcium

Calcium is the most common mineral in the human body. and most of it is found in teeth and bones (Higdon et al., 2012). While most of it is found as hydroxyapatite in the teeth and bones and less than 1% is in the blood and extracellular fluid, the levels in these fluids are critical for good health. Calcium is extremely important in cell signaling for vasoconstriction and vasodilation, nerve impulse transmission, muscle contraction, insulin secretion and enzyme and protein function. Calcium deficiency detected in the blood is often a sign of parathyroid or kidney malfunction since the body always has a large reserve of calcium in the skeletal system. Vitamin D or magnesium deficiency or excessive sodium, phosphorus or protein consumption may also lead to low blood calcium levels.

Goldenberries are not a very good plant source of calcium, only providing 9 mg per 100 g dw, compared to 34 mg per 100 g dw from Valencia oranges.

Even though much of our calcium usually comes from dairy products, certain plant products have calcium that is as readily absorbed and utilized as dairy-derived calcium. Kale, broccoli, bok choy, cabbage, collards and mustard greens are rich plant sources of such calcium. Some plants such as spinach and rhubarb and to a lesser extent sweet potatoes and kidney beans, are rich in oxalic acid, a potent inhibitor of calcium absorption, thus care

should be exhibited when consuming large quantities of any of these foods. Phytic acid, which is found in non-fermented grain and bean products, also inhibits calcium absorption.

Chromium

Chromium is an essential mineral important in glucose metabolism (Higdon et al., 2012) and may affect blood lipid profiles. Trivalent chromium is the form found in most foods and utilized by the body. Hexavalent chromium at low levels can be reduced to trivalent chromium by acids in some foods and the stomach. However, hexavalent chromium at high levels is a potent carcinogen. Claims that chromium picolinate supplements enhance weight loss are unfounded (Volpe et al., 2001) and it may even cause weight gain in individuals with type 2 diabetes taking sulfonylurea drugs (Martin et al., 2006).

Broccoli is particularly high in chromium while green beans, potatoes, grape juice, orange juice, apple and banana contain moderate amounts. Foods that are high in simple sugars are usually low in chromium and they also are known to promote chromium loss from the body.

Copper

Copper exists as both mono- and di-valent cations in the human body however the divalent form is predominant (Higdonet al., 2012). Copper easily accepts and donates electrons making it important in oxidation – reduction reactions and free radical scavenging. Copper is important in cellular energy production, iron metabolism, the synthesis and metabolism of neurotransmitters, synthesis and maintenance of the myelin sheath, melatonin synthesis and regulation of gene expression.

Goldenberries are fairly high in copper (0.28 mg per 100 g dw). Compare this to 0.03, 0.04 and 0.06 mg per 100 g dw for apples, oranges and strawberries, respectively.

Good plant sources for copper include cashews, sunflower seeds, hazelnuts, almonds, peanut butter, lentils and mushrooms.

Fluoride

Fluoride is a negatively charged molecule of fluorine mostly found in teeth and bones. It is not an essential mineral since it is not required to sustain life however, it is extremely important in preventing tooth decay. Fluoride interacts with hydroxyapatite in teeth and hardens tooth enamel making them less susceptible to decay.

Fluoride is often consumed in fluoridated drinking water, or applied to teeth using fluoride containing toothpaste. Tea and grape juice are relatively high in fluoride compared to other plant sources, but even so, both contain very little (0.6 mg per 100 ml serving) fluoride.

Iodine

Iodine is a non-metallic trace mineral found mostly in ocean water that is required by humans for the synthesis of the thyroid hormones triiodothyrine and thyroxine which are involved in regulating growth, development, metabolism and reproductive functions (Higdon et al., 2012). Iodine deficiency is a worldwide problem, leading to enlarged thyroid (goiter) in children and adults and when deficient in pregnant women or newborn infants, impaired intellectual development.

Plant-based foods particularly rich in iodine include seaweeds, navy beans and potatoes. The absolute iodine content of these foods varies widely due to differences in soil and seawater iodine concentrations. In many regions of the world, iodine is supplied through iodized salt. Some foods contain substances called goitrogens that interfere with the uptake of iodine. Cassava, some species of millet and many cruciferous vegetables contain goitrogens. Several of the soy based isoflavones including genistein and daidzein inhibit thyroid hormone synthesis. The negative impacts of goitrogens and soy isoflavones are only of concern in areas where iodine deficiency is severe or these products are consumed in excess.

Iron

Iron is a key mineral influencing metabolism in all living organisms as it is a major component of many proteins and enzymes (Higdon, et al., 2012). Iron is an important component of hemoglobin, important in the transport and storage of oxygen in the blood. Iron is also an important component of cytochromes, molecules important in mitochondrial electron transport and energy production. Both catalase and peroxidase contain iron and both are important as antioxidant enzymes, protecting cells from damage by hydrogen peroxide. The immune system also relies on iron in the enzyme myeloperoxidase, which is produced by white blood cells which engulf bacteria and kills them by exposing them to reactive oxygen species. Iron may also be important to physiological adaptations to low oxygen concentrations, such as in high altitude environments or in patients with chronic lung disease. Iron is also required for DNA synthesis. Since iron can be toxic to cells through generation of free radicals, the human body closely regulates the iron status of our cells.

Iron deficiency in humans occurs as one of three types. The first is when storage pools have been depleted but there is still enough iron in the blood for normal metabolism. Early functional iron deficiency is the second type. This occurs when the amount of iron in the blood limits the formation of red blood cells, but not low enough to detect anemia. The third level of deficiency, called iron-deficiency anemia, occurs when blood levels of iron reach a critical level where normal red blood cell formation cannot occur, red blood cells are smaller than normal and their hemoglobin content is lower than normal. At this stage, the oxygen carrying capacity of the blood is compromised and iron dependent enzyme function is deficient. Symptoms of anemia include those

Goldenberries contain 1.47 mg iron per 100 g dry weight

5 to 15 times higher than many other fruits.

Goldenberries contain more iron than traditional plant sources of iron such as beans (0.8 mg iron per 100 g dw) and similar amounts as animal sources such as beef (1.8 mg per 100 g dw).

that are concomitant with low blood oxygen levels, such as fatigue, rapid heart rate and rapid breathing upon exertion.

The iron content of food may be of the heme type (hemoglobin and myoglobin, from animal-based foods) and non-heme type (plant sources). The absorption of non-heme iron depends greatly on absorption enhancers and inhibitor consumed with iron containing food. Non-heme iron absorption is enhanced by vitamin C, organic acids such as citric, malic, tartaric, and lactic acids, and meat, fish or poultry. Absorption is inhibited by phytic acid (found especially in legumes, grains, and rice), polyphenols and soy protein. Good plant sources of iron include black-strap molasses, raisins, prunes, potatoes with skin, kidney beans, lentils, tofu and cashews.

Magnesium

Magnesium is involved in over 300 essential metabolic functions in the human body (Higdon et al., 2012). Magnesium is important in the synthesis of ATP, nucleic acids, carbohydrates, lipids and the antioxidant glutathione. Magnesium plays a role in transport of ions across cell membranes, and for the phosphorylation of proteins that is important in cell signaling. Magnesium is also part of structural molecules in bone, cell membranes and chromosomes.

Goldenberries are high in magnesium (34.7 mg per 100 g dw) compared to 17 and 10 mg per g dw for papaya and strawberry, respectively.

Green leafy vegetables are a great source of magnesium owing to their high chlorophyll content. Grains and nuts as well as lima beans, okra, molasses and bananas are also high in magnesium.

Manganese

Manganese is an essential mineral that is important for antioxidant enzyme function, gluconeogenesis, and liver detoxification of ammonia. Manganese activated enzymes are important in the metabolism of carbohydrates, collagen (important in wound healing), cartilage, amino acids, cholesterol and neurotransmitters.

Goldenberries are relatively high in manganese (0.26 mg per 100 g dw) compared to 0.01 and 0.06 mg per 100 g dw for apples and oranges.

Manganese deficiency is extremely rare. Plant based foods rich in manganese include pineapple, whole grains, nuts, leafy vegetables, and teas. Foods that are high in phytic acid, such as beans, seeds, nuts, whole grains, and soy products, or foods high in oxalic acid, such as cabbage, spinach, and sweet potatoes, may slightly inhibit manganese absorption. The tannins in tea may also reduce the absorption of manganese

Molybdenum

Molybdenum is a cofactor for three important enzymes in the human body, sulfite oxidase, xanthine oxidase and aldehyde oxidase (Higdon et al., 2012). Sulfite oxidase is important for metabolism of the sulfur-containing amino acids methionine and cysteine. Xanthine oxidase helps regulate the antioxidant capacity of blood and aldehyde oxidase is important in the metabolism of drugs and toxins.

Molybdenum deficiency is extremely rare. The best plant sources of molybdenum are legumes (beans, peas and lentils), grains and nuts. Most fruits and vegetables are low in molybdenum.

Phosphorus

Most of the phosphorus in the human body is in our bones in hydroxyapatite (Higdon et al., 2012). Phosphorus is also an important component of membranes, and is important in energy metabolism, nucleic acid synthesis, and maintaining the buffering system of cells. Many enzymes, hormones and cell signals rely on phosphorylation for activity.

Phosphorus deficiency is rare but increased consumption of fructose can lead to excessive urinary loss of phosphorus leading to a net daily loss of phosphorus from the body, especially in males (Milne and Nielsen, 2000). This is important in areas of the world where the consumption of high fructose corn syrup has skyrocketed.

Dairy foods, meat and fish are rich in phosphorus, and many food additives contain phosphorus. In addition, phosphoric acid is present in soft drinks. The phosphorus in plant based foods occurs as phytic acid. Only about 50% of the phosphorus in phytic acid is bioavailable to humans since we lack the enzymes required for liberating phosphorus from the phytate. Almonds, peanuts and lentils are particularly rich in phosphorus.

Potassium

Potassium is important as both an essential mineral and as an electrolyte (Higdon et al., 2012). Electrolytes conduct electricity and since many bodily functions rely on electrical impulses traveling throughout the body, extremely precise regulation of electrolyte levels is imperative for good health. Electrical charges throughout the body rely on potassium and sodium ions. Potassium ions are principally intracellular while sodium ions are predominantly extracellular. The general gradients of these two ions are such that there are approximately 30 times the potassium ions inside vs outside the cell and 10 times the number of sodium ions outside than inside the cell. These differences create an electrical gradient called the membrane potential. The gradients are maintained by ATP driven membrane pumps which use between 20 and 40% of the energy consumed by an adult at rest. This gives an idea of how crucial these gradients are. The gradients are particularly important for nerve impulse travel, heart function and muscle contraction. Potassium is also important in carbohydrate metabolism.

Potassium deficiency is usually caused by excessive excretion of potassium in the urine rather than a lack of potassium in the diet. Fruits and vegetables are particularly good sources of dietary potassium, especially

Goldenberries contain 347 mg of potassium per 100 g dw. Compare this to 117, 158 and 184 mg per 100 g dw for apples, oranges and strawberries.

bananas, potatoes with the skin, prunes, oranges, tomatoes, raisins, artichoke, lima beans, acorn squash, spinach, sunflower seeds, almonds and molasses.

Selenium

Selenium is a trace mineral required for specialized enzymes called selenoproteins (Higdon et al., 2012). Selenoproteins are important as antioxidants and antioxidant generators. Selenoprotein P found in plasma helps protect the lining of blood vessels and the biologically active thyroid hormone triiodothronine requires a selenoprotein. Other selenoproteins are important in spermatogenesis, protein folding and inflammatory and immune responses.

Selenium deficiency doesn't seem to cause a specific illness, but rather renders the deficient individual more susceptible to stress induced illnesses.

The best sources for selenium are organ meats and seafood. Plants are unreliable for selenium nutrition as they do not have a specific selenium requirement and merely absorb selenium that is in the soil. Levels of selenium in any particular plant-based food are entirely dependent on the soil in which it was grown. Brazil nuts are a good source of plant-based selenium, but their content can vary from 10 to 100 mcg per nut depending on where it is grown.

Sodium chloride

Sodium chloride provides sodium and chloride ions, both electrolytes, are the principal extracellular ions in the human body (Higdon et al., 2012). Their concentrations are carefully regulated within the body and an excess of either ion can lead to serious health problems. Both sodium and chloride ions are critical for generating and maintaining membrane potentials in the body for the transmission of nerve impulses, heart function and muscle contraction. Sodium is important in the absorption of chloride, amino acids, glucose and water in the small intestine. Chloride is an important component of hydrochloric acid in the stomach, crucial for proper digestion. Sodium is intricately involved in blood volume and blood pressure, with excess sodium leading to high blood pressure and its negative health consequences.

Goldenberries are low in sodium (1.1 mg per 100 g dw).

Sodium chloride is normally not deficient in human diets. On the contrary, the major concern with both nutrients, sodium in particular, is an excess.

Zinc

Zinc is important in growth and development, immune responses, neurological function and sexual reproduction (Higdon et al., 2012). Zinc is an important catalyst for innumerable enzymes and an important

structural component in proteins and cell membranes. Proteins containing zinc are important in DNA transcription, cell signaling and apoptosis.

Goldenberries are a good fruit source of zinc, containing 0.5 mg per 100 g dw.

Other plant sources that are better for supplying zinc include wheat germ and dried beans.

Zinc deficiency can be a serious problem causing growth retardation, immune system dysfunction, and cognitive impairment. Shellfish and red meats are good sources of zinc. Nuts and legumes are good plant sources of zinc however there is less bioavailable zinc in plant sources due to the presence of phytic acid in plant-based sources of zinc.

PHYTONUTRIENTS

Phytonutrients are components of plants that are often associated with maintaining good health or improving poor health. They are not considered essential as defined for other nutrients. Many products claim to have great health benefits but they should be considered with great caution. This section explores the major phytonutrients (and for completeness, even those not associated with goldenberries) and the latest information available regarding their potential benefits and the risks associated with their use. A great website for information regarding many aspects of nutrition is the Linus Pauling Institute at Oregon State University (http://lpi.oregonstate.edu/infocenter/). This website and associated references were the sources for much of the material presented here.

Carotenoids

There are more than 600 naturally occurring pigments classified as carotenoids that are produced by bacteria, algae and plants (Higdon et al., 2012). These pigments are yellow, orange and red and are often abundantly found in most fruits and vegetables. Green leaves are often rich sources of carotenoids even though they don't appear brightly colored because chlorophyll masks the other pigments. Carotenoids most consumed by humans include the carotenes (alpha-carotene, beta-carotene, lycopene) and xanthophylls (beta-cryptoxanthin, lutein, zeaxanthin). They are fat-soluble, thus must be consumed with fat to be absorbed by the body. Carotenes are pro-vitamin A components. Of the six listed carotenoids, only alpha-carotene, beta-carotene and beta-cryptoxanthin are provitamin A carotenoids that can be converted by the body into retinol (vitamin A) (Food and Nutrition Board, 2000). The vitamin A activity of beta-carotene in food is only 1/12 that of retinol. The vitamin A activity of alpha-carotene and beta-cryptoxanthin are both 1/24 that of retinol (Food and Nutrition Board, 2000).

Carotenoids (particularly lycopene) function as antioxidants in plants, but whether or not they have the same capacity in humans is not clear. Lutein and zeaxanthin are very effective in absorbing blue light. Both pigments absorb blue light entering our eyes before it reaches the rods and cones thus they may protect them from oxidative damage induced by light (Krinsky et al., 2003).

Carotenoids stimulate the synthesis of proteins called connexins that form pores in membranes that allow intercellular communication via the movement of small molecules between cells (Bertram, 1999) helping cells stay in a differentiated state. Cancer cells often lose the capacity to stay differentiated. While dietary carotenoids might be able to reduce the risk of cancer, in particular, lung cancer (Holick et al., 2002; Voorrips et al., 2000), the benefit is small (Gallicchio et al., 2008) and the best protection against lung cancer is not smoking. Beta-carotene supplement consumption actually increased the risk of lung cancer in high risk individuals, such as smokers and asbestos workers (Anon., 1994; Omenn et al., 1996).

Consuming tomatoes and cooked tomato products, exceptionally high in lycopene, has been suggested to reduce the risk of prostate cancer in men, however, the evidence supporting such a claim is limited. In several studies, a significantly decreased risk for prostate cancer was observed in men consuming large amounts of tomatoes and tomato products (Giovannucci, 2002; Giovannucci et al., 1995; Gann et al., 1999; Mills et al., 1989). In other studies, high dietary lycopene intake (mostly from tomatoes and tomato products) did not reduce the risk of prostate cancer (Schuurman et al., 2002; Etminan et al., 2004; Key et al., 2007).

Higher blood levels of carotenoids have been associated with lower measures of carotid intima-media thickness, a measure of cardiovascular risk (Rissanen et al., 2003; Dwyer et al., 2004; McQuillan et al, 2001; Rissanen et al., 2000; D'Odorico et al., 2000; Iribarren et al., 1997). Some studies evaluating decreased risk of cardiovascular disease and plasma carotene content suggest a decreased risk (Sesso et al., 2004; Rissanen et al., 2001; Street et al., 1994; Ito et al., 2006; Buijsse et al., 2008) while others suggest no effect (Sesso et al., 2005; Hak et al., 2003; Evans et al., 1998; Sahyoun et al., 1996). Even so, consumption of foods rich in carotenoids leads to a decrease risk of cardiovascular disease (Sahyoun et al., 1996; Rimm et al., 1993; Gaziano et al., 1995; Osganian et al., 2003). Since consumption of carotenoid rich foods leads to reduced risk but higher plasma levels of carotenes are not associated with the decreased risk, other factors associated with the consumption of carotenoid rich food (such as lifestyle, other nutrients) must be involved. Beta-carotene supplements do not offer the same protection as food-derived carotenoids (Voutilainen et al., 2006).

RIPE GOLDENBERRIES CONTAIN
***200 µG/G DW** TOTAL CAROTENOIDS*

COMPARED TO:
APRICOTS - 970
CHERRIES - 90
NECTARINES - 430
PEACH - 140
PLUMS - 170
CARROTS - 1970
RED BELL PEPPER - 3750
(ALL RAW, µG/G DW)

(ETZBACH, ET AL., 2018; LEONG AND OEY, 2012).

Even though many fruits and vegetables are good sources of carotenoids, many of the carotenoids they contain have limited bioavailability due to protein association within the food. Chopping and cooking often release bioavailable carotenoids. Bioavailable lycopene from tomatoes is substantially increased if the tomatoes are cooked with a little oil. Pumpkin and carrots are particularly rich in alpha-carotene while pumpkin, spinach, sweet potato, carrots, collards, kale and turnip greens are rich sources of beta-carotene. Remember alpha and beta-carotene are both provitamin A carotenoids that can be converted into retinol. Beta cryptoxanthin, another provitamin A carotenoid, can be found in many orange and red fruits including pumpkin, red peppers and papayas. Good sources of lycopene include tomatoes, tomato products and watermelon. Lutein and zeaxanthin are both xanthophylls and their levels are typically reported combined. Foods rich in lutein and zeaxanthin include spinach, kale, turnip greens and collards.

Chlorophyll

Chlorophyll, the major light-capturing pigment in plants, has the element magnesium at its center much like the hemoglobin in our bodies has iron at its center (Higdon et al., 2012). The two main types of chlorophyll are a and b, both fat soluble molecules, that are situated predominantly in the chloroplast membranes of leaf cells. The difference between chlorophyll a and chlorophyll b is that they absorb light of different wavelengths.

Chlorophyll forms molecular complexes with suspected carcinogens, most notably certain hydrocarbons found in tobacco smoke, compounds found in cooked meat and aflatoxin-b1, a potent liver carcinogen found in moldy grains and legumes, and allows them to be less easily absorbed during digestion, reducing the chances for cancer. Leafy greens such as spinach, kale, collards and herbs such as parsley and basil are the best natural sources of chlorophyll.

Curcumin

The spice turmeric is derived from the rhizomes of *Curcuma longa*, a relative of ginger (Higdon et al., 2012). The bright yellow color of turmeric comes from curcuminoids, fat-soluble polyphenols, and turmeric extracts are often used as food coloring agents. Curcumin is the most abundant curcuminoid in turmeric.

Curcumin accumulates in gastrointestinal tissues after ingestion, and only low levels of curcumin can be detected in the bloodstream after ingestion (Cheng et al., 2001; Sharma et al., 2004). The metabolites of curcumin such as curcumin glucuronides, curcumin sulfates and hexahydrocurcumin are readily detected in the bloodstream (Baum et al., 2008; Lao et al, 2006) but are much less effective than curcumin itself. Curcumin is a powerful anti-oxidant, however, limited translocation may reduce its effectiveness outside the gastrointestinal tract (Garcea et al., 2004). Curcumin also enhances the production of the antioxidant glutathione (Dickinson et al., 2003; Zheng, et al., 2007) and reduces symptoms of inflammation (Deodhar et al., 1980; Satoskar et al., 1986) by interfering with enzymes responsible for producing the irritants associated with inflammation (Hong et al., 2004). Curcumin has also been shown to arrest cell development in cultured colon cancer cells (Moos et al., 2004; Tsvetkov et al., 2005) and cultured breast cancer cells (Somasundaram et al., 2002). These responses to curcumin appear promising however, it is important to

emphasize the very low bioavailability of curcumin outside the gastrointestinal tract and that the cancer studies were performed using cell cultures, not patients.

Flavonoids

Flavonoids are water soluble polyphenolic pigments synthesized by plants with many functions in plants: floral pigmentation to attract pollinators, stimulating *Rhizobium* bacteria for nitrogen fixation, promotion of pollen tube growth, regulation of auxin accumulation, regulation of the resorption of mineral nutrients from senescing leaves, enhancing tolerance to abiotic stress, absorbing otherwise damaging UV radiation, acting as antioxidants, providing defense against herbivores and pathogens, and promoting allelopathic relationships with other plants.

Flavonoids are often divided into subclasses to include anthocyanidins, flavanols, flavanones, flavonols, flavones and isoflavones. While flavonoids are ubiquitous in plants, some plants are particularly rich in one or more of the flavonoid classes. Anthocyanidins (cyanidin, delphinidin, malvidin, pelargonidin, peonidin, petunidin) are found in red, blue and purple berries, red and purple grapes and red wine. Flavanol monomers or catechins (catechin, epicatechin, epigallocatechin epicatechin gallate, epigallocatechin gallate) are found in green and white teas, chocolate, grapes, berries and apples. The flavonol classes of theaflavins and thearubigins are found in black and oolong teas while the proanthocyanidin flavonols are found in chocolate, apples, berries, red grapes and red wine. Citrus fruits and juices are particularly rich in flavanones (hesperetin, naringenin and eriodictyol). Flavonols (quercitin, kaempferol, myricetin and isorhamnetin) can be found in yellow onions, scallions, kale, broccoli, apples, berries and teas. Flavones (apigenin and luteolin) are found in parsley, thyme, celery and hot peppers. Soybeans and soy products as well as other legumes are high in isoflavones (daidzein, genistein and glycitein).

When flavonoid molecules are attached to one or more sugar molecules they are called flavonoid glycosides. Those that are not attached to sugar molecules are called aglycones. The flavonoids we consume are of the flavonoid glycoside type except for catechins and proanthocyanidins (Williamson, 2004). Most flavonoid glycosides must be metabolized by intestinal bacteria before being absorbed. Regardless of their form, flavonoids are rapidly eliminated from the body, thus studies linking them to specific health benefits must be considered carefully. In addition, the biological activity of metabolites is often not the same as those of the parent compound from which they were derived.

Contrary to popular belief, flavonoids are probably not very important to human health when it comes to their antioxidant activity (Williams et al., 2004; Frei and Higdon, 2003; Lotito and Frei, 2006). Other antioxidants such as vitamin C, uric acid and glutathione are often 100 to 1000 times higher than flavonoids in the bloodstream. Additionally, the little flavonoids found in the blood are usually metabolites rather than the parent flavonoid. Similarly, it is not known whether or not flavonoids are effective as metal chelators in the body (Frei and Higdon, 2003).

Flavonoids are very important in cell signaling pathways (Williams et al., 2004) and may help prevent cancer by enhancing the excretion of potential carcinogens (Kong et al., 2001; Walle and Walle, 2002), by preserving normal cell cycle regulation limiting the production of mutations (Chen et al., 2004; Wang et al.,

2004) by inducing apoptosis in cancer cells (Sah et al., 2004; Kavanagh et al., 2001; Ramos, 2007) and by inhibiting tumor invasion and the development of tumor blood vessel networks, known as angiogenesis (Bagli et al., 2004; Kim, 2003).

Flavonoids may reduce the susceptibility to cardiovascular disease by decreasing inflammation (O'Leary et al., 2004; Sakata et al., 2003; Cho et al., 2003), reducing the expression of adhesion molecules by vascular wall cells, one of the first steps in the development of atherosclerosis (Choi et al., 2004; Ludwig et al., 2004), maintaining vasodilation (Anter et al., 2004) and decreasing platelet aggregation and the formation of blood clots (Deana et al., 2003; Bucki et al., 2003).

Soy isoflavones (phytoestrogens)

Soy isoflavones are considered separate from other flavonoids due to their importance as an estrogen mimicking hormone and since they are plant derived, they are called phytoestrogens (Lampe, 2003). Soybeans are the primary legumes containing phytoestrogens. The phytoestrogens in soybeans are isoflavones attached to sugar molecules, isoflavone glycosides, which include genistin, daidzin and glycitin. Once fermented or digested, the sugar molecule is removed leaving isoflavone aglycones, genistein, daidzein and glycitein, respectively.

The metabolism of soy isoflavones in our gut depends on the bacteria present in our intestine (Rowland et al., 2003). For example, some people metabolize daidzein to equol, a compound with greater estrogenic activity than daidzein, while others metabolize it to other less estrogenic compounds, all depending on intestinal flora (Setchell et al., 2002). An individual gut health and bacterial profile has great implications for the response to isoflavone ingestion.

Soy isoflavones mimic estrogen, a signaling molecule (hormone) responsible for many aspects of human function, especially heart, liver, bone, brain and reproductive growth and development. Estrogen works by attaching to receptors in cells to form an estrogen-receptor complex which then interact with DNA and alter the expression of estrogen sensitive genes. Soy isoflavones can bind to estrogen receptors and mimic estrogen effects in some tissues and block estrogen-like effects in others. Soy isoflavones are of interest for their potential for reducing the risk of certain hormone related cancers such as breast, uterine and prostate cancers, enhancing bone density and improving blood lipid profiles, particularly cholesterol levels. Soy isoflavones and their metabolites also inhibit the synthesis and activity of some enzymes involved in estrogen metabolism and may alter the biological activity of both estrogens and androgens (Kao et al., 1998; Whitehead et al., 2002; Holzbeierlein et al., 2005).

Isolflavones may also inhibit cell proliferation and act as an antioxidant. Consuming isoflavones may improve cardiovascular health by lowering serum LDL cholesterol (Sacks et al., 2006) and decreasing arterial stiffness (Nestel et al., 1997). While breast, uterine and prostate cancer rates often appear to be lower in populations consuming significant amounts of soy isoflavones (van Erp-Baart et al., 2003; de Kleijn et al., 2001; Horn-Ross et al., 2003; Goodman et al., 1997; Xu et al., 2004; Messina, 2003), there is little direct evidence that consuming soy isoflavones reduces one's risk for these diseases (Murray et al., 2003; Goetzl et al., 2007). Similarly, populations consuming soy foods generally have a lower incidence of hip fracture

suggesting greater bone density in those individuals. However, it is not clear whether or not consumption of soy isoflavones improves one's bone density profile (Setchell and Lydeking-Olsen, 2003). Use of isoflavones rather than estrogen therapy to counter symptoms of menopause, particularly hot flashes, has not been particularly effective (Krebs et al., 2004). However, women who produce equol from ingested isoflavones experienced a significant reduction in the occurrence of hot flashes (Jou et al., 2008).

It is important to note that not all soy products contain isoflavones, therefore it is important when considering the possible benefits associated with soy consumption, that the products include isoflavones. Some soy products rich in isoflavones include soy protein concentrate prepared via an aqueous wash (as opposed to an ethanol wash), miso, tempeh, boiled soybeans, dry roasted soybeans, soymilk, and tofu. Many soy-based infant formulas are high in isoflavones (Setchell et al., 1998). The isoflavone content of soy-based foods can vary considerably even within different lots of a single brand (Setchell et al., 2003). Supplements containing isoflavones are not standardized and quality control is an issue with many available on the market (Chua et al., 2004; Setchell et al., 2001), thus care should be exerted when considering such products.

Organosulfur compounds (garlic)

Garlic (*Allium sativum* L.) is especially rich in organosulfur compounds, the compounds responsible for the strong flavor of garlic as well as its possible health benefits (Block, 1985). The two main classes of organosulfur compounds in garlic are gamma-glutamylcysteines and cysteine sulfoxides. The gamma-glutamylcycsteine content is not altered by crushing, chopping or chewing raw garlic. Allylcysteine sulfoxide (alliin) is the predominant cysteine sulfoxide in garlic. When raw garlic is crushed, chopped or chewed the enzyme alliinase is released, converting alliin to allicin in 10 to 60 seconds (Block, 1985). Allicin then breaks down over time into a number of organosulfur compounds.

Allicin and allicin derived compounds are rapidly metabolized by the human body (Lawson, 1998) perhaps into allyl methyl sulfide, which is readily detected in the breath. Gamma-glutamylcysteines are absorbed then hydrolyzed to S-allylcysteine and S-1-propenylcysteine (de Rooij et al., 1996; Jandke and Spiteller, 1987).

Garlic may be good for cardiovascular health since the consumption of garlic and derived organosulfur compounds appears to decrease the synthesis of cholesterol by liver cells (Gebhardt and Beck, 1996) by inhibiting enzymes responsible for its production (Ferri et al., 2003; Liu and Yeh, 2002). Organosulfur compounds from garlic also inhibit platelet aggregation in lab tests (Chan et al., 2002). Cardiovascular disease is at least in part caused by inflammation and garlic has been shown to inhibit two enzymes in the inflammatory response pathway (Ali et al., 2000), and to decrease the production of inflammatory signaling molecules in vitro (Chang et al., 2005; Keiss et al., 2003). Hydrogen sulfide may act as a vasodilator, thereby protecting heart health (Pryor et al., 2006; Lefer, 2007).

Organosulfur compounds may help the body prevent activation of the carcinogenic capacity of some toxins as well as rid itself of potentially carcinogenic toxins (Gurley et al., 2002; Loizou and Cocker, 2001; Chen et al., 2004; Fisher et al., 2007). They may also act as antioxidants and stimulate the production of the

antioxidant glutathione (Banerjee et al., 2003). Organosulfur compounds also induce cell cycle arrest in cancer cell cultures (Herman-Antosiewicz and Singh, 2004; Knowles and Milner, 2001; Arunkumar et al., 2006) thereby preventing further unregulated cell division. These compounds also induce apoptosis in precancerous and cancerous cells (Balasenthil et al., 2002; Balasenthil et al., 2002) which are normally resistant to apoptosis (Wu et al., 2005). Sulfur compounds are also antibacterial and antimicrobial (Fenwick and Hanley, 1985; Harris et al., 2001).

The most potent source of these organosulfur compounds is chopped, crushed or chewed raw garlic. Cooking garlic inactivates the alliinase enzyme, thus if garlic must be cooked for consumption, allow it to stand for 10 minutes after chopping to allow the alliinase enzyme to convert alliin to allicin (Song and Milner, 2001).

Glucosinolates

Cruciferous vegetables are rich sources of sulfur-containing compounds called glucosinolates and diets rich in cruciferous vegetables seen to reduce the risk of several types of cancer (Verhoeven et al., 1997).

Indole-3-Carbinol

Cruciferous vegetables are rich sources of glucobrassicin (Kim and Milner, 2005). When these vegetables are chewed or chopped, indole-3-carbinol (I3C) is enzymatically produced from glucobrassicin by myrosinase, an enzyme that is normally isolated from glucobrassicin in the plant cell. When I3C hits the acidic environment of the stomach, a number of acid condensation products are formed including the dimer 3,3-diindolylmethane (DIM) and a cyclic trimer (CT) which are the substances responsible for biological reactions attributed to the consumption of cruciferous products. These acid condensation products are less likely to form if the vegetables are cooked since myrosinase is inactivated by heat and any I3C formed by intestinal bacteria is not likely to form condensates in the alkaline environment of the intestine.

The active components of I3C condensation seem to interfere with the transformation many potential carcinogens (procarcinogens) must undergo in the body before they become carcinogenic (Bonnesen et al., 2001; Nho and Jeffery, 2001; Wallig et al., 1998). In addition, I3C and DIM have been shown to induce apoptosis in cultured prostate (Chinni et al., 2001), breast (Hong et al., 2002; Howells et al., 2002; Rahman and Sarkar, 2005), pancreatic (Abdelrahim et al., 2006) and cervical cancer cells (Chen et al., 2004). They may also inhibit angiogenesis (Chang et al., 2005; Wu et al., 2005), required for tumor growth.

Rich sources of glucobrassicin include broccoli, Brussels sprouts, cabbage, cauliflower, collard greens, kale, mustard greens, radish, rutabaga and turnips.

Isothiocyanates

Isothiocyanates are hydrolysis breakdown products of glucosinolates, catalyzed by the enzyme myrosinase. Each glucosinolate has a different breakdown product and specific foods are often rich in one particular glucosinolate. For example, broccoli is rich in glucoraphanin and sinigrin, precursors to the isothiocyanates

sulforaphane and allyl isothiocyanate, respectively. Watercress is rich in gluconasturtiin which is converted to phenethyl isothiocyanate while garden cress is rich in glucotropaeolin, which yields benzyl isothiocyante. All of the isothiocyanates seem to have possible anticarcinogenic properties.

Isothiocyanates appear to interfere with the transformation of procarcinogens into carcinogens (Conaway et al., 2002; Hecht, 2000; Hecht et al., 1995). Many isothiocyanates protect DNA from damage caused by carcinogens and reactive oxygen species (Zhang, 2004; Fimognari and Hrelia, 2007; Kensler and Talaway, 2004). They also induce apoptosis in cultured cancer cells (Hecht, 2004). Isothiocyanates may also decrease the secretion of inflammatory signaling molecules (Gerhauser et al., 2003; Heiss et al., 2001). They are also fairly effective as an antibacterial agent towards *Helicobacter pylori*, a bacterial strain associated with an increased risk of gastric cancer (Normark et al., 2003; Fahey et al., 2002).

Nearly all of the cruciferous vegetables including bok choy, broccoli, broccoli sprouts, Brussels sprouts, cabbage, cauliflower, horseradish, kale, kohlrabi, mustard, radish, rutabaga, turnip, and watercress, are rich sources of the glucosinolate precursors of isothiocyanates (Fenwick et al., 1983). The amount of active isothiocyanates derived from each food depends on preparation and cooking methods.

Lignans (phytoestrogens)

Lignans are polyphenolic compounds found in many plants. Lignan precursors are found in many of the plant based foods we eat and are converted by bacteria in the intestines into enterodiol and enterolactone (Lampe, 2003) where they are then absorbed into the bloodstream. The quantity of enterodiol and enterolactone derived from lignan precursors depends on the microflora in the gut. Both enterodiol and enterolactone mimic estrogen in the human body, thus their precursors are called phytoestrogens. Even though phytoestrogens from soy seem to have received the most attention as phytoestrogens, especially in the popular press, lignan precursor phytoestrogens are equally important, especially in western diets. The lignan precursors identified in the average human diet include pinoresinol, lariciresinol, secoisolariciresinol and matairesinol.

Enterodiol and enterolactone both have weak estrogenic activity in the human body including effects on bone, liver, heart, brain and reproductive health similar to those of soy isoflavones. Lignans may alter endogenous estrogen activity (Brooks and Thompson, 2005) and can act as antioxidants. Diets that are rich in lignans are associated with a reduced risk of cardiovascular disease. Many of the foods containing significant lignans are also rich in other nutrients and phytonutrients which may also contribute to their cardioprotective status.

The best source of lignans is ground flax seed. Other good sources include pumpkin, sunflower, poppy and sesame seeds, rye oats and barley, bran from wheat, oat and rye, beans, berries and vegetables.

Phytosterols

Phytosterols are plant-derived substances that mimic the structure and function of cholesterol. Two main classes of phytosterols are recognized: (1) sterols have a double bond in the sterol ring and (2) stanols lack

the double bond. The most abundant sterols in the human diet are sitosterol and campesterol. Stanols are also present in plants but at much lower levels.

Phytosterols inhibit the absorption of cholesterol in the intestines and reduce both total and LDL serum cholesterol, reducing the risk of cardiovascular disease (Berger et al., 2004; Katan et al., 2003). In addition, sitosterol has been shown to induce apoptosis in cultures of human prostate (von Holtz et al., 1998), breast (Awad et al., 2003) and colon (Choi et al., 2003) cancer cells.

All plant-based foods contain phytosterols with the highest levels in unrefined plant oils including corn, soy, peanut, canola, nut, rice bran and olive oils (Ostlund, 2002). Wheat germ, nuts, seeds, whole grains and legumes are also very good sources of phytosterols (de Jong et al., 2003). Many plant-based margarine spreads are enriched with plant sterols and stanols, providing a convenient way to supplement normal phytosterol intake.

Resveratrol

Resveratrol (3,4',5-trihydroxystilbene) is a polyphenolic, fat-soluble molecule that occurs in two configurations, cis and trans, or as glucosides, often produced by some plants in response to stress (Aggarwal et al., 2004). Trans-resveratrol is readily absorbed by humans when ingested, but it is rapidly metabolized and eliminated from the body (Walle et al., 2004; Wenzel and Somoza, 2005). It is important to keep in mind that many of the studies touting the benefits of resveratrol have been performed with resveratrol at 10 to 100 times the level observed in human plasma immediately after consumption. Human tissues are exposed primarily to metabolites of resveratrol and not resveratrol itself and very little is known about the metabolic activity of resveratrol metabolites.

While there are claims that resveratrol is a powerful antioxidant, there is not much evidence that resveratrol is an important in vivo antioxidant (Bradamante et al., 2004). Resveratrol may or may not influence estrogen metabolism (Tangkeangsirisin and Serrero, 2005) and may have anti-inflammatory properties (Donnelly et al., 2004; Pinto et al., 1999). Resveratrol may help prevent cancer since it has been shown to increase the transformation of potentially carcinogenic chemicals to excretable forms in cultured cells (Jang et al., 1997; Yang et al., 2003), induce cell cycle arrest in cancer cell culture (Joe et al., 2002), and inhibit proliferation of cancer cells in culture and induce apoptosis in them (Aggarwal et al., 2004). Resveratrol has also been observed to inhibit angiogenesis in vitro (Igura et al., 2001; Lin et al., 2003; Chen and Tseng, 2007). Again, whether or not these observations can be made in vivo remains to be seen, especially considering the fact that resveratrol is quickly metabolized and many human tissues are never likely going to be exposed to resveratrol levels used in many studies.

Resveratrol may reduce cardiovascular risk by reducing vascular cell adhesion (Carluccio et al., 2003; Ferrero et al., 1998), one of the earliest events in atherosclerosis, inhibiting the proliferation of vascular smooth muscle cells (Mnjoyan and Fujise, 2003; Haider et al., 2003), another component of atherosclerosis, by stimulating arterial relaxation (Klinge et al., 2005; Wallerath et al., 2002) and inhibiting platelet aggregation (Kirk et al., 2000; Pace-Asciak et al., 1995). Resveratrol is the component in red wine that many have suggested explain the "French Paradox" of low coronary heart disease despite the consumption of high

levels of saturated fat and extensive cigarette smoking. While some component of red wine or lifestyle associated with red-wine drinkers may account for at least some of the paradox, there is still much work that needs to be done to establish even limited causality.

Some studies with yeast, worms (*C. elegans*), fruit flies (*D. melanogaster*) and fish (*N. furzeri*) have indicated that resveratrol seems to extend the lifespan by a mechanism similar to caloric restriction (Wood et al., 2004; Valenzano et al., 2006).

Resveratrol is found in grapes (skins only), peanuts, blueberries and cranberries (Rimando et al., 2004; Sanders et al., 2000).

PARTICULAR IMPORTANT NUTRITIONAL COMPONENTS FOUND IN GOLDENBERRIES

Antioxidants

The antioxidant properties of goldenberry fruit has been reported by several authors (Restrepo, 2008; Botero, 2008) and some of the medicinal qualities attributed to goldenberry consumption may be associated with the antioxidant capacity of polyphenols in the fruit (Puente, et al., 2011). Results from three different methods for estimating antioxidant activity were reported with an average value of: 202 (µmoltrolox/100 g sample, DPPH free radical scavenger (DPPH method)), 40 mg galic acid / 100 g sample (the concentration of total phenols (Folin–Ciocalteu method)) and 55 mg ascorbic acid / 100 g sample (the Ferric Reducing / Antioxidant Power (FRAP method)).

Minerals

Goldenberries are a good source of phosphorus, iron, potassium and zinc (Rodríguez et al., 2009) and they have an exceptionally high phosphorus content for a fruit (National Research Council (NRC), 1989).

AVERAGE VALUES FOR GOLDENBERRY FRUIT PULP MINERAL CONTENT DERIVED FROM DATA PRESENTED BY NATIONAL RESEARCH COUNCIL (1989), LETERME ET AL. (2006), MUSINGUIZE ET AL. (2007) AND REPO DE CARRASCO & ZELADA (2008).

MINERAL	MG/100 G PULP
SODIUM	**3**
POTASSIUM	**322**
CALCIUM	**17**
MAGNESIUM	**13**
PHOSPHORUS	**39**
IRON	**1**
ZINC	**0.3**

Vitamins

Goldenberries are high in vitamins A, B and C. The main active components of vitamin A in goldenberry fruits are α-carotene, β-carotene and β cryptoxanthin (Fischer, Ebert, & Lüdders, 2000).

AVERAGE VALUES FOR THE VITAMIN CONTENT OF GOLDENBERRY FRUIT PULP DERIVED FROM DATA PRESENTED BY NATIONAL RESEARCH COUNCIL (1989), CORPORACIÓN COLOMBIA INTERNACIONAL (CCI) (1994), FISCHER ET AL., (2000), OSORIO & ROLDAN (2003).

VITAMIN	MG/100 G PULP
BETACAROTENE (VITAMIN A)	**1460**
THIAMINE (VITAMIN B1)	**0.13**
RIBOFLAVIN (VITAMIN B2)	**0.08**
NIACIN (VITAMIN B3)	**1.3**
ASCORBIC ACID (VITAMIN C)	**29.7**

Oils extracted from goldenberry fruits are characterized by high levels of vitamin K1, also called phylloquinone, and vitamin E.

Phytosterols

Phytosterols have many reported effects on human health including anti-inflammatory, antitumor, antibacterial and antifungal effects, however, they are most important for their hypocholesterolemic effect, for both total cholesterol and LDL cholesterol (Valenzuela & Ronco, 2004). Campesterol is the most abundant phytosterol in the oils in goldenberry fruit. Fruit also contains the sterols β-sitosterol and stigmasterol which may be responsible for the fruit's ability to reduce cholesterol levels (Puente, et al., 2011). Other sterols extracted from goldenberry fruit include Δ5-avenasterol, lanosterol, Δ7-avenasterol and ergosterol (Ramadán et al., 2003).

Phytoprostanes

Phytoprostanes (PhytoPs, new active oxylipins) were isolated from goldenberry calyces (Medina et al., 2018) identifying goldenberries as a source for these phytonutrients which have been shown to have a wide range of biological activities including anti-inflammatory activity, apoptosis inducement, immune function regulation, and protection against oxidative stress (Barden et al., 2009; Durand et al., 2011; Gilles et al. 2009; Minghetti et al., 2014).

Physalins

Physalins are pseudo-steroids isolated from *Physalis* species, and are likely the source of the anti-immunoinflamatory responses observed in traditional medicines utilizing these species (Puente et al, 2011). Physalins also show potent anticancer activity (Wu et al., 2004).

Withanolides

Withanolides are steroidal lactones found in many solanaceous plants, particularly in goldenberry (Dinan, et al., 1997). They are known to possess antimicrobial, antiparasitic, antitumor, anti-inflamatory and hepatoprotective properties (Maldonado et al, 2010; Lan et al, 2009). Withanolides also deter insect feeding (Ascher et al, 1980), making goldenberries somewhat pest resistant (Baumann and Meier, 1993). The withanolides phyperunolid A, 4-β hidroxiwithanolid E, withanolid E and withanolid C have been shown to have cytotoxic activity against lung, breast and liver cancer (Lan et al., 2009).

POTENTIAL BENEFITS OF GOLDENBERRIES

As previously mentioned, goldenberries are rich in Vitamins A, B, C, E and K1, high in polyunsaturated fatty acids, phytosterols, withanolides and physalins (Puente et al, 2011). One of the main components of Vitamin A is beta-carotene, which along with Vitamins C and E are powerful antioxidants, helping protect cells from damage by free radicals. Vitamin B is important in cellular energy metabolism. Diets rich in polyunsaturated fatty acids and phytosterols help prevent coronary heart disease, atherosclerosis and hypertension. Goldenberry is rich in oil for a fruit (2% by weight) with linoleic the predominant (73%) polyunsaturated fatty acid (Rodrigues et al, 2009). Goldenberries are also a rich source of iron, K and Mg. Goldenberries have one of the highest levels of vitamin K (40 mcg/100g) of any commercially available fruit.

The scientific literature contains numerous reports of goldenberry nutraceutical benefits. The following section highlights a few specific documented effects of goldenberry consumption on biological activity in both humans and test animals. It is by no means complete, but rather, an introduction to the many possible health benefits obtained from the consumption of this novel fruit.

Anti-diabetic

Diabetes is characterized by postprandial hyperglycemia and is an ever increasing health threat worldwide. In patients consuming five goldenberries 40 minutes before eating, blood sugar at 90 and 120 minutes after a meal was significantly reduced (Rodriguez and Rodriguez, 2007) likely due to effects of one or more of the many bioactive compounds found in goldenberry. Sucrose esters (peruvioses) found in the sticky exudate of the fruit appear to act as a-amylase inhibitors which helps explain the hypoglycemic effect traditionally attributed to goldenberry consumption (Bernal et al., 2018).

Many anti-diabetic properties have been observed in studies with lab animals (Kasali, et al., 2013; Hassan and Ghoneim, 2013). Hyperglycemia associated with diabetes mellitus is often induced in lab animals using various toxins such as alloxan and streptozotocin. Both toxins kill pancreatic beta cells, thus reduce the ability of the pancreas to produce insulin in sufficient quantities.

Ethanolic extracts of P peruviana fruit exhibit several modes of anti-diabetic activity: (1) they increase insulin sensitivity in streptozotocin-induced type 2 diabetic rats (Sathyadevi et al., 2014), (2) they contain potent aldose reductase inhibitors (Sathyadevi et al., 2014; Sathyadevi and Subramanian, 2014; Rey et al., 2015) and they reduce oxidate stress in pancreatic beta cells (Sathyadevi and Subramanian, 2015). A dry powder formulation from standardized extracts of the fruit also exhibits hypoglycemic activities (Bernal et al., 2016).

Extracts of fruit from *Physalis angulata*, a relative of goldenberry, exhibit significant anti-diabetic properties when fed to alloxan-induced diabetic rats (Raju and Mamidala, 2015; Sanchooli, 2011; Sulistyowati et al., 2014). A specific compound (Withangulatin-A) appears to be responsible for freeing bound insulin or stimulating production of insulin by beta cells similar to that observed when the drug glibenclamide is used to combat diabetes (Raju and Mamidala, 2015). Similar anti-diabetic properties have been reported for *Physalis pubescens* (Hassan and Ghoneim, 2013), however, the material used for treatment (i.e. fruit, leaves, husk, extract) was not reported. Chromium has been shown to increase the anti-diabetic activity of Physalis powders or extracts (El-Mehiry, et al., 2012).

A methanolic extract from the leaves of another goldenberry relative *Physalis minima*, exhibited significant in vitro α-amylase and α-glucosidase inhibitory activities and glucose uptake by yeast cells (Karpagasundari and Kulothungan, 2015).

Anti-inflammatory

Two potent compounds, 4β-hydroxywithanolide E and physalactone extracted from goldenberry greatly reduces markers associated with inflammation (Park et al., 2019). Peruvioses A and B, found as sucrose esters in trichomes of goldenberry calyces, also contribute important anti-inflamatory and immunomodulatory effects with no known side effects (Ocampo et al., 2017). Phytoprostanes (PhytoPs, new active oxylipins) were isolated from goldenberry calyces (Medina et al., 2018) identifying goldenberries as a source for these phytonutrients which have been shown to have anti-inflammatory activity. Sustained inflammation is often a factor in the development of chronic conditions such as asthma, atherosclerosis, cancer, cardiovascular diseases, inflammatory bowel diseases, mood disorders, neurological disorders and periodontal disease. Thus these compounds in goldenberry may help to reduce inflammation and associated disorders.

Goldenberry fruit juice has high antioxidant activity associated with high levels of polyphenols and vitamins A and C (Rop et al., 2012; Rockenbach et al., 2008; Wu et al., 2005; Bravo, 2010). These compounds may also prevent peroxidative damage to liver microsomes and hepatocytes (Wang et al., 1999).

Skin Health

Sucrose esters extracted from the calyces of goldenberry improved production of collagen I, elastin and fibrillin-1 in aged normal human dermal fibroblast cells (Cicchetti et al., 2018). This suggests that extracts from goldenberry calyces may be useful as an ingredient in skin care products. Moreover, the extracts are derived from plant parts normally discarded after harvest and fruit preparation for consumption.

Anti-cancer

An ethanolic extract of goldenberry fruit inhibited both colon and breast cancer cell growth in an in-vitro study (Ramadana et al., 2015). Ethanolic leaf and stem extracts inhibited tumor cell growth rate (Zavala et al. (2006) and goldenberry extracts reduced lung and breast cancer cell proliferation (Higgins, et al., 2015). Withanolide E and 4-hydroxywithanolide E seem to have anticancer properties (Cassady and Suffness, 1980).

Antiseptic

Extracts from seeds of goldenberry exhibited potent antimicrobial activity against a number of bacteria when compared to ampicillin in lab evaluations (Erturk et al., 2017). Extracts from all plant parts exhibited varying degrees of antiseptic activity against a wide range of organisms (*Staphylococcus aureus* ATCC 25923, *Bacillus cereus* ATCC 11778, *Escherichia coli* ATCC 25922, *Klebsiella pneumonia*, *Salmonella typhi* ATCC 700931, *Pseudomonas aeroginosa* ATCC 27853, *Candida albicans* ATCC 90028 and *Aspergillus flavus*) (Kamau, et al., 2017).

General

Besides the specific examples highlighted above, goldenberries have long been utilized in folk medicine for strengthening the optic nerve, clearing cataracts, eliminating intestinal parasites and amoeba, purifying the blood, an antipyretic, antispasmodic, diuretic, sedative, analgesic and for treating diseases such as asthma, hepatitis, malaria, dermatitis, throat affections, and rheumatism (Wu et al., 2005). Goldenberry also has anti-ulcer activity as well as cholesterol lowering properties (Arun and Asha, 2007; Ramadan, 2011).

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