WESTVILLE

Horticulture to Horti-Business

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HUMAN HEALTH AND NUTRITION
Functional Foods

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1. INTRODUCTION

In today's world consumer and producer alike have become highly conscious about the health benefits of food leading to value added products as the opportunity in health sector through agriculture. This phenomenon has led to the coining of the term "*Functional Food*" that encompasses all edible items having a health-promoting and/or disease-preventing property beyond the primary function of providing nutrients. Although, lately it has become possible to identify functional foods as a well-defined group of food products, in reality, the term implies a concept denoting increasing health awareness in dietary habits. On the other hand, a "*Nutraceutical*" is a product isolated/purified from foods and is normally sold in medicinal forms that are not usually associated with food. It has demonstrable physiological benefit/ provides protection against chronic disease. The concept of mutually inclusive diet and health dates back to Hippocrates (400 BC) who coined the phrase "*Let food be thy medicine and medicine be thy food*". The major driving forces for moving functional foods into the corporate mainstream are continuously increasing health care costs, an expanding aging population arising out of increased life expectancy, rising consumer awareness about health aspects of foods and food regulations and above all an increased level of education and literacy.

2. NEED FOR FUNCTIONAL FOODS

In the knowledge-driven economies, nutrition concepts are known to evolve with agricultural advances. The cereal crops provide essential food nutrients like carbohydrates, lipids, minerals, proteins and vitamins in a direct or indirect fashion. Since the level and constitution of nutrients varies significantly in different food crops, many plant foods are deficient in certain nutrient components and malnutrition related to deficiency of micronutrients like vitamin A, iron and zinc, affects >40% of the global population.. Thus relying on single or limited crops for one's nutritional requirements may prove risky. Herein, comes the role of functional foods and biotechnology (particularly when the necessary genetic variability is not available) to achieve a balanced diet. Although initial emphasis of agricultural biotechnology was on input traits of crops like herbicide tolerance and pathogen resistance, recent efforts have led to encouraging proof-of-concept products in output traits of crops like enhancement in their nutritional quality.

It is noteworthy that most functional foods are of plant origin. Strong evidence from epidemiological, *in vivo*, *in vitro*, and clinical studies indicates that a plant-based diet reduces the risk of chronic diseases, particularly cancer. Nutritionists have now accepted the role of phytochemicals in human health maintenance as well as improvement.

3. HORTICULTURE CROPS AS THE MAINSTAY OF FUNCTIONAL FOODS

Horticulture crops including vegetables and fruits are among the best examples of edible items having functional food properties or a potential to develop such properties. The paradigm shift is need of the day to change our perception of horticultural crops and products only as food, pulps and juices in various forms. The chemistry of horticultural crops including edible and non-edible plant biomass is indicative that these plant species while continuing to provide food base, their metabolome has all capabilities to compete with conventional medicinal plants constituents (Pengelly, 2004) for preventive health care. Here we present a snapshot of some horticulture crops that have prominent functional food/nutraceutical value.

3.1 Botanical Berries

Botanically, a berry is a fleshy fruit produced from a single ovary and plants that bear berries are called bacciferous. It is the most common type of fleshy fruit having the complete ovary wall ripened into an edible pericarp. Berries which develop from an inferior ovary are sometimes termed epigynous berries or false berries, as opposed to true berries which develop from a superior ovary. In so-called epigynous berries, the berry includes tissue derived from parts of the flower besides the ovary. Common fruits that are sometimes classified as epigynous berries include bananas, members of the genus *Vaccinium* like cranberries and blueberries, and members of the cucurbitaceae like cucumbers, melons and squash (http://en.wikipedia.org/wiki/Berry). Therefore the berries represent a huge diversity and great potential to be used in or as functional food. Some case examples are cited as follows:

3.1.1 Grape (Vitis vinifera)

It is a non-climacteric fruit and eaten raw or used to prepare wine, juice, jam, jelly, raisins, grape seed oil, etc. Around 71% of global grape crop goes into wine production, 27% is consumed raw fresh fruit and 2% as dried fruit. This fruit is associated with the *French Paradox*, whereby it is commonly believed that despite consuming higher levels of animal fat the French encounter lower risk of cardiac disease due to the protective effect of regular consumption of red wine. The skin of red grape contains resveratrol, which is a phytoalexin. Chemically it is a stilbenol (3,4',5-trihydroxystilbene) and exists in isomeric (*cis* and *trans*) forms of which the *trans* form is biologically active. *Trans*-resveratrol has been shown to possess anti-aging/longevity-conferring property. Besides, anthocyanins are the major polyphenolics in purple grapes and flavan-3-ols (like catechins) are the major phenolic in white grapes. Flavonols such as, syringetin, syringetin 3-*O*-galactoside, laricitrin and laricitrin 3-*O*-galactoside are present in purple grape but not in white grape. Grape seed oil is used in skincare products for its potential health promotion. It possesses high contents of tocopherols (vitamin E), phytosterols, and polyunsaturated fatty acids (like linoleic acid, oleic acid and alpha-linolenic acid). Recently, a metabolomics approach has been used to analyze the wine chemoprofiles (responsible for their organoleptic properties) arising out of complex interplay between G X E effects, viticultural and ageing (oak barrel used) processes (Gougeon *et al*, 2009). This approach has potential use for quality control of wines and other beverages.

3.1.2 Banana (Musa spp.)

It is a staple starch diet for several tropical populations and is available in diverse sizes and colors (yellow, purple, and red) when ripe. It mitigates the risk of colorectal cancer, breast cancer and renal cell carcinoma. It contains significant amounts of vitamin B6, vitamin C, and potassium (helps user athletes to quickly replenish electrolytes). The juice (honey may also be added) of the corm is used as a remedy for jaundice and kidney stones.

3.1.3 Tomato (Solanum lycopersicum)

Globally, tomato is one of the most important vegetable crops, and its fresh fruits as well as processed products are equally popular in every society. It is known primarily for its carotenoid pigment lycopene, which is one of the most powerful natural antioxidants. Although it is not an essential ingredient of human diet, it is believed to prevent prostate cancer and enhance the skin's ability to protect against harmful UV rays. Structurally, lycopene is a tetraterpene assembled from eight isoprene units. Its deep red color (useful for food coloring) and antioxidant property is attributed to its conjugated double bonds. It is an intermediate in the biosynthesis of β-carotene. Tomato processing/cooking enhances the bioavailability of lycopene. Since lycopene is fat soluble, the oil content in the diet helps its absorption. Although gac (*Momordica cochinchinensis*) or spiny bitter cucumber has around 70 fold higher content of lycopene (and also the highest content of â-carotene, which is also highly bioavailable) compared to tomato, its availability is restricted to southeast Asia. *Blakeslea trispora*, a fungal plant pathogen, is another source of commercial lycopene and â-carotene for dietary supplements and food additives. Tomato is not usually reported to contain anthocyanins that are the most common class of purple, blue and red plant pigments and belong to the flavonoid (synthesized via the phenylpropanoid pathway) category of secondary metabolites. Anthocyanins have received major focus of nutraceutical research because of their strong antioxidant activity as measured by the oxygen radical absorbing capacity (ORAC). However, conventional plant breeding has been carried out for high anthocyanin content in tomato by crossing wild relatives with the common tomato to transfer a gene called the anthocyanin fruit (*Aft*) gene into a larger and more palatable fruit (Jones *et al.*, 2003). Tomatoes have also been genetically engineered using transcription factors from snapdragon to produce high levels of anthocyanins in the fruits that is comparable to the anthocyanin levels found in blackberries and blueberries (Butelli *et al*, 2008). Flavonol biosynthesis in tomato has also been upregulated (to levels comparable with onion, a crop with naturally high flavonol levels) using the petunia chalcone isomerase gene (Muir *et al*, 2001). Several tomato varieties are now available that have higher-than-usual content of dietary nutrients like vitamin C, vitamin A, anthocyanin, lycopene, etc.

3.1.4 Watermelon (Citrullus lanatus)

It contains about 6% sugar and 92% water by weight. It is a source of vitamin C and also contains large amount of amino acid citrulline, lycopene and beta-carotene. The fruit is used as a febrifuge and is also diuretic, being effective in the treatment of dropsy and renal stones. The seed is demulcent, diuretic, pectoral, tonic, used for treating bed wetting and as a vermifuge. Gene expression has been studied in developing watermelon fruit in order to elucidate the flow of events associated with fruit development and ripening (Wechter *et al*, 2008).

3.2 Other Fruits

3.2.1 Aonla/Indian gooseberry (Phyllanthus emblica)

It has a small subtropical fruit and grows widely in the low mountain areas of North India. Since the fruit is acrid, cooling, diuretic and laxative, it is used for treating chronic dysentery, bronchitis, diabetes, fever, diarrhoea, jaundice, dyspepsia, cough, etc. Besides, it is highly nutritive being one of the richest sources of ascorbic acid (500–1500 mg of ascorbic acid per 100g fruit pulp). The gallic acid present in the fruit has antioxidant properties. The fresh fruits are not consumed due to high astringency but its processed forms are highly appreciated, providing an opportunity for preparation of value-added products (like amla candy, jam, sauce, etc).

3.2.2 Avocado (Persea americana)

This tree, which is native to Mexico, South America, Carribeans and Central America, bears a commercially valuable fruit. Fruits of horticultural cultivars have significantly higher fat content compared to most other fruits. Major constituent is mono-unsaturated fat, which makes it an important staple in the diet of communities which have limited access to other fatty foods (meats, dairy products, etc). Besides, the avocado fruit contains higher potassium content (around 60% higher) than bananas and is also rich in vitamins. High fiber content in the fruit (including 75% insoluble and 25% soluble fiber) is another desirable feature. Avocadene (16-heptadecene-1,2,4-triol), which is found in the fruit, is a fatty triol (fatty alcohol) having one double bond. Avocado-rich diet has been shown to have a beneficial effect on blood serum cholesterol levels.

3.2.3 Bael (Aegle marmelos)

It is a tree native to India and its juice is widely consumed in the form of a sweetened drink in the summers. In Ayurveda it has been described to pacify the kapha and vata doshas and as a cure for diarrhea, dysentery, intestinal parasites, dryness of eyes, cold and as an antidote for chronic constipation. It is a blood purifier and used to cure sinusitis, dyspepsia and anorexia. A confection ("iLakam" in Tamil) made of this fruit is used to cure tuberculosis, loss of appetite, emaciation etc. Chemoprofiling of the plant has shown that varied classes of compound like alkaloids, coumarins, terpenoids, fatty acids and aminoacids are present in its different parts. A major constituent of the fruit is the mucilage and marmelosin (0.5%), which is a coumarin having anthelmintic property.

3.2.4 Citrus fruits

Plants belonging to the genus Citrus like orange (*Citrus sinensis*), lemon (*Citrus limon*), etc are rich source of vitamin C (required to prevent scurvy), folate, limonoids and fiber. Limonoids belong to the tetranortriterpenes class of phytomolecules. They are presently under investigation for several therapeutic properties like antifungal, antibacterial, antiviral, antineoplastic and antimalarial.

3.2.5 Cranberry (Vaccinium spp.*)*

They are evergreen dwarf shrubs. Around 95% of the fruit produced is used for processing into juice drinks, sauce and sweetened dried form. The fruit has moderate amount of vitamin C, dietary fiber, manganese alongwith a balanced profile of other essential micronutrients. Its ORAC score is 9,584 units per 100g putting it near the top of the food chart for antioxidant activity. The fruit is a source of polyphenol antioxidants beneficial to the heart, immune system and also in cancer prevention. Its juice contains high molecular weight non-dializable material (NDM) that inhibits and often reverses plaque formation by *Streptococcus mutans* that causes tooth decay. The juice is also prevents formation of kidney stones.

3.2.6 Pomegranate (Punica granatum)

It is mainly native to central Asia and India. Pomegranate aril (seed casing) juice is capable of providing ~ 16% of an adult's daily vitamin C requirement per 100 ml of serving. It is also a rich source of vitamin B5 (pantothenic acid), potassium and antioxidant polyphenols. Its seeds are a good source of fibre and unsaturated oils. The most abundant polyphenols in the juice are the hydrolyzable tannins known as ellagitannins that are formed when ellagic acid binds to a carbohydrate. Punicalagins are specific pomegranate tannins that confer it with its antioxidant (free-radical scavenging) and health-promoting properties. During metabolism in the intestines mediated by bacteria, ellagitannins and punicalagins get converted into urolithins, whose biological activity is not known *in vivo*. Polyphenolic catechins, gallocatechins, as well as anthocyanins, like prodelphinidins, delphinidin, cyanidin, and pelargonidin are also phytoconstituents of pomegranate.

3.3 Other Vegetables

3.3.1 Broccoli var. Italica (Brassica oleracea)

It is high in vitamins and dietary fiber. It also contains multiple nutrients with potent anti-cancer properties, such as diindolylmethane (DIM) and minor amounts of selenium. DIM is also a potent modulator of the innate immune response system and possesses anti-viral and anti-bacterial properties. Broccoli also contains glucoraphanin that can be converted into an anticancer compound sulforaphane. It is also a rich source of lutein, beta-carotene and indole-3-carbinol, which enhances DNA repair in cells and blocks cancer cell growth. Regular consumption of broccoli reduces the risk of prostate cancer and heart disease.

3.3.2 Capsicum/Chilli (Capsicum annuum)

There is a variety of cultivars within the same species. Capsaicin and several related compounds (collectively called capsaicinoids) are produced by chili peppers, probably as deterrents against pathogens and herbivores. Upon ingestion, capsaicin produces a burning sensation. It is a potential inhibitor of cholera toxin production in *Vibrio cholerae* (Chatterjee *et al.,* 2010). Capsaicin containing creams reduce itching and inflammation and are thus used for treatment of psoriasis. It is also used in topical ointments and high-dose dermal patches to relieve the pain of peripheral neuropathy (for example post-herpetic neuralgia caused by shingles). It is also beneficial in treatment of ear infections like otitis.

3.3.3 Carrot (Daucus carota)

It is a root vegetable and gets its characteristic bright orange colour from â-carotene, which is metabolised into vitamin A in humans when bile salts are present in the intestines. It is also rich in dietary fibre, antioxidants and minerals. Besides, it is a good *companion plant* for horticulturists. If intercropped with tomatoes it increases tomato productivity and if it is allowed to flower in the field it attracts predatory wasps that prey upon several harmful pests. Its ethnopharmacological use in treatment of digestive problems, intestinal parasites, tonsillitis and constipation is popular. It absorbs odours from apples and pears. Cooked carrots have a *Glycemic Index* (GI, scale used in diabetes treatment for measuring the rate at which blood sugar levels rise upon ingesting a particular carbohydrate bearing food) value of 49. Lower GI (below 50) foods are more complex and hence digested more slowly, ensuring a longer feeling of satiety, longer term energy maintenance and keeping blood sugar levels constant.

3.3.4 Garlic (Allium sativum)

It is grown globally but China is the major producer. The typical flavor and pungency of garlic is due to high levels of oil-and water-soluble, sulfur-containing compounds that are also supposed to be responsible for its various medicinal attributes. The intact garlic bulb contains an odorless sulfoxide alliin, which is a derivative of cysteine. When garlic is chopped, the enzyme alliinase converts alliin to allicin, which is responsible for the specific garlic aroma. Allicin spontaneously decomposes to form numerous sulfur-containing compounds. Diallyl sulfide is also one of the odour components of garlic. Garlic is used as a home remedy for strep throat. It is also claimed to prevent heart disease (like atherosclerosis) and cancer.

3.3.5 Ginger (Zingiber officinale)

The rhizome of the plant is known as ginger. The fresh tuber contains an active phytomolecule, gingerol, which is responsible for its hot, pungent taste, as well as its stimulating and healing properties. Gingerol gives rise to shogaols and zingerone upon cooking. Gingerol reduces nausea caused by motion sickness or pregnancy and also relieves migraine. Ginger also contains upto three percent of an essential oil, which mainly contains sesquiterpenoids, with (-)-zingiberene being the major constituent. Ginger is mostly used as a therapeutic spice, working on the digestive system (by enhancing digestive enzyme secretion) and it also has a sialagogue action, stimulating the production of saliva, which facilitates swallowing of food.

3.4. Misc Crops

3.4.1 Tea (Camellia sinensis)

Apart from water, tea is the maximally consumed beverage in the world. Up to 30% of the total dry weight of fresh tea leaves is made up by polyphenols among which, catechins are the most predominant and significant. Epigallocatechin-3-gallate, epigallocatechin, epicatechin-3-gallate and epicatechin are the four major green tea catechins. Although not conclusively proved in humans, tea consumption has possible beneficial effects in the prevention of cancer and cardiovascular diseases. Large intake of tea causes problems due to its caffeine content.

3.4.2 Vanilla (Vanilla planifolia)

It is an species of vanilla orchid and used for extraction of vanillin for flavoring of icecreams, bakery products, etc. Green vanilla contains glycosides, glucovanillin (vanilloside) and glucovanillic alcohol. In the process of curing they are acted upon by an oxidising and hydrolising enzyme that is present throughout the plant. Glucose and vanillic alcohol are the hydrolysis products of glucovanillic alcohol. Vanillic alcohol is further oxidized to vanillic aldehyde (vanillin). A cDNA encoding a multifunctional methyltransferase that can catalyze the conversion of 3,4-dihydroxybenzaldehyde to vanillin has been isolated and functionally characterized from *V. planifolia* tissue cultures (Pak *et al.*, 2004).

3.5 Comparable Value of Other Functional Foods of Plant Origin

3.5.1 Oat (Avena sativa)

It is a species of cereal grain grown for its seeds. It is considered to be a health food. Consumption of its bran is known to reduce the risk of coronary heart disease. It contains more soluble fiber than any other grain, which results in gradual digestion with a prolonged sensation of satiation. The soluble fiber in whole oats comprises of polysaccharides known as beta-*D*-glucan that is reported to have cholesterol-lowering property. The characteristic of oat beta-*D*-glucan is that unlike other non-soluble and non-digestible beta-glucans (like cellulose) it is is composed of mixed-linkage polysaccharides (bonds between the D-glucose units are either beta-1, 3 linkages or beta-1, 4 linkages). Oat is the only cereal containing a globulin or legume-like protein, avenalin, which forms a major portion (80%) of the storage protein. Avenin is the minor component of oat proteins. Oat protein is comparable in quality to soy protein that is considered to be equivalent to meat, milk, and egg protein.

3.5.2 Soy (Glycine max)

It is a legume species native to East Asia. However, it is considered more of an oilseed rather than a pulse. It provides high quality complete protein (rich in most essential amino acids) that is considered to prevent occurrence of cardiovascular disease, cancer, osteoporosis, and alleviate menopausal symptoms. The seed contains 40% protein 20% oil, 35% carbohydrate and about 5% ash. Soybeans must be cooked with 'wet' heat in order to destroy the trypsin inhibitors (serine protease inhibitors) for human consumption. Genetically modified 'Roundup Ready' (RR) soybean was introduced by Monsanto in 1995 for an input trait of resistance to the herbicide Roundup (that mainly comprises of glyphosate). Soybean oil is one of the few common vegetable oils that contain a significant amount of the omega-3 fatty acid, alpha-linolenic acid (ALA). It also contains large amount of omega-6 fatty acids (omega-3:omega-6 ratio is 1:7). Soy also contains high level of phytic acid as well as the isoflavones, genistein and daidzein that probably possess phytoestrogen activity.

3.5.3 Flax (Linum usitatissimum)

It is native to the region between the Mediterranean and India. The seeds of the plant are normally brown or golden in color. Flaxseed oil contains high amount (57%) of the omega-3 fatty acid, ALA, among all seed oils. The omega-3:omega-6 ratio is 3:1 in flaxseed oil. Besides, its seeds contain high levels of dietary fiber (including lignans) and micronutrients. The dietary fiber (present in flaxseed mucilage) makes it useful as a laxative. The two major mammalian lignans, enterodiol and its oxidation product, enterolactone, are formed in the human intestine by bacterial action on plant lignan precursors (that are abundant in flax). The seeds are found to lower cholesterol levels, mainly in women.

3.5.4 Chia (Salvia hispanica)

It is a flowering plant species of the mint family, Lamiaceae. It is mainly grown for its seeds (providing 25-30% extractable oil) that are rich in the omega-3 fatty acid, ALA. The concentration of omega-3 fatty acid in chia seed oil is very high (~64%). Apart from ALA it also contains 20% protein, 25% dietary fibres (both soluble and insoluble) and significant levels of antioxidants.

3.5.5 Evening Primrose (Oenothera biennis)

It is a biennial flowering plant containing high levels of (~ 7-10%) gamma-linolenic acid (GLA), a rare essential fatty acid, in its mature seeds. GLA is useful in suppressing inflammation, treating diabetic neuropathy, atopic eczema, as well as certain cancers like malignant human brain glioma. *O. biennis* seed oil is used to relieve the pain of premenstrual stress syndrome and is also beneficial to the face skin.

4. FRUIT AND VEGETABLE TISSUES AS SOURCE OR MATRICES FOR IMPREGNATION OF FUNCTIONAL INGREDIENTS

Fruit and vegetable matrices enriched with probiotics and minerals (like calcium and zinc) have been developed as novel functional food. Vacuum and/or atmospheric impregnation methods have provided feasible technologies for exploitations of fruit and vegetable tissues as new matrices into which functional ingredients can be successfully incorporated, providing novel functional product categories and new commercial opportunities (Alzamora *et al*, 2005). Some case examples have been listed to provide the base for strategic research that may be envisaged for future functional food products from horticultural sources overcoming the bottlenecks that emerge in such cases (Table 1). This is a list that sets the direction and not an exhaustive status of all plants in the domain of horticulture.

5. ANALOGY-DRIVEN SCIENCE: FUNCTIONAL SYNTENY IN HORTICULTURAL PLANTS

Knowledge about the regulation of the flavonoid pathway is significant for maximally enhancing the nutritional value of horticulture crops and possibly enhancing their resistance towards pathogens. *Petunia hybrida* has emerged as the model of choice to study volatile benzenoid and phenylpropanoid biosynthesis, emission and regulation. The information obtained from

Table 1. Case examples of some potent functional ingredients from horticultural plant sources and R&D challenge for product development

Functional Ingredient	*Plant Source(s)*	*Nutritional Potential/Use*	*R & D Challenge/Scope*
Sulforaphane	Broccoli	Stimulant for enzymes that detoxify chemical carcinogens.	The trait has been selectively bred out of commercial broccoli because of its bitter taste.
Dietary fibres	Avocado, Oat, Flax, Chia, Whole grains, Cranberry,	Essential dietary ingredient but average consumption is only 14-15g daily against the RDI of 38 grams.	Fiber content needs to be enhanced in food items for optimum fiber diet that can be RDI equivalent.
Omega-3 fatty acids	Chia, Flax, Soy	Docosahexaenoic acid (DHA) and Eicosapentaenoic acid (EPA) are made by seawater microalgae, which in turn is consumed by fish that accumulate these fatty acids. Therefore source is mainly fish or rarely microalgae but not plants	Plant sources normally contain only alpha linolenic acid (ALA) and lack the more healthful DHA and EPA. Strategic breeding and biotech interventions are required so that DHA and EPA, can be produced directly from microalgae or designer plants.
Peptides	Wheat germ, Spinach	Certain food-derived peptides lower blood pressure by inhibiting angiotensin-converting enzyme (ACE).	Most horticulture sources are not even explored for such peptides.
Calcium fortified food	Soybean, Peanuts, Pea etc	Soy milk fortified with calcium is the option for people suffering from milk allergy due to lactose intolerance.	Taste acceptability demands improvement. Similarly bioavailability of calcium (vis-à-vis cow milk) and need of alternate sources can be visualized.
Vitamins and minerals	Most fruits and vegetables	Nutritional deficiencies arising out of geographical and regional variation in horticulture crop production patterns can be managed through functional foods.	Identification of synergistic interactions that enhance accessibility, bioavailability and biological potency is desirable.
β-Carotene	Carrot, Moringa, GM rice	Golden Rice developed by transforming rice with three genes: phytoene synthase (*psy*) and lycopene cyclase (*lyc*) from daffodil (*Narcissus pseudonarcissus*) and *crt1* from the soil bacterium *Erwinia uredovora*. In Golden Rice 2, *psy* gene from maize was used with *crt1* from the original golden rice to get a higher carotenoid content.	Technology could not be commercialized effectively beyond proof-of-concept stage due to large dietary requirements of the fortified rice.Sources like Moringa offer non-GM sources that are edible and cultivable both and have no sfety risks or toxicity.
Probiotics	Jerusalem artichoke, jicama chicory root, soybean, onion, garlic, raw oats, unrefined wheat, unrefined barley and yacon	Non-digestible food components (oligofructose and inulin) stimulating the growth and / or activity of bacteria in the digestive system, which in turn benefit body health.	Some people suffer from fructose malabsorption, excess dietary intake of inulin (a fructan) may lead to minor side effects, like increased flatulence and loose stools. Better formulation required to overcome this.

this system is being applied to alter tomato fruit volatile production and thereby taste. As an example, the flavonoid 3'5'-hydroxylase (F3'5'H) enzyme has been found to function at an important branch point between flavonol and anthocyanin biosynthesis, through studies in petunia (*Petunia hybrida*) and potato (*Solanum tuberosum*). This information led to the identification and characterization of a F3'5'H gene from tomato (Olsen *et al.,* 2010). Thus, from a biotechnological perspective, not many horticulture crops have been taken up for extensive research as evident from the current status of entries (Entrez records) in the NCBI database (Table 2; accessed on 7th October 2010). This status indicate all the potential that these crops offer in gene and molecule bioprospection for designer genotypes and chemotypes for future health crops.

Table 2. Current status of Entrez records for major horticulture and functional food crops in the NCBI database (accessed on 7th October 2010).

Botanical Name (Common Name)	*Nucleotide*	*Nucleotide EST*	*Nucleotide GSS*	*Protein*	*Genome Sequences*	*Genome Projects*
Aegle marmelos (Bael)	16	6	-	6	-	-
Allium cepa (Onion)	516	20,159	10,725	300	-	1
Allium sativum (Garlic)	210	42	287	183	-	-
Annona squamosa (Custard apple)	8	-	-	3	-	-
Arctous alpina (Bearberry)	4	-	-	1	-	-
Artocarpus altilis (Breadfruit)	15	-	-	6	-	-
Avena sativa (Oat)	482	25,344	2,671	282	-	1
Brassica napus var. napus (Canola)	72	63	57	31	-	-
Brassica oleracea var. Italica (Broccoli)	104	2,285	-	71	-	-
Ananas comosus (Pineapple)	259	5,659	-	148	-	-
Camellia sinensis (Black tea)	813	12,727	1	481	-	1
Carica papaya (Papaya)	3,746	77,393	44,297	574	2	1
Capsicum annuum (Capsicum/chilli)	1,637	118,060	13	1,288	-	1
Capsicum frutescens (Bird pepper)	114	33	24	54	-	-
Carissa carandas (Karonda)	3	-	-	-	-	-
Citrullus lanatus (Watermelon)	349	8,584	-	252	1	1
Citrus limon (Lemon)	131	1,505	-	79	-	-
Citrus sinensis (Sweet orange)	699	210,535	-	663	1	2
Cucumis sativus (Cucumber)	1,791	8,128	65,624	1,318	1	1
Daucus carota (Carrot)	3,839	93	-	1,182	1	1
Foeniculum vulgare (Fennel)	33	-	-	14	-	-
Fragaria ananassa (Strawberry)	1,219	10,831	15	820	-	-
Glycyrrhiza glabra (Yashtimadhu / Mulethi)	43	-	-	29	-	-
Glycine max (Soybean)	51,753	1,461,336	368,555	35,143	1	1
Laurus nobilis (Bay laurel)	202	-	-	113	-	-
Linum usitatissimum (Flax)	4,744	12,574	2	1,832	-	-
Litchi chinensis (Litchi)	266	-	-	48	-	-
Malus domestica (Apple)	2,687	324,512	35	2,242	-	1
Mangifera indica (Mango)	406	116	-	157	-	-
Mentha spicata (Spearmint)	101	-	-	16	-	-
Mentha arvensis (Wild mint)	23	81	-	4	-	-
Mentha piperita (Peppermint)	171	1,316	-	87	-	-

(Contd.)

Botanical Name (Common Name)	*Nucleotide*	*Nucleotide EST*	*Nucleotide GSS*	*Protein*	*Genome Sequences*	*Genome Projects*
Momordica charantia (Bitter gourd)	159	-	-	147	-	-
Musa spp. (Banana)	4,594	31,314	7,186	2,796	-	1
Moringa oleifera (Drumstick)	38	-	-	15	-	-
Ocimum spp. (Tulsi / Basil)	101	23,260	-	84	-	-
Oenothera biennis (Evening Primrose)	39	-	-	232	1	1
Panax ginseng (Ginseng)	420	7,186	2,789	499	1	1
Persea americana (Avocado)	494	16,558	-	449	-	2
Phyllanthus emblica (Amla / Indian Gooseberry)	28	-	1	10	-	-
Psidium guajava (Guava)	57	-	22	9	-	-
Punica granatum (Pomegranate)	250	-	-	31	-	-
Salvia hispanica (Chia)	1	-	-	1	-	-
Sambucus spp. (Elderberry)	195	-	-	138	-	-
Solanum lycopersicum (Tomato)	26,979	298,229	413,448	5,832	1	1
Stevia rebaudiana (Stevia / Sweetleaf)	134	5,548	-	97	-	-
Syzygium cumini (Jamun / Java plum)	12	-	-	93	-	-
Trachyspermum ammi (Ajwain)	5	-	-	1	-	-
Trigonella foenum-graecum (Fenugreek)	45	-	-	20	-	-
Vaccinium spp. (Cranberry)	611	5,267	-	138	-	-
Vanilla planifolia (Vanilla)	70	31	-	41	-	-
Vitis vinifera (Grape)	99,077	362,196	229,272	76,208	22	1
Withania somnifera (Ashwagandha)	93	88	-	67	-	-
Zingiber officinale (Ginger)	161	38,115	-	50	-	-
Ziziphus mauritiana (Ber / Indian plum)	12	-	-	2	-	-

6. METABOLOMICS: THE STRATEGIC TOOLKIT FOR BIO-HORTICULTURE, THE FUTURE WAY

In recent years, metabolomics has facilitated and widened the horizons of the research on horticulture crops. Research on tomato volatiles presents the best example of the power of metabolomics-based research. Many tomato fruit volatile compounds have been described in literature (Petro-Turza 1987) but only a fraction of these may be actually affecting the organoleptic properties of the tomato fruit. Variation in the volatile metabolome of red-ripe tomato fruits has been studied in a collection of 94 tomato cultivars (representing the available diversity within commercial germplasm) and the cultivars could be divided into two groups – emitters and non-emitters, on the basis of emission of three phenylpropanoid volatiles (methyl salicylate, guaiacol and eugenol) upon fruit tissue disruption (Tikunov *et al.*, 2005). Recently, a metabolic data fusion approach has been used to show that differential glycoconjugation plays a role in the emission of phenylpropanoid volatiles from ripening tomato fruit upon fruit tissue disruption (Tikunov *et al.*, 2010). The significance of such findings on volatile emission lies in their potential application to horticulture engineering for favorable consumer perception of fruit taste differences. Conjugated metabolic and phenotypic analysis of tomato introgression lines has provided chemical markers of fruit quality through *metabolic genomics* (Giovannoni, 2006). As evident from the tomato example, for horticulture crops, the integrated systems approach or metabolic genomics offers a better route for gaining novel insights into associations between fruit chemistry and quality traits. In a related manner, phenotypic and fine genetic characterization of the D locus controlling fruit acidity has been carried out in peach (*Prunus persica*) (Boudehri *et al.*, 2009).

The emergence of novel network-wide analysis tools has shown that the textbook view of regulation of plant metabolism is often incomplete. The metabolome of plants is case example of evolving secondary metabolome and metabolic pathway diversity (Khanuja *et al.*, 2010). These tools for small-molecule analysis aided by software innovations have enabled identification and quantification of numerous phytomolecules and the generated metabolomics data provides novel opportunities for comprehending plant metabolism (Last *et al.*, 2007). Transcriptome and metabolome analyses have been carried out with tomato microarrays and analytical methods (including proton nuclear magnetic resonance and liquid chromatography-mass spectrometry), respectively for analyzing gene and metabolite regulatory network in early developing tomato fruit tissues (Mounet *et al*, 2009).

7. CONCLUSIONS

Although an expanding body of research indicates that functional foods (horticultural as well as of other origin) provide health benefits, they must not be considered 'magic bullets' or panacea for poor dietary, health and hygiene habits. Moreover, diet is only one of the components (others being drinking and smoking habits, physical activity, drug abuse, psychological mindset and stress) of an overall lifestyle, which has an impact on health. Although the functional food industry is in its infancy, day by day tailored foods are becoming available for specific segments of consumers in the society like children, senior citizens, lactating mothers, sportsmen, armed forces personnel, etc. In due course of time there is a real possibility that customized functional foods might become available on an individual basis depending upon the person's body constitution (defined as *Prakriti* in Ayurveda). Such possibilities will offer novel challenges and opportunities for the functional food industry in the times to come. In the meantime, scientific communication must continue to educate the consumer as functional food research will not be able to help in advancing public health until the benefits of functional foods are fully known to the consumer. Finally, a quote from a very recent publication (Hui, 2010), the Handbook of fruit and vegetable flavors, *" Fruit has been a part of human diet and is an important nutritional source, with high water content (70-85%) and a relatively high amount of carbohydrates but low contents of fat (less than 0.5%) and protein (<3.5%)"*. Further it is referred that, *"It usually contains many useful vitamins as well as minerals, dietary fiber and antioxidants (Golf and Klee 2006, Knee 2002)"*. Don't these facts directly induce the use of fruits (vegetables included scientifically) to make the base as well as bioactives for designer functional foods of coming age? Certainly, they would!

8. REFERENCES

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