FRUIT JUICE - NUTRITION & HEALTH

AN IFU SCIENTIFIC REVIEW

General Dietary Recommendations

The lack of adequate consumption of fruit and vegetables has become a worldwide dietary concern since fruits and vegetables play a pivotal role in attaining and maintaining good health. Decades of research have found that fruits and vegetables are crucial dietary components consumption of which has been associated with a reduced risk of developing a number of chronic diseases, particularly those which are thought to be initiated by chronic inflammation (Holt et al. 2009; Joseph et al. 2015). The World Health Organization (WHO) as a cosponsor of the global 5+ a day program promotes the inclusion of at least five servings a day of fruit and vegetables (a minimum of 400 g of fruits and vegetables daily) as an essential element in a healthy diet (WHO, 2004). Fruits, vegetables and one hundred percent (100%) fruit juices are deemed to be an integral part of the 5 + a day program. For example, the United States Department of Agriculture (USDA), in the description of MyPlate states that 100% fruit juice counts as part of the fruit group (http://www.choosemyplate.gov). The American Academy of Pediatrics suggests that, although fruit juices should be consumed in moderation, 6 fl oz. of juice (ca. 177 ml) can count toward a serving of fruit (Amer. Acad. Pediatrics. 2001). General dietary advice including 5+ a day recommendations, has also been published by the various countries, among others the majority of European countries (UK, France, Germany, Sweden, Austria, Finland, Poland, Norway, Ireland, Denmark, Italy, Spain). The Australian government and Canadian dietitians also note fruit juice as an important part of a healthy diet.

Fruit and Fruit Juice

According to the CODEX General Standard for Fruit Juices and Nectars "fruit juices have the essential physical, chemical, organoleptical, and nutritional characteristics of the fruit(s) from which it comes (CODEX STAN 247-2005). Properly extracted juices are very similar to the fruit; they contain most substances which are found in the original ripe and sound fruit from which the juice is made. A fruit juice is made from the whole fruit (edible parts) and does not contain more sugar than the corresponding fruit. Ruxton et al. (2006) reviewed the literature comparing health benefits of fruits and fruit juices and concluded that there were no significant differences.
The similarities between the composition of fruits and fruit juices were also pointed out by Landon (2007) and Nicklas et al. (2015).
The Nicklas study conducted two modelling strategies to evaluate nutrient intake and dietary impact of replacing 100% fruit juice with whole fruit in children ages 2-18. Model 1 replaced 100% fruit

juice with a composite of the top 20 most commonly consumed whole fruit. Model 2 replaced individual 100% fruit juice with the same fruit.

The data showed replacing 100% fruit juice with whole fruit resulted in no difference in energy intake and no difference in 85% of nutrients (17 out of 20). Of the three nutrients affected -- vitamin C, fibre and total sugars -- vitamin C significantly decreased in both models; dietary fibre slightly increased by one gram and only in Model 2; total sugars decreased significantly by a small amount (6 grams or 24 kcalories) only in Model 1. This research shows fruit juice is nutritionally similar to whole fruit.

Fruit juices and 100% fruit juice-puree mixtures ("smoothies" with 100% fruit content) are more convenient to consume, and have in general a longer shelf-life than fresh fruit. Therefore, moderate intake of juices along with fruit should be considered suitable for a 5+ a day programme and can help the consumer to reach the dietary recommendations.

In most cases, fruit juices need no additives. Only in a few cases, for example cloudy apple juice or white grape juice, the addition of ascorbic acid (vitamin C) is used for the prevention of browning. Citric acid may be used occasionally to acidify fruit juices made from fruits with a low natural acid content. In most countries of the world, like the EU, the use of chemical preservatives is not allowed. Due to climatic conditions and packaging demands some countries have permitted the use of chemical preservatives which have to be mentioned in the label.

Fruit juice contains essentially all substances which are found in the original fruit which must be ripe and healthy. It is the major task of modern food technology to transfer the valuable fruit components into the juice and to produce stable products by physical means. The only exception is the dietary fibres which are predominantly lost during pressing, whereas fruit purees contain essentially the same amount of dietary fibres as the original fruit. Fruit purees can be used to make juice containing products such as nectars and smoothies.

The (biochemical) complexity of fruit juices and bioavailability of relevant substances for the human body

Fruit and vegetable juices show a very complex composition with several hundred substances, in most cases more than 500. Beside water (80-90%) and the common metabolites of fruits and vegetables [for example carbohydrates (ca. 20), organic acids (30), amino acids (20), peptides (number unknown), minerals and trace elements (ca. 30), vitamins (9), aroma compounds (>200)], fruit and vegetable juices are characterized by a large number of secondary plant metabolites (also known as "phytochemicals"). The two most prominent groups are the polyphenols including the colourful anthocyanins, and the carotenoids.

Every fruit and corresponding juice has its own characteristic pattern: For example, analyses of oranges have revealed the presence of 224 phytochemicals including 32 flavones, 13 flavanones, 6 flavanols, 9 anthocyanins, 15 carotenoids, and 4 coumarins. Grapefruit also contains many phytochemicals including 13 polyphenols, mostly naringin and narirutin, and 20 carotenoids, particularly beta-carotene and lycopene (Cancalon 2016). In strawberries, a total of 56 individual polyphenols were identified and quantified Gasperotti et al. 2015).

Therefore, some authors consider fruit juices as natural "functional foods" without the need of additions, and it is misleading to reduce a fruit juice solely to the sugars which originate exclusively from the fruit. This is confirmed by a study of Serpen (2012) from the comparison of sugar concentration in extracted juice of fresh fruit to that of commercially-bottled 100% fruit juice with a "no sugar added" attribute. Statistical analysis of the experiment results indicated that there was no significant difference in the sugar concentrations between the two in all tested varieties.
Principally, there is no other beverage with a higher ratio between bioactive substances and the energy (sugar) which is consumed from one portion.

The question was raised if the bioavailability of substances from fruit juices is comparable with that from fruits. During eating fruits, we produce a juice/puree in the mouth, compounds are released in the same way as in juices. There is a consensus in nutrition science that the bioavailability for the major substances (sugars, organic acids, amino acids, minerals etc. from both sources is more or less comparable.

For some substance, especially secondary plant metabolites, like carotenoids, the bioavailability from juices is significantly better than from fruits or vegetables. This is known since decades for ß-carotene from carrots. The availability by eating fresh carrots is very poor, better for sliced carrots with the addition of edible oils and best from carrot juices. The major reason is the release of this provitamin from the chemical matrix by heating processes. As heat can damage carotenoids (Dhuique-Mayer et al. 2007), the pasteurisation of fruit juice must be performed carefully.
Orange fruits and the juices thereof represent dietary sources of carotenoids, particularly β-cryptoxanthin. Since previous studies reported a positive effect of vegetable processing on carotenoid absorption, Aschoff et al. (2015) compared the bioavailability of β-cryptoxanthin from either fresh navel oranges (Citrus sinensis L. Osbeck) or pasteurized orange juice in a randomized cross-over study. It was shown that the β-cryptoxanthin bioavailability from pasteurized orange juice was 1.8-fold higher than from fresh oranges. Similarly, mean absorption of the carotenoids lutein, zeaxanthin, and zeinoxanthin were slightly higher from orange juice, although not reaching statistical significance. The in vitro digestion revealed a 5.3-fold higher bioaccessibility of β-cryptoxanthin from orange juice. Dietary fibre contents in the test foods were inversely associated with carotenoid bioavailability. It was concluded that orange juice represents a more bioavailable source of β-cryptoxanthin than fresh oranges. In another human study, the same authors compared bioavailability and colonic catabolism of flavanones from orange juice to a 2.4-fold higher dose from fresh oranges. Despite 2.4-fold higher doses, excretion of flavanones from ingested fresh orange fruit did not differ from that following orange juice consumption, possibly due to a saturation of absorption or their entrapment in the fibre-rich matrix of the fruit. Thus, orange juice should be considered an excellent dietary source of flavanones, being widely equivalent to fresh orange fruit regarding flavanone uptake (Aschoff et al. 2016).

There is a great number of scientific papers which prove the bioavailability of polyphenols (phenolic acids, flavonoids, stilbenes) and anthocyanins from fruits and fruit juices (Zamora-Ros et al. 2016; Williamson and Stalmach 2012).
Evidence suggests that the bioavailability of anthocyanins varies markedly depending on food matrices, including other antioxidants and macronutrients present in foods consumed, which consequently affects the absorption and antioxidant properties of anthocyanins (Yang et al. 2011).

As the goal of eating five servings of fruits and vegetables a day, as recommended by different nutritional organisations, has not yet been achieved by many consumers the daily intake of polyphenols such as anthocyanins could also be improved by consuming smoothies and juices. This was shown by a study of Borges et al. (2010) on the bioavailability of multiple components following acute ingestion of a polyphenol-rich juice. The plasma pharmacokinetics and recoveries of urinary metabolites of flavan-3-ols, flavanones, dihydrochalcones and 5-O-caffeoylquinic acid, both in terms of their identity and quantity, were, in most instances, not markedly different to those reported in other feeding studies with green tea, orange juice, apple cider and coffee. This indicates that the combination of polyphenolic compounds in the polyphenol-rich beverage are absorbed and excreted to a similar extent whether fed individually or together in a single beverage. It was concluded that the juice can deliver the intended blend of bioavailable polyphenols, which would normally require consumption of several different plant-derived foods.
Kuntz et al. (2015a) conducted a randomised, cross-over study to determine the bioavailability of anthocyanins and their metabolites from an anthocyanin-rich grape/blueberry juice (841 mg/litre) and smoothie (983 mg/litre) After the intake of beverage (0.33 litres), plasma and fractionated urine samples were analysed. The most abundant anthocyanin found in plasma and urine were malvidin and peonidin, also as glucuronidated metabolites as well as 3,4-dihydroxybenzoic acid (3,4-DHB). Plasma pharmacokinetics and recoveries of urinary metabolites of anthocyanins were not different for juice or smoothie intake; however, the phenolic acid 3,4-DHB was significantly better bioavailable from juice in comparison to smoothie. Whether smoothies as well as juices should be recommended to increase the intake of potentially health-promoting anthocyanins and other polyphenols requires the consideration of other ingredients such as their relatively high sugar content of juices (Kuntz et al. 2015) which is identical with that of fruits.

Fruit juice health promoting components

Fruits and vegetables form a versatile and complex substance group category of foods.
The relevant substance groups include carbohydrates, acids, minerals, polyphenols including the colourful anthocyanins, water-soluble vitamins, amino acids, aroma compounds, carotenoids, fibres and other bioactive substances. During processing, they are essentially transferred into the pressed juice or into the puree.

According to Clemens et al. (2015) processing fruit into juice can protect nutrient and phytonutrient content. Different juices require different juice processing methods. This results in varying levels of phytonutrients among nutrients.

Juices are low in compounds such as sodium and fat which are believed to have negative health effects when ingested in large amounts. Conversely, juices contain a variety of beneficial micronutrients, including minerals, such as potassium (Dillon, 1995), calcium and magnesium which contribute significantly to the recommended daily intake. The potassium content of fruit juices is in the gram-per–litre-range. This element is the major cation of the intracellular fluid. The movement of potassium out of cells, and sodium in, changes electrical potentials in nerves and muscles which is important for a regular function (Landon 2007). This mineral element plays a key role in the regulation of the blood pressure and is able to blunt the effect of sodium on blood pressure. Many trace elements of fruits are also found in the corresponding fruit juices. The B- vitamin folate is present in orange, grapefruit, pineapple juices and some other tropical juices. Vitamin C, although sometimes added to fruit juices, is found in significant amounts in different fruit juices. Examples are orange juice, grapefruit juice, black currant juice, strawberry juice, and acerola juice. These properties have given rise to most of the health claims that have been approved by authoritative bodies. Health claims have been formulated under Article 13 of the EC Regulation on nutrition and health claims (2009) and by the FDA in 21 Code of Federal Regulations Part 101. In recent years, many of the potentially beneficial phytochemicals present in all the major fruits and fruit juices have been characterized and a database on the polyphenol food content is now available online (http://www.phenol-explorer.eu/, 2009).

Apples and cloudy apple juice contain quercetin, chlorogenic and other phenolic acids as well as phloridzin and phloretin xyloglucoside (Soler et al. 2009). The two last mentioned substances belong to the group of dihydrochalcones which are typical for apple products and seem to play a positive role in the regulation of blood glucose level.

Berries are rich in anthocyanins (cyanidin, delphinidin, peonidin, petunidin, pelargonidin, and malvidin) and other flavonoids (kaempferol and quercetin derivatives) (Szajdek and Borowska 2008, Seeram 2008). Every fruit has its own characteristic anthocyanin pattern, and the concentration of anthocyanins is dependent on the varieties. Among berries, cranberries [Vaccinium macrocarpon] have been particularly studied for providing bacterial anti-adhesion, urinary tract and anti-inflammatory benefits due to its rich content of proanthocyanidins and flavonoids (Neto 2007; Coté et al. 2010; Wang et al. 2012; McKay et al. 2015; McKay and Wilson 2016). Generally, the genus Vaccinium (esp. Blueberries) and the juices thereof were in the focus of research (Borges et al. 2010b).

Citrus contains vitamin C, thiamin, folate, flavanones (hesperidin, naringin), carotenoids such as beta-carotene, alpha-carotene, beta-cryptoxanthin, lutein zeaxanthin, and lycopene in red grapefruit, (Baghurst 2003; Benavente-García and Castillo 2008; Marti et al. 2009; Cancalon 2016), finally limonoids are found in grapefruits (Manners 2007).
Pomegranate juice is rich in ellagitannins, like punicalagin (Basu and Penugonda, 2009) which have been shown to have both antioxidative and anti-inflammatory effects. Other ellagitannins are found in berry juices and nectars made from blackberry, raspberry, and strawberry. Grape juice is well known for the presence of resveratrol and flavonoids, like anthocyanins (Pezzuto et al. 2009; Marquez et al. 2009; Iriti and Faoro 2009; Stalmach et al. 2011), and tomato juice[1] is a major source of lycopene (Lee et al. 2009).

In addition, juices may serve as carriers for added nutrients and beneficial dietary components (so called “fortified fruit juices”) such as calcium, vitamin D and phytosterols that may not be inherent in the fruit itself or vitamin C that is lost during processing.

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[1] *Vegetable juices are assumed to be within the term ‘fruit juice’ and their properties are referred to without distinguishing them as a vegetable source of juice.*

Fruit Juice Phytochemical Properties

In the last twenty years, the mechanisms responsible for the health benefits of fruit juices have been considerably investigated. It was hypothesised that the antioxidant properties of fruit juices were responsible for some of their health benefits. However, it is now thought that the biological activities cannot be solely explained by antioxidant effects.
A direct antioxidant effect of polyphenols in vivo is questionable because concentrations in blood are low compared with other antioxidants and extensive metabolism following ingestion lowers their antioxidant activity. Therefore, the biological relevance of direct antioxidant effects of polyphenols for cardiovascular health could not be established (Hollmann et al. 2011).
The health benefits of fruit juice cannot be explained simply by their antioxidant properties measured in a test tube by chemical reactions. This can only be achieved by assessing the physiological properties of juices phytochemicals in vivo. There is only a very limited relationship between antioxidant potentials measured by chemical reactions and the physiological effects of fruit juices. The emerging view is that phytochemicals exert their beneficial action on cells through cellular interaction with receptors and enzymes involved in signal transduction, and that antioxidant capacity and scavenging activities have only a limited influence. Hence, a ranking of fruits and fruit juices according to their antioxidant capacity (ORAC; TEAC) is scientifically not justified. Most of the antioxidant benefits of food based on chemical oxido-reduction reactions have now been shown to be unfounded (EFSA Journal 2010; 8(2):1489). Antioxidant effects occur through the up or down regulation of specific enzymes.

All fruits and vegetables and the juices thereof contain a great number polyphenols which were thoroughly investigated. The major effects can be summarized as follows (Cancalon 2007):
1) Chemical Antioxidants, scavenge reactive oxygen and nitrogen species.
2) Physiological antioxidants, inhibition of the redox-sensitive transcription factors (acting on genes), Inhibition of pro-oxidant enzymes and induction of antioxidant enzymes.
3) Inhibition of atherosclerotic plaques, reduction of adhesion molecule expression, anti-inflammatory effects and reduction of the capacity of macrophages to oxidatively modify LDL (low-density lipoprotein).
4) Platelet function and homeostasis, inhibition of platelet aggregation.
5) Beneficial effects on blood pressure and vascular reactivity, promotion of nitric oxide-induced endothelial relaxation.
6) Reduction of plasma lipids and lipoproteins.

In conclusion, phytochemicals act through the modulation of signal cascades in the human body, most often starting at the genes level. Based on these interactions signals are transferred into the cells leading to activation or deactivation of metabolic pathways. (Serafini 2011; Koltover 2009; Crozier et al. 2009, Little et al. 2015).

The most beneficial effects of phytochemicals seem to involve the dampening of chronic inflammation which is considered to be at the root of most chronic diseases, including cardiovascular dysfunctions, osteoporosis, dementia, and some forms of cancer.

Within the last ten years, it has been recognized that the anti-inflammatory properties of the phytochemicals of fruit and fruit juices (vegetable resp. vegetable juices) are more decisive than the

“chemical property of being antioxidant” and can better explain the mechanistic effects on signal cascades (metabolic pathways) in the human body.
Underlying etiological factors in the development of obesity-related chronic diseases are long-term imbalances of oxidative and inflammatory stress leading to tissue dysfunction, damage, and ultimately failure (Joseph et al. 2015). Poor dietary quality contributes significantly to the oxidative and inflammatory status of an individual. Recent evidence indicates that plant-derived polyphenolic compounds may confer anti-inflammatory and/or inflammatory response stabilizing activities, which would have important implications in health maintenance and disease risk reduction. Commonly consumed fruits and their juices, such as grapes, berries, and oranges, contain polyphenolic compounds that have been studied for their effects on inflammation, but the nature and extent of their effects in humans is not yet fully understood (Joseph et al. 2015).

Anti-inflammatory effects of polyphenols, (mainly flavonoids, anthocyanins and stilbenes [resveratrol and its oligomers]) were in the focus of research, and many researchers think that the mechanisms by which polyphenols express these beneficial properties appear to involve their interaction with cellular signalling pathways and related machinery that mediate cell function under both normal and pathological conditions (Vauzour et al. (2010).
Pan et al. (2009, 2010) describe the influence of phytochemicals and flavonoids on signal cascades and modulation of the inflammatory gene expression. Joseph et al. (2014) reviewed the current state on berry and berry products as a source of dietary polyphenols, particularly anthocyanins, to modulate inflammatory status.

Beside the huge group of polyphenolic compounds also other phytochemicals may be anti-inflammatory, as was shown for carotenoids from tomatoes and vegetables (genus Brassicaceae). Lutein, as an example, is an oxycarotenoid that belongs to the xanthophyll family of carotenoids and is found in several dark-green leafy vegetables such as kale and spinach as well as in some brightly coloured fruit. Lutein is an important substance and is one of the six major carotenoids routinely measured in human serum. It is one of the few carotenoids that could cross the blood–brain barrier (BBB). It also preferentially accumulates in the human brain and plays an important role in the development and function of brain tissue. It has been reported that lutein possesses a wide variety of biological activities such as antioxidative, anti-inflammatory, and neuroprotective properties (Wu et al. 2015).

The question of the mode of action of vitamins and phytochemicals was raised as early as 2004 by Azzi et al. for vitamin E. The lack of relationship between in vitro antioxidant activity of phytochemicals and their physiological properties was examined by most groups involved in the health benefits of these compounds. (Williams et al. 2004; Cerda et al. 2004; Scalbert et al. 2005; Sies 2007; Stevenson and Hurst 2007). Similar processes have now been reported for lycopene (Erdman et al. 2009) and even vitamin C (Wu et al. 2007; Kelly et al. 2008; Maeng et al. 2009). It is now accepted that phytochemicals, once ingested, are modified and metabolized in the intestinal tract. Parts of these phytochemicals and their metabolites are absorbed into the blood stream, and then modified again in the liver and other organs. Finally, these metabolites act with cells signalling pathways and start a series of cascading reactions promoting physiological changes. Recent studies have shown that following orange juice ingestion, genes are affected much sooner than cardiovascular health markers (Morand et al. 2011a, b). This has led to the development of new analytical procedures to examine the effects of fruit juices and other foods, based on genomics,

proteomics and metabolomics (Ovesna 2008; Scalbert and Knasmüller 2008; Fardet et al. 2008; Steiner et al. 2008; Mauray et al. 2010).
Recent research underlines that the juice phytochemicals have an impact on epigenetics and particularly micro RNAs, but the mechanisms are not yet fully understood. It seems that miRNAs could act by affecting post-transcriptional regulation of protein synthesis (Milenkovic et al. 2013).

Health Benefits of Fruit Juices

The health benefits of fruits and fruit juices have been reviewed by Landon (2007) and more recently by Hyson (2015). The high potassium and low sodium characteristic of most juices help maintain a healthy blood pressure, furthermore the lack or near absence of saturated fat in fruit juices is beneficial for the cardiovascular system (Delichatsios and Welty 2005).
Several studies revealed an inverse association between potassium and blood pressure (Demigné et al. 2004). Binia et al. (2015) evaluated the efficacy of daily potassium intake on decreasing blood pressure in non-medicated normotensive or hypertensive patients. It is shown that potassium supplementation is associated with reduction of blood pressure in patients who are not on antihypertensive medication, and the effect is significant in hypertensive patients. Patients with elevated blood pressure may benefit from increased potassium intake along with controlled or decreased sodium intake.
The fortification of juices with calcium (Andon, 1996) and phytosterol (Devaraj et al. 2004) provide some supplemental bone and cardiovascular benefits. Recently, several reviews have summarized the health benefits of fruit polyphenols (Spencer, 2010; Chong et al. 2010; Gonzalez-Gallego et al. 2010; Hardcastle et al. 2011).

Vitamins have a special role since they are essential for life and are usually not produced by the body. Vitamin C (ascorbic acid), naturally present or added to most juices, is necessary for the body to form collagen, cartilage, muscle, and blood vessels, and aids in the absorption of iron. The enzymatic and non-enzymatic functions of vitamin C were reviewed by Levine et al. (1993). Its role as an antioxidant has been extensively examined, in addition many vitamin C effects appear to be due to its role as a coenzyme in many biochemical reactions (Levine et al. 1993). More recently, the influence of vitamin C in gene modulation and biochemical pathways modifications has been shown, particularly in blood vessel endothelium (Wu et al. 2007) and atherosclerosis (Frikke-Schmidt and Lykkesfeldt 2009). Folate is another vitamin which is found in some fruits and fruit juices (citrus, pineapple and strawberry). According to literature, folate reduces the risk of spina bifida (Bell and Oakley 2009) and premature birth (Bukowsky et al. 2009). It also helps in maintaining a low level of the amino acid homocysteine, a marker of inflammation, that has been associated with a higher risk for heart disease, stroke, and heart failure (Sánchez-Moreno et al. 2009).
The health benefits of minerals, vitamins, and micronutrients have been well characterized but many of the potentially beneficial properties of juices have been shown to come from phytochemicals, mainly polyphenols, carotenoids and limonoids. It should be pointed out that data on the health benefits of fruit juices are still fragmented and that many studies have been done on cell cultures and animal models. Longer term clinical studies with doses of juices similar to those ingested in normal life are underway and will provide a better understanding of the health impact of fruits juices. If health claims are to be accepted, it will be necessary to determine the bioavailability of the

main fruit juice phytochemicals and to define some type of RDI values (Williamson and Holst, 2008; Holst and Williamson, 2008).
Some phytochemicals have anti-inflammatory properties and may have an influence on chronic inflammation. This process, which had been called the silent killer, is an attempt by the organism to remove injurious stimuli and to initiate healing. The diseases that may be initiated by chronic inflammation include aging diseases such as Alzheimer's disease (Granic et al. 2009; Kanapuru 2009), diabetes, insulin resistance (King 2008; Blüher 2008) and cardiovascular disease, particularly atherosclerosis (Bucova et al. 2008). In addition, bone diseases such as osteoporosis and arthritis (Hardy and Cooper, 2009), cognitive functions and brain diseases (Wärnberg et al. 2009) and some forms of cancer (Gonda et al. 2009) may be induced by chronic inflammation.

In a different area related to inflammation, cranberry juice has long been associated with a reduction in urinary infections. Anthocyanins and proanthocyanidins may inhibit the adhesion of uropathogens (e.g. uropathogenic E. coli) to the uroepithelium, thus impairing colonization and subsequent infection (Guay 2009). Consumption of a cranberry juice beverage lowered the number of clinical urinary tract infection episodes in women with a recent history of urinary tract infection (Maki et al. 2016).

A major point must be underlined: Fruits and their juices are not drugs, and measurable health effects can be expected to be mild relative to the more dramatic outcomes expected with pharmacological medications. It can be proposed that the main role of fruit and fruit juices is a disease risk reduction.

Cardiovascular Health

The area of cardiovascular diseases is, so far, the one that appears to show the most promising potential for the beneficial effects of fruit juices (Duthie et al. 2006; Leifert and Abeywardena 2008; Ross, 2009; Grassi et al. 2009; Dalgård et al. 2009; Chong et al. 2010). Cardiovascular disease is a leading cause of death globally. Many cardiovascular risk factors can be modified through lifestyle modification, including dietary patterns that emphasize daily consumption of a variety of fruits and vegetables. Recent observational and clinical studies suggest that flavonoids, may be associated with health benefits, particularly cardiovascular benefits. A review of the beneficial effects of citrus flavonoids on the development of atherosclerosis has recently been published by Mulvihill and Huff, 2012. The authors summarize the dose effect relationship of citrus flavonoids and cardiovascular benefits. It can be noted that the patients ingest between 300 and 800 mg of citrus flavonoids per day.

Several reviews on the beneficial effects of grape polyphenols and grape juice in cardiovascular health have been recently published (Vislocky and Fernandez 2010; 2013; Blumberg et al. 2015; Wightman and Heuberger 2015). Grape juice has well-established health effects on cardiovascular disease risk, including endothelial function, LDL oxidation, progression of atherosclerosis, and reduction in oxidative stress.

Also, Wightman and Heuberger (2015) describe cardioprotective benefits of grapes through inhibition of platelet aggregation, decreased low-density lipoprotein (LDL) oxidation, reduction in oxidative stress and improvements in endothelial function. Grapes may also have a favourable effect on blood lipids, decrease inflammation and reduce blood pressure in certain populations. The authors recommend to incorporate products made with grapes and other berries into a heart-healthy diet.

The formation of a blood clot in the circulatory system (thrombosis) can lead to disturbance in the blood supply resulting in embolism and stroke. Several fruit juices seem to be able to limit blood clot formation by preventing platelets from agglutinating in the blood vessels (Freedman et al. 2001; Mattiello et al. 2009). Platelets agglutination is the first step in the formation of atherosclerotic plaques.

Atherosclerosis is the condition in which an artery wall thickens as the result of an accumulation of fatty material, which leads to a dysfunction of the endothelial cells of the blood vessels. This build up, called plaque, hardens and narrows arteries. The blood flow is reduced and can lead to heart attack and stroke. Fruit juices have been shown to act at the various levels of the processes leading to atherosclerosis. Several years ago, it was shown that fruit juices can increase the level of high density lipoproteins (HDL), the lipids disposed of in the liver (good lipids) and decrease the formation and oxidation of low density lipoproteins (LDL) that are deposited in the blood vessels (bad lipids) (Gorinstein et al. 2004, 2006). Although, preventing the oxidation of LDL may play an important role in the beneficial effects of fruit juices (Aviram et al. 2002), it appears that the effects of fruit juice phytochemicals is complex and involves modulation of cell physiology. Fruit juice components have been shown to act at every level of the blood lipid process from cholesterol synthesis to the formation of lipoproteins (LDL, HDL). For about fifteen years it has been known that naringin and hesperidin inhibit the first enzyme in the biosynthesis of cholesterol (HMG-Co Reductase), this is the same enzyme targeted by the statin class of drugs (Bok et al. 1999). Nahmias et al. (2008) showed that naringin inhibits the transcription of HMG-Co reductase, the activity of microsomal triglyceride transfer protein (MTP) and the transcription of acyl-coenzyme A: cholesterol acyltransferase 2 (ACAT2) the enzyme which in the final phase of LDL production attaches cholesterol to the lipoproteins. Similarly, naringin from grapefruit (Mulvihill et al. 2009) and anthocyanins from berries (Qin et al. 2009) have a beneficial effect on lipoprotein profiles by decreasing LDL-cholesterol and increasing HDL-cholesterol concentrations. Apple polyphenols (Lam et al. 2008) may act by inhibiting cholesterol ester transfer protein (CETP). Morin et al. (2008) showed that a reduction of plasma cholesterol by citrus flavonoids is associated with a modulation of the expression of the LDL receptor (LDLR) gene.

Morand et al. (2011a) investigated the effect of orange juice and its major flavonoid, hesperidin, on microvascular reactivity, blood pressure, and cardiovascular risk biomarkers through intervention studies. Twenty-four healthy, overweight men (age 50-65 y) were included in a randomized, controlled, crossover study. Throughout the three 4-wk periods, volunteers daily consumed 500 mL orange juice, 500 mL control drink plus hesperidin (CDH), or 500 mL control drink plus placebo (CDP). Diastolic blood pressure was significantly lower after 4 wk. consumption of orange juice or CDH than after consumption of the placebo, whereas microvascular endothelium-related reactivity was not significantly affected when measured after an overnight fast. However, both orange juice and CDH ingestion significantly improved postprandial microvascular endothelial reactivity compared with CDP ($P < 0.05$) when measured at the peak of plasma hesperetin concentration. The study suggests that hesperidin could be causally linked to the beneficial effect of orange juice.

Recently, it was found that flavanol metabolites, like quercetins, reduce monocyte adhesion to endothelial cells through modulation of expression of genes via p38-MAPK and p65-Nf-kB pathways (Claude et al. 2014).

Cranberry juice contains polyphenolic compounds that could improve endothelial function and reduce cardiovascular disease risk. Dohadwala (2011) examined the effects of cranberry juice on vascular function in subjects with coronary artery disease. The experimental design was an acute pilot study with no placebo (n = 15) and a chronic placebo-controlled crossover study (n = 44). Chronic cranberry juice consumption reduced carotid femoral pulse wave velocity-a clinically relevant measure of arterial stiffness. The uncontrolled pilot study suggested an acute benefit; however, no chronic effect on measures of endothelial vasodilator function was found.

Rodriguez-Mateos et al. (2016) investigated whether cranberry juice intake can improve vascular function in healthy men in a dose- and time-dependent manner. A double-blind randomized controlled crossover trial was conducted in ten healthy males. Flow-mediated dilation (FMD), blood pressure, pulse wave velocity and augmentation index were investigated at baseline, 1, 2, 4, 6, and 8 h post-consumption of cranberry juices containing 409, 787, 1238, 1534, and 1910 mg of total cranberry (poly)phenols (TP), and a control drink. They observed dose-dependent increases in FMD at 1, 2, 4, 6, and 8 h with a peak at 4 h and maximal effects with juice containing 1238 mg TP. A total of 60 metabolites were quantified in plasma after cranberry consumption. Twelve polyphenol metabolites significantly correlated with the increases in FMD. In conclusion, polyphenols in cranberry juice can improve vascular function in healthy males.

The health promoting effects of anthocyanins on vascular functions are still discussed. Kuntz et al. (2015) studied their anti-inflammatory effect on activated human umbilical vein endothelial cells after their transport across an epithelial monolayer. Anthocyanins in physiological concentrations reached the serosal compartment and reduced inflammation-related parameters, which were related to the initial steps during the pathogenesis of atherosclerosis. In another study with an anthocyanin-rich fruit juice the same authors (Kuntz et al. 2014) found an improvement of the antioxidant status of healthy young female volunteers without affecting anti-inflammatory parameters.

Another signalling molecule affected by fruit juices is nitric oxide (NO). The endothelium (inner lining) of blood vessels uses nitric oxide to signal the surrounding smooth muscle to relax, thus resulting in vasodilation and increasing blood flow. The proper level of NO is largely modulated by enzymes such as endothelial nitric oxide synthase (eNOS), and nitric oxide oxidase. Fruit juices play a role in the maintenance of NO levels. This has been shown to occur with many juices (George et al. 2009) including grape (Ekshyyan et al. 2007), pomegranate (de Nigris et al. 2005) and citrus juices (Morand et al. 2011a, b). These beneficial changes have been noted at various levels of the cardiovascular system including blood pressure (Reshef et al. 2005; Morand et al. 2011a, b) and measures of arterial stiffness (Habauzit et al. 2015).

Novotny et al. (2015) showed that consumption of low calorie cranberry juice for 6 weeks resulted in a significant decrease in diastolic blood pressure. In addition, this and another study (Basu et al, 2011) showed that long term consumption of cranberry juice can reduce C reactive protein, an important inflammatory risk marker associated with cardiovascular disease.

Taken together, bioactive compounds in plant-based foods have health properties that contribute to the prevention of age-related chronic diseases, particularly cardiometabolic disorders, but there are marked differences between individuals in the absorption, distribution, metabolism and excretion of bioactive compounds. The main factors likely to affect the individual responses to consumption of plant food bioactives are reviewed by Manach et al. (2016).

Bone Health

Bone health is largely the result of an equilibrium between osteoclast cells destroying bone and osteoblasts building it. Several fruit juice phytochemicals, mainly polyphenols and carotenoids, have been shown to have a positive influence on bone health and particularly the bone mineral density of post-menopausal women (Trzeciakiewicz et al. 2009, 2010). Positive activity has been reported for citrus (Deyhim et al. 2008; Mandadi et al. 2009) and pomegranate (Mori-Okamoto et al. 2004). Citrus juice hesperidin and naringin may act through bone morphogenetic proteins (BMPs) pathways that induce the formation of bone and cartilage (Wong and Rabie 2006; Trzeciakiewicz et al. 2009; Habauzit et al. 2007, 2009; Chiba et al. 2007; Horcajada et al. 2008). Fruit juice carotenoids, β-cryptoxanthin, β-carotene and lycopene may also improve bone health by preventing bone destruction by osteoclasts (Sugiura et al. 2008; Sahni et al. 2009 a, b). It should also be mentioned that citrus and pomegranate may have a positive effect on arthritis (Murakami et al. 2007; Shukla et al. 2008; Hadipour-Jahromy and Mozaffari-Kermani 2010). Dietary flavonoid intakes may be associated with bone mineral density, supporting the evidence from animal and cellular studies (Hardcastle et al. 2011). Further studies in humans are required to substantiate these findings as the majority of existing research has been based on cell culture or animal studies so does need to be interpreted with caution. Two clinical studies on orange juice failed to show a significant effect on bone health.

Brain health, cognition and aging

Reports have shown that fruit juices may play a role in maintaining cognition, limiting brain aging and possibly slowing the progress of Alzheimer's disease (Dai et al. 2006). The beneficial effects of grape juice (Joseph et al. 2009; Wang et al. 2008; Krikorian et al. 2010, 2012; Lamport et al. 2016), berries (Shukitt-Hale et al. 2008, 2009; Willis et al. 2008) and citrus (Datla et al. 2001; Kean et al. 2015) have been examined although many of these studies have only been carried out on animals. The ability of juice compounds, particularly flavonoids, to cross the barrier protecting the brain (blood brain barrier) is at the origin of the beneficial activity of these compounds (Youdim, 2003). Spencer's group reviewed the potential neuroprotective properties of dietary flavonoids (Spencer 2008, 2009a, 2010). Firstly, they appear to promote cerebral vascular blood flow and secondly, they have been shown to interact with neuronal signalling cascades leading to an inhibition of cell death and to a promotion of neuronal differentiation. As a result, they may prevent deterioration or even improve cognitive performance (Macready et al. 2009; Spencer, 2009b; Vafeiadou et al. 2009; Harrison and May, 2009). Vitamin C can also reach the brain and ascorbate is proposed as a neuromodulator of neurotransmitters, thus vitamin C may have potential therapeutic roles against ischemic stroke, Alzheimer's disease, Parkinson's disease, and Huntington's disease (Harrison and May, 2009). Also, Lamport et al. (2015) assume cognitive benefits associated with the long-term consumption of flavonoid-/anthocyanin-rich Concord grape juice but the mechanisms are still unclear. Most likely the effect is linked to increased blood flow.

Wu et al. (2015) investigated the effects of lutein, a carotenoid in different vegetable juices, on neuroinflammation in lipopolysaccharide (LPS)-activated BV-2 microglia. Microglia are the resident immune surveillance cells of the central nervous system. They play an important role in the inflammatory immune response in the brain as well as in degenerative processes. Aberrantly activated microglial cells cause excessive expression of various proinflammatory cytokines and mediators, which could lead to neurodegenerative diseases. The results suggest that lutein attenuates neuroinflammation in LPS-activated BV-2 microglia partly through inhibiting p38-, JNK-, and Akt-stimulated NF-κB activation and promoting ERK-induced Nrf2 activation, suggesting that lutein has great potential as a nutritional preventive strategy in inflammation-related neurodegenerative disorders.

Cancer and Inflammation

Several epidemiological studies have shown that fruit juices may have a beneficial role in preventing the development of some types of cancer (Cutler et al. 2008; Wu et al. 2009, Kyle et al. 2009). Many juice phytochemicals (polyphenols, carotenoids and limonoids) may influence mechanisms relevant for cancer prevention. These include antimutagenic activity, control of angiogenesis, anti-inflammatory mechanisms, modulation of signal transduction pathways. Positive results have been associated with most juices, including apple juice (Gerhaeuser 2008, Veeriah et al. 2008) grapes and grape juice (Iriti and Faoro 2009). Anthocyanins from various berry juices (Hochman et al. 2008; Thomasset et al. 2009; Matsunaga, 2010), citrus flavonoids (Benavente-García and Castillo 2008) and limonoids (Poulose et al. 2006) may also have potential anticarcinogenic activities. Among those, the control of chronic inflammation may be very important (González-Gallego et al. 2010). Further studies are required to substantiate these findings as the majority of existing research has been based on cell culture or animal studies.

Colon cancer arises due to the conversion of precancerous polyps (benign) found in the inner lining of the colon. Various epidemiologic studies have linked colorectal cancer with food intake. Apple and berry juices are widely consumed among various ethnicities because of their nutritious values. In the review article of Jaganathan et al. (2014) chemopreventive effects of these fruit juices against colon cancer are discussed. A thorough literature survey indicated that various phenolic phytochemicals present in these fruit juices have the innate potential to inhibit colon cancer cell lines. The conclusion of the review is that apple and berry juices will be possible candidates in the campaign against colon cancer (Jaganathan et al. 2014). These findings must be substantiated by further studies as the significance of cell culture studies is limited.

Also, Little et al. (2015) support further investigation of polyphenols and colorectal cancer risk. These may exert their anti-carcinogenic effects via the modulation of inflammatory pathways. Key signal transduction pathways are fundamental to the association of inflammation and disease progression.

It was already shown in two animal studies by Barth et al. (2005, 2007) that cloudy apple juice decreases DNA-damage, hyperproliferation and aberrant crypt foci development in the distal colon of DMH-initiated rats and is more effective than clear apple juice. The different results are most likely explained by the presence of procyanidins in cloudy juice.

Beside flavonoids and anthocyanins also the non-flavonoids are in the focus of research. Ellagitannins and ellagic acid are polyphenols abundant in pomegranate, walnuts, and berries (esp. strawberry, raspberry, blackberry, grape) that have been acknowledged with anticancer properties. Ellagitannins, ellagic acid, and the colonic metabolites urolithins (Uros) exhibit anticancer effects against colon cells. Gonzalez-Sarrias et al. (2016) examined cell growth, cell cycle, apoptosis, and the expression of related genes and microRNAs in a panel of nonmalignant and malignant colon cell lines and found anticancer effects against colon cancer cells via a common upregulatory mechanism.

Resveratrol is a pleiotropic phytochemical belonging to the stilbene family. Though it is only significantly present in grapes and grape products, a huge amount of preclinical studies investigated its anticancer properties in a plethora of cellular and animal models. Molecular mechanisms of resveratrol involves different inflammatory and signalling pathways which were reviewed by Varoni et al. (2016).

Skin health

In recent years, fruits, fruit juices and their phytochemicals have been promoted in various magazines and web sites as being able to provide “beauty from within”.
Vitamin C has long been known to maintain skin collagen (Sheretz and Goldsmith 1991, Cosgrove et al. 2007). A beneficial effect of vitamin C on skin, starting at the gene expression level has been revealed (Arai et al. 2009, Duarte et al. 2009). Carotenoids have also been shown to improve skin health (Stahl and Sies 2007).
Flavonoids have been shown to improve skin microcirculation (Neukam et al. 2007) and collagen formation (Stipcevic et al. 2006; Bae et al. 2009).
Strawberry polyphenols have been extensively studied over the last two decades for their beneficial properties. Gasparrini et al. (2015) demonstrated recently that the topical use of strawberry extract may provide good photoprotection but it remains unclear if drinking strawberry juices or smoothies would have a similar effect “from within”.

Body weight and insulin resistance

Excessive consumption of any calorie source is likely to lead to obesity. For example, Faith et al (2006) showed that the consumption of very high levels of fruit juice could have a negative effect (24-30fl oz., 709-889 ml). Concern has been expressed that fruit juice sugar can contribute to weight gain, especially for children. However, O’Connor et al. (2006) reported that on average, preschool children drank less than 177 ml/day of 100% fruit juice. Similarly, Nicklas et al. (2015) reported that the mean daily juice consumption among children was 3.6 fl oz. which contributed a meant intake of 50 kcal (2.9% energy intake). This was confirmed by an in-depth critical systematic review (Crowe-White et al. 2016) conducted by the American Academy of Nutrition and Dietetics and looking at research from 1995-2013 which found drinking 100% juice was not associated with weight status or adiposity in children, 1-18 years of age. On average, children consumed less than the maximum

amounts of 100% juice recommended by the American Academy of Pediatrics. The Academy recommends limiting fruit juice consumption to 4 – 6 ounces/day for children 1 to 6 years old and 8 – 12 ounces or 2 servings/day for children 7 – 18 years old (Amer. Acad. Pediatrics, 2001).
Limited evidence from eight studies suggests that children consuming 100% FJ have higher intake and adequacy of dietary fibre, vitamin C, magnesium, and potassium. In context of a healthy dietary pattern, evidence suggests that consumption of 100% FJ may provide beneficial nutrients without contributing to pediatric obesity (Crowe-White et al. 2016).

Several studies have looked at the effects of drinks by grouping sodas and 100% fruit juice, and examining populations of various sizes, therefore providing skewed and confusing data (Palmer et al. 2008). These questions were reviewed by Nicklas et al. (2008). O'Neil and Nicklas (2008) evaluated the relationship between consumption of 100% fruit juice and bodyweight among children and adolescents and found that there is no systematic association between consumption of 100% fruit juice and overweight in children or adolescents. The findings of this analysis support previous studies by Skinner et al. (1999, 2001) and Newby et al. (2004) that showed no significant correlation between weight change and the consumption of 100% fruit juice, fruit drinks, milk, soda, or diet soda in preschool-aged children. It has been suggested that the amount of sugar being absorbed can be monitored by using the Glycemic Index (GI). This concept has led to a reassessment of the role of sugars in juices within the diet. Slowly absorbed foods have a low GI rating while foods that are more quickly absorbed will have a higher rating (Foster-Powell et al. 2001; Mendosa 2003). However, the glycemic index tells you how quickly a carbohydrate-containing food turns into sugar, but it doesn't tell you how much carbohydrate is in a serving of a food (Vrolix and Mensink 2010). In many cases, the use of the glycemic load which considers both the glycemic index and the amount of carbohydrate in a food would be more appropriate. The carbohydrate in carrots, for example, has a high GI, but carrots are low in carbohydrate compared to other foods, so carrots glycemic load is relatively low (Venn and Green 2007).

Study of fruit juice intake based only on calorie calculations ignores several important points. It has been shown that fruit juices contain compounds that may limit or prevent insulin resistance. The benefits of citrus in the management of diabetes were reviewed by Aruoma et al. (2012). Yoshida et al. (2007) showed that fruit juice consumption was inversely associated with fasting plasma glucose. A reduction of insulin resistance, oxidative stress and inflammation were reported after ingestion of several fruit juices including grapefruit juice (Yao et al. 2004), grapefruit naringin (Kannappan and Anuradha, 2010), orange juice (Ghanim et al. 2007), cranberry juice (Wilson et al. 2008), and blueberry, (DeFuria et al. 2009). These results were recently confirmed by Wu et al (2009) who showed that flavonoids can attenuate the expression of glucose induced inflammatory cytokines. Alçada et al. (2009) also showed that orange juice may increase the production of somatostatin, an inhibitor of insulin secretion. The authors concluded that fruit juices are a good source of the sugars needed by the body, and also provide phytochemicals with a wide range of health benefits.

Also, Rampersaud et al. (2017) underline in their review that citrus juices as excellent sources of vitamin C and contribute other key nutrients such as potassium, folate, magnesium, and vitamin A. OJ intake has been associated with better diet quality in children and adults. OJ intake has not been associated with adverse effects on weight or other body measures in observational studies in children and adults. In adults, some observational studies report more favourable body mass index or body measure parameters in OJ consumers compared to non-consumers. Intervention studies in adults report no negative impacts of OJ or GJ consumption on anthropometric measures, although these measures were typically not the primary outcomes examined in the studies. Moderate consumption of citrus juices may provide meaningful nutritional and dietary benefits and do not appear to negatively impact body weight, body composition, or other anthropometric measures in children and adults.

In the public perception, sugar (“free sugar” in fruits or honey, fruit juices, beverages etc.) has a negative image. Efforts to “outlaw” sugar in general is the wrong approach (Belkova et al. 2017). For many, sugar represents a threat to their health, a perception that is driven by increase in the prevalence of obesity, diabetes, and metabolic disorders, which directly or indirectly is connected with the consumption of sugar. However, is sugar to blame for this health crisis, or are sedentary lifestyle and unhealthy diet equally important? Today, sugars and fats are being targeted for restriction or even prohibition. Should we get rid of sugar altogether and/or does it merit a reprieve? Is the effort to "outlaw" sugars a symptom of nutritional extremism (Belkova et al. 2017).

Dental health

Several reports have postulated that fruit juices can affect dental health, promote caries and dissolve enamel. Reports of these effects appeared as early as 1954 (Thomas). These studies have been performed either in vitro or under, very long, unnatural conditions (Willershausen et al. 2008; Ren et al. 2009; Ehlen et al. 2008). No measurable association of intake of 100% fruit juice, milk, tea and some other drinks with the prevalence of tooth loss were reported by Tanaka et al. (2008). Furthermore, recent data (Vargas et. al 2014), analysed on nearly 2,300 US preschool children from several studies found no association between intake of 100% fruit juice and early childhood caries. While all fermentable carbohydrates can contribute to the development of dental caries, they can be prevented by using proper dental hygiene practices including use of a fluoridated toothpaste (ILSI Europe, 2009; Amer. Dental Assoc., 2005; WHO, 2006).

Hooper et al (2007) suggested that the sodium hexametaphosphate containing paste could be used to provide significant erosion protection in susceptible individuals. Lim et al. (2008) reported that damage can be avoided by regular use of fluoridated toothpaste Scaramucci et al. (2011) proposed that, calcium added to juice can provide another beneficial effect. While possible detrimental effect of juice sugar and acidity can easily be eliminated by proper hygiene, recent studies have revealed that juice polyphenols have a beneficial effect on dental health (Hannig et al. 2009; Ferrazzano et al. 2009; Chankanka et. al. 2011). Koo et al. (2006) investigated the influence of cranberry juice on several activities in vitro associated with the development of Streptococcus mutans biofilms. Biofilm formation and accumulation were significantly reduced by topical applications of 25% cranberry juice twice daily with 1-min exposures.
Furthermore, calcium and vitamin D added to juice can also add another beneficial effect (Davis et al. 2007).

Several studies have also suggested that juice phytochemicals can have a beneficial effect on tooth health. Varoni et al. (2012) reported that plant polyphenols prevent oral diseases. Hiraishi et al. (2011) showed on bovine root dentine that hesperidin could preserved collagen and inhibited demineralization, and enhanced remineralization. Ghazal and Levy (2015) observed this protective effect in a small study on children 3-22 months. They found children who consumed 100% juice more frequently (2 or more times per day) had less dental caries than those who did not. In fact, those 3-year-old children who consumed 100% juice one more time per day (3 times per day) had approximately 60% lower odds of developing dental caries, compared to those who consumed 100% juice less frequently per day. The protective effect of juice on early caries in preschool children was also found by Chankanka et al. (2011) and Wafaa et al. (2015).

Recent research revealed a possible role on dental health of NO (nitric oxide) which is an important cellular signalling molecule involved in many physiological processes. It is also known as a vasodilator. Dietary inorganic nitrate (NO_3^-) and its reduced forms nitrite (NO_2^-) and nitric oxide (NO), respectively, are of critical importance for host defence in the oral cavity. High concentrations of salivary nitrate are linked to a lower prevalence of caries due to growth inhibition of cariogenic bacteria. In a randomized clinical study with 46 subjects Hohensinn et al. (2016) investigated whether nitrate-rich beetroot juice exhibits a protective effect against caries by an increase of salivary pH. The results show that, in comparison to a placebo group, consumption of beetroot juice that contains 4000 mg/L NO_3^- results in elevated levels of salivary NO. Furthermore, they determined an increase of the mean pH of saliva from 7.0 to 7.5, confirming the anti-cariogenic effect of the used nitrate-rich beetroot juice. Taken together, the study found that NO_3^--rich beetroot juice holds potential effects against dental caries by preventing acidification of human saliva.

Dietary nitrate consumption may also be a useful adjunct in the control of chronic gingivitis. Jockel-Schneider et al. (2016) found a positive influence of dietary nitrate consumption on gingival inflammation which could be significantly reduced. They used a lettuce juice containing either a standardized amount of nitrate resulting in an intake of approximately 200 mg nitrate per day (test) or being devoid of nitrate (placebo).

Conclusion

Fruit juices and vegetable juices are very complex, consisting of hundreds of substances. They contain also essential vitamins and minerals as well as bioactive compounds that are known to have many health benefits. Although studies are fragmented and need to be expanded, particularly in the clinical area, juices may play a role in diseases related to chronic inflammation, cancer, heart and bone diseases, problems related to cognition and aging, and possibly insulin resistance. The mode of action of these fruit juice compounds in most cases seems to be by modulating gene activity. Fruit juices, consumed in moderation as part of a balanced diet, offer both: health and disease risk reduction properties. Furthermore, to identify moderate fruit juice consumption as inadvisable in the context of obesity and dental health, would deny the consumer a perfectly healthy and nutritious food, and be completely contrary to the totality of the current scientific evidence.
Fruits and juices are not drugs, and measurable health effects can be expected to be mild relative to the more dramatic outcomes expected with pharmacological medications. It can be proposed that the main role of fruit and fruit juices is a disease risk reduction.

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Date: 14th March 2017

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