FRUIT JUICE NUTRITION & HEALTH – 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). 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). Practical aspects of the program can be found at the CDC (Centers for Disease Control and Prevention) web site (http://www.fruitsandveggiesmatter.gov). 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 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. Recently 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).

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 is deemed to be completely appropriate by the 5+ a day programme and can help the consumer to reach the dietary recommendations.

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As a mirror image of the fruit, it 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 fibers which are predominantly lost during pressing, whereas fruit purees contain essentially the same amount of dietary fibers as the original fruit. Fruit purees can be used to make juice containing products such as nectars and smoothies.

Fruit juice health promoting components

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

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. 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, 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, peonidin, petunidin, pelargonidin, and malvidin) and other flavonoids (kaempferol and quercetin derivatives) (Szajdek and Borowska, 2008, Seeram, 2008). Among those, cranberries have been particularly studied (Neto 2007).
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), 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), and tomato juice[1] is a major source of lycopene (Lee et al, 2009).

[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.*

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In addition, juices may serve as carriers for added nutrients and beneficial dietary components such as calcium, vitamin D and phytosterols that may not be inherent in the fruit itself.

Fruit Juice Phytochemical Properties

In the last ten years, the mechanisms responsible for the health benefits of fruit juices have been considerably investigated. The biological activities cannot be solely explained by antioxidant effects. 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. It has been shown that 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, 2009; Koltover, 2009; Crozier et al 2009).
The question of the mode of action of 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 signaling 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 lead 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.

Health Benefits of Fruit Juices

The health benefits of fruits and fruit juices have been reviewed by Landon (2007). 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). 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, 2010).

Vitamins have a special role since they are essential for life and most are 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, however 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

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literature, folate is jointly responsible for the prevention 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).

Most of the diseases that seem to be targeted by phytochemicals are those induced by 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.

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). 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.
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).

Atherosclerosis is the condition in which an artery wall thickens as the result of a accumulation of fatty material. 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 ten 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)

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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.

Another signaling 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).

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).

Brain health, cognition and aging

Many 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), berries (Shukitt-Hale et al, 2008, 2009; Willis et al 2008) and citrus (Datla et al 2001) have been examined. 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 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 signaling 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

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have potential therapeutic roles against ischemic stroke, Alzheimer's disease, Parkinson's disease, and Huntington's disease (Harrison and May, 2009).

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).

In a different area related to inflammation, cranberry juice has long been associated with a reduction in urinary infections. Anthocyanidin and proanthocyanidin may inhibit the adhesion of uropathogens (e.g. uropathogenic E. coli) to the uroepithelium, thus impairing colonization and subsequent infection (Guay, 2009).

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). Flavonoids have been shown to improve skin microcirculation (Neukam et al, 2007) and collagen formation (Stipcevic et al, 2006; Bae et al, 2009). Carotenoids have also been shown to improve skin health (Stahl and Sies, 2007).

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 (2008) reported that the mean daily juice consumption was 4.1 fl oz, which contributed a mean intake of 58 kcal (3.3% of total energy intake). 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).

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

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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 may that limit or prevent insulin resistance. Recently 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, 2009), 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. Alcada 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.

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). 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 children with a high consumption of soft drinks are at a higher risk of developing dental caries relative to those consuming milk and 100 percent fruit juice, and 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

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2009; Ferrazzano et al, 2009). Furthermore, calcium and vitamin D added to juice can also add another beneficial effect (Davis et al, 2007). Recent 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

Conclusion

Fruit juices contain essential vitamins and minerals 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 fruit juices 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.

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