Chapter 7

The Role of Fruit and Vegetable Consumption in Human Health and Disease Prevention

O. O. Oguntibeju, E. J. Truter and A. J. Esterhuyse

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1. Introduction

Several reports have shown that adequate intake of fruits and vegetables form an important part of a healthy diet and low fruit and vegetable intake constitute a risk factor for chronic diseases such as cancer, coronary heart disease (CHD), stroke and cataract formation (Van Duyn & Pivonka, 2000). Scientific evidence indicates that frequent consumption of fruits and vegetables can prevent oesophageal, stomach, pancreatic, bladder and cervical cancers and that a diet high in fruits and vegetables could prevent 20% of most types of cancers (Crawford *et al*., 1994). According to reports, fruit and vegetable consumption is influenced by gender, age, income, education and family origin (Wardle *et al*., 2000; Giskes *et al*., 2002). Other studies suggest that education may influence nutritional knowledge about fruits and vegetables and consequently also influence their intake. Empirical findings also indicate that family origin and socioeconomic status affect the purchasing power of food, food choice, food preparation and food availability which in turn affects consumption. Studies have shown that preferences of fruit and vegetable consumption differ in males and females (Wardle *et al*., 2000; Wang *et al*., 2002). A study carried out by Sylvestre *et al* (2006) revealed that mothers consumed 2 1/2 vegetable servings and 2 1/2 fruit servings on average daily and that the reported daily average of fruit and vegetable servings was slightly below the basic recommendation of 5 servings per day (Sylvestre *et al*., 2006). The same study suggested that children of mothers who consume high fruit and vegetable consumption are more likely to consume fruits and vegetables frequently than children of mothers with low fruit consumption. If the mothers with high fruit and vegetable consumption eat fruits and vegetables at home during meals which are shared with children, then their findings could underpin the importance of fruit and vegetable availability at home. However, it may be important to verify whether the relationship is simply a reflection of the control mothers have over food availability at home or it relates to shared nutritional knowledge about the benefits of fruits and vegetables.

2. Fruits and vegetables as sources of vitamins, minerals and antioxidants

Fruits and vegetables play an important role in human nutrition and health, particularly as sources of vitamin C, thiamine, niacin, pyridoxine, folic acid, minerals and dietary fibre (Wargovich, 2000). In the USA, the consumption of fruits and vegetables as a group is known to contribute to an estimated intake of 91% of vitamin C, 48% of vitamin A, 30% of folate, 27% of vitamin B6, 17% of thiamine and 15% of niacin. It is also known that fruit and vegetable intake supply 16% of magnesium, 19% of iron and 9% of the calories (United States Department of Agriculture, 2000). Other vital nutrients supplied by fruits and vegetables include riboflavin, zinc, calcium, potassium and phosphorus. Some components of fruits and vegetables (phytochemicals) are strong antioxidants and modify the metabolic activation and detoxification/disposition of carcinogens and may even influence processes that may change the course of the tumor cell (Wargovich, 2000). Although antioxidant capacity varies greatly among fruits and vegetables (Kalt, 2002), it is better to consume a variety of them rather than limiting consumption to a few with the highest antioxidant capacity. The United States Department of Agriculture (2000) encourages consumers to take at least two servings of fruits and at least three servings of vegetables per day, choose fresh, frozen, dried or canned forms of a variety of colours, kinds and choose dark-green leafy vegetables, orange fruits, vegetables and cooked dry beans and peas regularly. However, in some countries, consumers are encouraged to eat at least 10 servings of fruits and vegetables per day. There is evidence that consumption of whole foods is better than isolated food components such as dietary supplements and nutraceuticals. For instance, previous reports (Southon, 2000; Seifried *et al.* 2003) showed that increased consumption of carotenoid-rich fruits and vegetables offer a better protective effect than carotenoid dietary supplements by increasing LDL-oxidation resistance, lowering DNA damage and inducing higher repair activity in human volunteers who participated in a study conducted in European countries such as Italy and Spain. High consumption of tomatoes and tomato products have been associated with reduced carcinogenesis, especially of prostate cancer and is thought to be due to the presence of lycopene, which gives red tomatoes their colour (Giovannucci, 2002). Boileau *et al.* (2003) observed that the use of tomato powder significantly reduced prostate carcinogenesis in rats. Examples of fruits and vegetables recommended for daily consumption include spinach, orange, mango, carrot, melon, pineapples red grapefruit etc.

3. Fruit and vegetable consumption: Human health and disease prevention

Childhood and adolescent obesity have reached epidemic proportions especially in the USA and the alarming rate at which this condition continues to increase is of great concern (Muriello *et al.*, 2006). Unfortunately, obesity among children and adolescents is also increasing in South Africa and in other African countries due to western influence, and since behavior-related attitudes to obesity prevention such as physical activity and fruit and vegetable consumption tend to decline with age, it is important that intervention efforts begin early in life (Muriello *et al.*, 2006). Research has shown that the consumption of fruits and vegetables may be associated with a decreased incidence and mortality of a variety of chronic diseases which includes obesity. Fruit and vegetable intake has been shown to have positive effects in terms of weight management and obesity prevention (Tohill *et al*., 2004). Duncan *et al*. (1983) conducted a study using a diet rich in fruits and vegetables and low in fats versus a diet which was higher in fats but lower in fruits and vegetables. Although both groups were eating to satiety, the group eating the diet rich in fruits and vegetables consumed on average, one half the energy intake when compared to those on high fat, low fruit and vegetable diet. He *et* al. (2006) carried out a study in respect of fruit and vegetable consumption and its relationship to weight management. Their study found that an increase in fruit and vegetable intake was associated with a 24% lower risk of becoming obese.

In a large cohort of pre-adolescents and adolescents living in the USA, body mass index (BMI) changes were relatively consistent during a three year follow-up study. At the beginning of the study, more males than females were overweight and during the follow-up, change in body mass index (BMI) was slightly higher among the boys than in the girls. Among both genders, about 75% of the adolescents did not meet the public health recommendation to consume at least five servings of fruits and vegetables per/day (Field *et al*., 2003). There are various benefits gained by consuming a diet rich in fruits and vegetables, but it is not clearly understood why a diet rich in fruits and vegetables would prevent obesity or excessive weight gain, suggesting that further studies are needed to elucidate and confirm possible mechanisms involved in the prevention of obesity by fruit and vegetable consumption.

Several cohort studies have examined the relationship between fruit and vegetable intake and coronary heart disease. These studies reported an inverse relationship between intake of fibre from fruits and vegetables and the risk of developing coronary heart disease. Meta-analyses of previous studies showed an inverse association between fruit and vegetable consumption and the occurrence of stroke which supports the concept that fruit and vegetable consumption has the potential to protect against cardiovascular events (Daucher *et al*., 2005; He *et al*., 2006). Daucher and co-workers (2006) carried out a meta-analyses of cohort studies and observed that the risk of developing coronary heart disease decreased by 4% for each additional portion per day intake of fruit and vegetables and by 7% for fruit consumption, indicating that fruit offer a more protective effect in reducing the risk of developing coronary heart disease (CHD). It has been observed that clinical and biological investigations support the protective effect offered by the intake of fruit and vegetables against coronary heart disease. Interestingly, the relationship is biologically valid with many clinical and laboratory data showing that the micro- and macro-constituents of fruit and vegetables improve important risk factors of CHD such as hypertension, dyslipidaemia and diabetes (Appel *et al*., 1997; Van Duyn *et al*., 2000; Bazzano *et al*., 2003). In different population studies, adequate fruit and vegetable intake have been shown to correlate with healthy lifestyles which may explain the lower CHD incidence rates among individuals who adequately consume fruits and vegetables. Generally, it is assumed that consumers of fruits and vegetables smoke less, exercise more and are better educated than non-consumers (Joshipura *et al*., 1999). Although many of the clinical and biological studies adjust for lifestyle factors, basic confounders may still explain part of the favourable association with CHD. High fruit and vegetable intakes are related to a healthy diet pattern (Hu *et al*., 1999; Hu *et al*., 2000) and inversely associated with the consumption of saturated fat-rich food (Tucker *et al*., 2005), which may also contribute to a lower CHD risk (Hu *et al*., 1999; Hu *et al*., 2000; Fung *et al*., 2001). It should be noted however, that most of the clinical and laboratory studies to date have not established a causal relationship between inadequate consumption of fruits and vegetables and the risk of developing CHD. Daucher *et al*. (2006) reported that in different observational studies selected for meta-analyses, the association between vegetable consumption and CHD risk was more pronounced for cardiovascular mortality than for incident CHD. They stated that the reason for the difference is not known but possible explanations may be related to publication bias since mortality studies have fewer outcomes than studies reporting incident CHD or that consumption of vegetables might have specific effects on mortality, a hypothesis that needs confirmation in cohorts with a large number of fatal outcomes. It is also possible that residual confounding factors such as measurement errors affected the association between fruit and /or vegetable intake and risk of developing CHD and differences in study types, including dietary assessment methods, the variety of fruits or vegetables investigated and the definition of the reference group may further explain the difference.

Ness and Powles (1997) reviewed evidence about fruit and vegetable intake and the development of coronary heart disease and found a significant inverse association between the amount of fruits and vegetables consumed and the incidence of coronary heart disease. Alonso *et al*. (2004) also reported a similar association between fruit and vegetable consumption and decreased blood pressure.

A study carried out by He *et al*. (2006) found a significant lower risk of stroke development among those with the highest intake of fruits and vegetables and Lock *et al* (2005) showed that increasing individual fruit and vegetable consumption by 600 grams per day could reduce the global burden of stroke by 19% and decrease the risk of CHD by 31% respectively.

High blood pressure increases the risk of heart disease and stroke (Chobanian *et al*., 2003). Adding more fruits and vegetables to a healthy diet is one possible pathway to reduce blood pressure. In the Dietary Approaches to Stop Hypertension (DASH) study (Appel *et al*., 1997), 459 people with and without high blood pressure were randomly assigned to one of three diets: a) a typical American diet that provided about 3 servings per day of fruits and vegetables and one serving per day of a low-fat dairy product, b) a fruit and vegetable diet that provided 8 servings per day of fruits and vegetables and one serving per day of a low-fat dairy product or c) a combination diet (called the DASH diet) that provided 9 servings per day of fruits and vegetables and 3 servings per day of low-fat dairy products. After 8 weeks, the blood pressures of those on the fruit and vegetable diet were significantly lower than those on the typical American diet.

It is believed that the evidence for a beneficial effect of a diet rich in fruits and vegetables on diabetes is not as convincing as it is for heart disease, however the results of a few studies suggest that higher intakes of fruits and vegetables are associated with improved blood glucose control and lower risk of developing type-2 diabetes. In a cohort study of 10, 000 adults in the USA, the risk of developing type-2 diabetes over the next 20 years was about 20% lower in those who reported consumption of at least 5 servings per day of fruits and vegetables as compared to those who did not consume fruits and vegetables (Ford & Mokdad, 2001). In a prospective cohort study that followed over 40 000 USA women for an average of nine years, fruit and vegetable intake was not associated with the risk of developing type-2 diabetes, however higher intakes of green leafy and yellow vegetables were associated with a significant reduction in the risk of developing type-2 diabetes in overweight women (Liu *et al*., 2004). A cross-sectional study of over 6000 non-diabetic adults in the UK, who consume higher volumes of fruits and vegetables showed to exhibit significantly low levels of glycosylated haemoglobin and it is postulated that potential compounds in fruits and vegetables that may enhance glucose control include fibre and magnesium (Sargeant *et al*., 2001).

Dietary factors are estimated to account for about 30% of cancers in developed countries, making diet second only to tobacco smoking as a preventable cause of all cancer. This contribution of diet to the incidence of cancer is estimated to be about 20% in developing countries but it may decrease with fruit and vegetable consumption (WHO, 2008). Evidence from case-control and cohort studies has indicated that the intake of fruits and vegetables have a strong protective effect against various types of cancer (oropharynx, oesophagus, stomach, colon and rectum) and that people with a higher intake may have less risk than people with low or very low fruit and vegetable intake (Block *et al*., 1992; Steinmetz & Jansen, 1996). Van't Veer and co-workers (2000) indicated that people with higher intakes of fruits and vegetables could reduce their risk of developing cancer by 19%. The association between fruit and vegetable intake and the risk of cancer has been said to be relative to the quantities of fruits and vegetables consumed and that there are three potential dose-response associations. It is anticipated that an extra serving of fruit and vegetables might achieve a much greater risk reduction when the total intake is relatively low than when it is high (a vitamin-like minimal requirement) or when the total intake is relatively high (a high threshold effect) and thirdly when intake is at all levels (not higher or lower) (Temple & Gladwin, 2003). With reference to the association between fruit and vegetable consumption, two cohort studies showed contrasting results. A study carried out by Terry *et al*. (2001) reported that fruit and vegetable intake could indicate a protective association only at intakes of about two servings per day whereas Mitchells *et al*. (2000) indicated that fewer than three servings of fruits and vegetables per week are not related to elevated risk of colorectal cancer. However, higher intakes of fruits and vegetables have been associated with a modestly significant reduction in lung cancer risk in a pooled analysis of eight prospective studies (Smith-Warner *et al*., 2003). Higher intakes of cruciferous vegetables have been linked to a significant reduction in the risk of developing bladder cancer in men (Micaud *et al*., 1999) and higher intakes of tomato products have been linked to a significant reduction in the risk of developing prostate cancer (Giovannucci *et al*., 2002). Joseph and coworkers (1999) indicated that supplementation of the diet of rats with fruits or vegetables (blueberry, strawberry or spinach) prevented or reversed age-related changes in neuronal and behavioural function. In our opinion, the finding of Joseph and coworkers is suggestive of a possible association between the mechanisms by which health may be modified by diet in both animal and man by the consumption of fruits and vegetables. A study carried by Galeone *et al*. (2007) showed that a high intake of fruits and vegetables significantly reduced the risk of lung cancer and that the reduced risk was significantly evident in smokers as well as non-smokers.

The incidence of cataracts has been reported to be related to oxidative damage of proteins in the eye's lens which is induced by long-term exposure to ultraviolet light. The cloudiness and discoloration of the lens resulting from such exposure have been known to lead to vision loss that becomes more severe with age. The results of various prospective cohort studies tend to suggest that diets rich in fruits and vegetables, particularly carotenoid and vitamin C-rich fruits and vegetables are associated with decreased incidence and severity of cataracts (Brown *et al*., 1999; Jacques *et al*., 2001; Christen *et al*., 2005). High intakes of broccoli and spinach have been reported to be associated to reduced cataracts among USA males (Brown *et al*., 1999).

Lutein and zeaxanthin are carotenoids that are found in relatively high concentrations in the retina and could play a role in preventing damage to the retina which is caused by light or oxidants (Mares-Perlman *et al*., 2002). In two reported case-control studies, high intakes of carotenoid-rich vegetables particularly those rich in lutein and zeaxanthin were said to be associated with a significant reduced risk of developing age-related macular degeneration (Seddon *et al*., 1994; Shellen *et al*., 2002). Another study involving more than 118 000 male and female participants found that those who consumed three or more servings of fruits and vegetables daily had their risk of developing age-related macular degeneration reduced by 36% than those participants who consumed less fruits and vegetables (Cho *et al*., 2004).

A beneficial association between reduced risk of developing chronic obstructive pulmonary disease and fruit and vegetable consumption has been documented (Romieu & Trenga, 2001). Epidemiological studies in Europe and elsewhere showed that higher fruit intake (particularly apple) can be associated with higher forced expiratory volume values, indicating a better lung function (Tabak *et al*., 2001; Butland *et al*., 2002). A European study of 2917 participants followed over twenty years with an increase in the daily consumption of fruits has been associated with a 24% decrease in the risk of death from chronic obstructive pulmonary disease. Although the reason for the association between increased fruit consumption and decreased risk of developing chronic obstructive pulmonary disease is not known but it is suggested that antioxidants such as vitamin C or flavonoids found in fruits may be playing a protective role in reducing the risk of developing chronic obstructive pulmonary disease.

Few studies have claimed that antioxidants found in most fruits and vegetable juices could help lower a person's risk of developing Alzheimer's disease. This may be related to the fact that freshly squeezed juices from fruits and vegetables are very good sources of minerals and vitamins which catalyze chemical reactions occurring in the body. Another benefit of fruits and fruit juices is their ability to promote detoxification of the human body. Fruits help to cleanse the body and tomatoes, pineapples and citruses such as oranges, red grapefruits and lemons are well known for their detoxifying properties (Cuthbertson, 2002).

Increased fruit and vegetable consumption of about 3 to 9 servings per day has been shown to decrease urinary calcium loss of about 50 mg/day and lower biochemical markers of bone turnover especially bone resorption (Appel *et al*., 1997; Lin *et al*., 2003).

The effects of HIV infection on the nutritional status of persons living with HIV and AIDS have been reported (Oguntibeju *et al*., 2006; 2007; 2008; 2009). It is known that good nutrition including the consumption of fruits and vegetables can contribute to the wellness and sense of well-being of people living with HIV and AIDS and may even prolong life. Fruits and vegetables are an important part of a healthy food intake and may supply the necessary vitamins, minerals and other substances that could boost the immune system (Department of Health, South Africa, 2001).

4. Possible mechanism of action of fruits and vegetables in human health and disease prevention

It is a common knowledge in biological science that mammalian and plant cells are constantly exposed to a variety of oxidizing agents. These oxidizing agents may be present in air, food, and water, or they may be produced by metabolic activity within the cells, however, it is important to maintain a balance between oxidants and antioxidants to be able to sustain optimal physiological conditions. Overproduction of oxidants can cause an imbalance, leading to oxidative stress (Ames *et al*., 1993; Adom *et al*., 2003). Oxidative stress can cause oxidative damage to macromolecules such as lipids, proteins and DNA and consequently lead to increased risk for developing chronic diseases such as cancer and cardiovascular disease (Ames *et al*., 1993; Liu *et al*., 1995). In order to prevent or reduce the oxidative stress induced by free radicals, sufficient amounts of antioxidants need to be consumed and fruits and vegetables are known to contain a variety of antioxidant compounds such as phenolics and carotenoids which may help protect cellular systems from oxidative damage and reduce the risk of developing chronic diseases (Wang *et al*., 1996; Vinson *et al*., 2001; Adom *et al*., 2003). It is known that carotenoids demonstrate photoprotection which originate from their ability to quench and inactivate reactive oxygen species (Britton, 1995).

Phenolics provide essential functions in the reproduction and the growth of plants; acting as defense mechanisms against pathogens, parasites, and predators as well as contributing to the colour of plants and may also provide health benefits associated with reduced risk of chronic diseases in humans (Sun *et al*., 2002).

Different species and varieties of fruits, vegetables, and grains have different phytochemical profiles (Adom & Liu, 2002; Adom *et al*., 2003) The combination of orange, apple, grape, and blueberry has been shown to display a synergistic effect in antioxidant activity and obtaining antioxidants from dietary intake by consuming a wide variety of foods is of significant importance due to the fact that foods originating from plants contain many diverse types of phytochemicals in various quantities.

Carcinogenesis is a multistep process, and oxidative damage is linked to the formation of tumors through several mechanisms (Ames *et al*., 1993; Liu *et al*., 1995). Oxidative stress induced by free radicals causes DNA damage, which, when left unrepaired, can lead to base mutation, single- and double-strand breaks, DNA cross-linking, and chromosomal breakage and rearrangement (Ames *et al*., 1993). This potentially cancer-inducing oxidative damage might be prevented or limited by the intake of dietary antioxidants which are found in fruits and vegetables. Studies to date have demonstrated that phytochemicals in common fruits and vegetables can have complementary and overlapping mechanisms of action, including antioxidant activity and the scavenging of free radicals, regulation of gene expression in cell proliferation, cell differentiation, oncogenes, and tumour suppressor genes, induction of cell-cycle arrest and apoptosis, modulation of enzyme activities in detoxification, oxidation, reduction, stimulation of the immune system, regulation of hormone metabolism, and antibacterial and antiviral effects (Ames *et al*., 1993; Liu *et al*., 1995; Adom & Liu, 2002).

It is believed that fruits and vegetables are rich in precursors to bicarbonate ions which serve to buffer acids in the body, therefore if the concentration of bicarbonate ions is inadequate to maintain normal pH, the body is capable of mobilizing alkaline calcium salts from bone in order to neutralize acids consumed in the diet and those generated by metabolism, thus increased consumption of fruits and vegetables reduces the net acid content of the diet and may preserve calcium in bones which might otherwise be mobilized to maintain normal pH (New, 2002).

The relationship between fruit and vegetable consumption and obesity has also been envisaged. It is not clear how fruit and vegetable consumption prevent obesity or excessive weight gain. However, one possible mechanism could be that fruits and vegetables might serve as healthy substitutes for more calorie-dense foods (Field *et al*., 2003).

5. Factors affecting the nutritional qualities and consumption of fruits and vegetables

Climatic conditions such as temperature and light intensity have been shown to have a strong effect on the nutritional quality of fruits and vegetables (Mozafar, 1994). Low temperature is believed to favour synthesis of sugar and vitamin C while short duration decreases the rate of ascorbic acid oxidation. Maximum beta-carotene content in tomatoes occurs at a temperature range of 15 to 21^{o}C but beta-carotene content is reduced if temperatures are higher or lower than this range, mainly due to the temperature sensitivity of lycopene, the precursor to beta-carotene and lutein.

The B vitamins are crop specific with reference to temperature sensitivity. Warm season crops (beans, tomatoes, peppers, melons) produce more B vitamins at high (27 to 30 ^{o}C versus low (10 to 15 ^{o}C) temperatures. In contrast, cool season crops such as broccoli, cabbage, spinach, peas produce more B vitamins at low versus high temperature. It has been reported that light intensity has little effect on the B vitamins but as light intensity increases, vitamin C increases and total carotenoids and chlorophyll decrease (Gross, 1991). Higher light intensities produce more sugars thus favouring the synthesis of vitamins and also increase plant temperatures, inhibiting beta-carotene production which protects chlorophyll from light bleaching. According to Goldman *et al*. (1999), the type of soil, the rootstock used for fruit trees, irrigation, fertilization and other traditional practices influence the water and nutrient supply to the plant and have been shown to affect the composition and quality attributes of fruits and vegetables. Other environmental factors such as altitudes, soil pH, salinity, insects and plant diseases have also been reported to affect composition and quality of fruits and vegetables. Also, processing and cooking methods do affect the nutritional value of fruits and vegetables (Lee & Kader, 2000). For example, water-soluble vitamins such as vitamin C and folic acid are readily lost at high rates when cooking water is discarded.

The level of education has been shown to be related to fruit and vegetable consumption in children and adults. It has been shown that mothers with a higher level of education tend to consume more fruits and vegetables and also influence their children to do so (Gibson, *et al*., 1998) and that higher income influences the availability of fruits, which in turn affect consumption in both adults and children. Family origin is said to influence food choice and preparation and one study indicated that the frequency of fruit and vegetable consumption in both mothers and children differs according to origin (Shatenstein & Ghadirian, 1998).

6. Recommendations and further studies

For an adequate supply of vitamins, minerals and other compounds from fruits and vegetables, it is important to purchase fresh fruits and vegetables without bruises, soft spots, mold, decay or broken skins. It is very important to wash all fruits and vegetables before cutting, slicing and eating. It is also advisable to store fruit and vegetables in the refrigerator but once cut or sliced, fruits and vegetables should be placed in a refrigerator in tightly sealed plastic bags and consumed within two to three days.

There is a need for more controlled, clinical intervention trials in order to confirm findings that support the view that consumption of fruits and vegetables promotes health and reduces the risk of developing chronic diseases. Accurate assessment of dietary intake remains difficult and cost-efficient methods for estimating fruit and vegetable intake are needed to be able to confirm the relationship between fruit and vegetable consumption. Although research evidence supports the association between fruit and vegetable consumption and decreased incidence and mortality of chronic diseases such as obesity, different cancers and cardiovascular diseases, controversies still exist in the science community with reference to their association, therefore further studies with large population groups over long periods of time is recommended.

Author details

O.O. Oguntibeju, E.J. Truter and A.J. Esterhuyse
Oxidative Stress Research Centre, Department of Biomedical Sciences, Faculty of Health & Wellness Sciences, Cape Peninsula University of Technology, Bellville Campus, South Africa

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