Functional Properties of Fruit

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ABSTRACT

In recent years a number of nutritional studies have been devoted to examining specific foods for their putative healthy protective role and disease-preventing potential. Different epidemiological studies have consistently shown that there is a positive association between the intake of fruits alone or in combination with vegetables with a reduced rate of heart disease mortality, and between some common tumors and other chronic diseases such as obesity and diabetes as well as, risk of eye diseases. Fruits may reduce blood lipids and when included in hypocaloric diets may help to lose weight. Recently, fruits have attracted a great deal of attention focusing on their role in some oxidative stress related diseases. This interest is attributed to the fact that these foods may provide an optimal content of phytochemicals such as natural antioxidants, vitamins, minerals, polyphenols and other compounds with healthy properties. Moreover, typical fruit components like fructose and fiber have been suggested to produce specific effects on oxidative stress. In addition, the effects of fruit on weight loss and lipid profile when included in energy restricted diets could be triggered through the antioxidant properties of fruit.

Keywords: antioxidant capacity, fruit, oxidative stress, total cholesterol, weight loss

Abbreviations: ABTS, 2,2'-azinobis(3-ethylbenzothiazoline-6-sulfonic acid); ROS, reactive oxygen species; FRAP, ferric reducing-antioxidant power; TAC, total antioxidant capacity; TEAC, trolox equivalent antioxidant capacity; TRAP, total radical-trapping antioxidant parameter

INTRODUCTION

Eating patterns in Western industrialized countries are characterized by a high energy intake and an overconsumption of saturated-fat, cholesterol, sugar and salt (Engbers et al. 2006). Many chronic illnesses such as obesity, diabetes, cardiovascular or neurodegenerative diseases, as well as cancer, are partially associated with these unhealthy habits (Engbers et al. 2006). In contrast, low saturated fat intake and high fruit and vegetable intake have been found important in the prevention of health problems and in the reduction of chronic diseases risk (Liu 2003; Engbers et al. 2006).

Fruit are rich sources of a variety of nutrients, including vitamins, fiber and also of some kinds of biologically active compounds such as polyphenols and carotenoids among others, that may be as an essential in dietary disease prevention, either alone or in some cases in combination with vegetables, nuts, and other plant foods (Lampe 1999).

In this context, daily consumption of at least three to five servings of fruits and vegetables may inhibit or slow down chronic disease progression, due to their capacity to modulate biological processes by means of their nutrients and phytochemical compounds (Pajk et al. 2006). However, the putative mechanisms that may be responsible for the favourable effect of fruit consumption remain mainly undefined. In this review, some mechanisms currently proposed to prevent chronic disease risk and promote health status concerning fruit consumption are reported.

NUTRITIONAL VALUE AND PHYTOCHEMICALS CONTENT OF FRUITS

High intakes of fruits are commonly recommended because plant-foods contain a high proportion of water, are low in fats, high in fiber and fructose, and are good sources of vitamins and minerals (Pajk et al. 2006). Also, there are many minor components in such foods, particularly plant-derived foods, denominated phytonutrients, which elicit biological responses in mammalian systems that are consistent with reduced risk of one or more chronic diseases (Beecher 1999).

Fruit can be consumed fresh, canned or as juice. Both fruits and fruit juices are rich in vitamins and minerals like vitamin C, potassium and folate. Assessed total antioxidant capacity in fruit juices showed a similar value as compared with whole fruit (Pellegrini et al. 2003). Therefore, individuals can consume fruit and vegetable juices to achieve the...
recommended amounts of Vitamin A, Vitamin C, folate and potassium. However, whole fruits offer some nutritional advantages. Fresh, canned and frozen fruits are generally a good source of fiber, but fruit juices often are not.

**Nutritional value of fruits**

Fruits constitute an indispensable group of foods for balancing the human diet, especially by their contribution to fiber and vitamin supply (Table 1). Fruits tend to be juicy because of their high content of water, usually ranging from 75% to 90%. Soluble substances that can be found in the moisture are sugars, salts, organic acids, water-soluble pigments, and vitamins (Ansorena 1999). Aside from water, carbohydrates are the main constituents in fruits, which include sugars, starches and non-digestible carbohydrates (Beliz 2004). The sugar content of fruits increases as they ripen. In addition, fruits provide bulk to the diet through their content in fiber; including celluloses, hemicelluloses and pectin substances, which are not digested by the lack enzymes capable of hydrolyzing such substances. Moreover, one serving of most fruits commonly contains 1 gram or less of protein with a low amount of fat. Fruits are poor in calcium and phosphorus and, in general, are not particularly good sources of iron (Ansorena 1999; Beliz 2004).

As concerns vitamins, most fruits are low in the B-vitamins. Citrus fruits, including oranges, lemons and grapefruit, are excellent sources of ascorbic acid (Beliz 2004). Yellow fruits such as peaches are a fairly good source of carotenoids, the precursor of vitamin A (Table 1). Furthermore, fruits are able to supply different non-nutritional components such as polyphenols or other compounds, which may have healthy benefits (Pellegrini et al. 2003).

**Antioxidant capacity of fruit**

The antioxidant capacity of several substances occurring in plants has been documented in human intervention studies, although most of the work has been directed towards the effects of vitamins C and E and β-carotene (Lampe 1999; Takase et al. 2004; Goralczyk et al. 2006). Also, flavonoids, more potent antioxidants than vitamin C and E have received more attention in the last years (Scalzo et al. 2005). These constituents operate additive and synergistically contributing to the health benefits attributed to the diet (Liu 2003; Saura-Calixto et al. 2006). Because different antioxidant compounds may act in vivo through different mechanisms no single method can fully evaluate the total antioxidant capacity (TAC) of foods. Based on this assumption, several studies evaluated the TAC of individual foods by means of three assays (Halvorsen et al. 2002; Pellegrini et al. 2003); trolox equivalent antioxidant capacity (TEAC), radical-trapping antioxidant parameter (TRAP), and ferric reducing-antioxidant power (FRAP). The TRAP assays evaluate the chain-breaking antioxidant potential and FRAP methods assess the reducing power of the sample (Pellegrini et al. 2003), while trolox equivalent antioxidant capacity (TEAC) assay measures the ability of antioxidants to quench a 2,2’-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) radical cation (ABTS+) in both lipophilic and hydrophilic environments (Re et al. 1999). Based on TAC data from Pellegrini et al. (2003), the TAC of some common consumed fruits in the European and American diet (Naska et al. 2000; Darmon et al. 2005) is reported (Table 1).

Analysed berries, plums, and some varieties of apples have a relatively high TAC, which is likely to be associated to the high content of flavonoids such as anthocyanins. Oranges and grapes exhibited intermediate antioxidant capacity in agreement with the higher concentrations of phenolic compounds and vitamin C, while bananas, melon and watermelon had low TAC values (Halvorsen et al. 2002; Pellegrini et al. 2003).

**CLINICAL AND EPIDEMIOLOGICAL EVIDENCES ABOUT BENEFITS OF FRUIT CONSUMPTION**

Epidemiological and experimental studies have shown a role of plant-food intake in the maintenance of health (Potter 2005; He et al. 2006; Gonzalez 2006). So, scientific evidences (Table 2) suggest that a vegetable-based and high-fiber diet is associated with improvement in overall survival after breast cancer diagnosis in postmenopausal women (Jaiswal McEligot et al. 2006). The risk of oral pre-malignant lesions is significantly reduced with higher consumption of fruits, particularly citrus fruit and juices (Maser- rejian et al. 2006) and frequent consumption of fruit may reduce the risk of colorectal adenoma (Michels et al. 2006). Furthermore, the effect of cigarette smoking on bladder cancer risk was reduced by fruit consumption (Kellen et al. 2006). However, some cohort studies concluded that fruit and vegetable have no effect in relation to overall cancer (Potter 2005; van Gils et al. 2005). There is limited evidence for a cancer-preventive effect of the consumption of fruits and vegetables, nevertheless it is important to recognize that some cancers might be preventable by increasing fruit and vegetable intake (Vainio et al. 2006).

Many studies have reported a benefit of fruit on cardiovascular disease (Hu and Willett 2002). In fact, in a case-control study, an inverse association has been found between the first acute myocardial infarction and the consumption of fruits among the Spanish Mediterranean diet (Martinez-Gonzalez et al. 2002). Recent studies have shown, for instance (Table 1), that fresh red grapefruit inclusion in generally accepted diets could be beneficial for hyperlipidemic patients suffering from coronary atherosclerosis (Gor-
inst et al. 2006). Also, fruit consumption in smoking subjects could contribute to the prevention of cardiovascular disease (McAnulty et al. 2005) and a combination of fruit and vegetables intake may improve some cardiovascular risk factors in hypertensive patients (Adebawo et al. 2006). Epidemiological studies concerning the metabolic syndrome (Table 2) have demonstrated that a high dietary consumption of fruit and vegetables results in lower risks of diabetes. Furthermore, after 10 weeks administration of the fruit extract, intraperitoneal glucose tolerance tests revealed significant decrements of blood glucose levels after glucose loading, supporting an advantageous association of fruit consumption with diabetes (Sugiura et al. 2006). Moreover, other surveys revealed an inverse association of fruit/vegetable consumption with weight gain (Bes-Rastrollo et al. 2006). However, interventions prescribing a plant-based diet without a specific energy restriction do not appear to promote changes in body weight (Thomson et al. 2005). Therefore, enriched fruit hypocaloric diets have seem to be involved in the beneficial effects on cardiovascular disease associated risk factors by decreasing cholesterol plasma levels (Rodriguez et al. 2005; Crujeiras et al. 2006).

On the other hand, several studies have examined the relationship of eye diseases with foods and specifically, fruits intake shows a beneficial effect to prevent cataract attributed to their antioxidant content (Christen et al. 2005).

### MECHANISMS OF FRUIT TO PROTECT AGAINST CHRONIC DISEASE

Experimental trials involving fruit intake have shown a decrease in lipid profile as well as weight loss, when fruit is included in hypocaloric diet, in relation with the composition of fruit (Conceição de Oliveira et al. 2003; Rodriguez et al. 2005; Crujeiras et al. 2006). The fiber content, minerals and other compounds of fruit may be responsible for such protective effect. However, the beneficial effects of fruit have been also attributed to their high level of antioxidant compounds by decreasing oxidative stress.

### Fiber-fruits effect

Fruit, together with vegetables and cereals, are the major sources of dietary fiber. Nowadays and after 30 years of research, dietary fiber is a substantial key of healthy diet according to current recommendation criteria. Dietary fibers reach the large bowel where they are attacked by colonic microflora, yielding short chain fatty acids, hydrogen, carbon dioxide, and methane as fermentation products. Short chain fatty acids are implicated in some beneficial functions for the human organism. Although there are no yet conclusive data on recommendations of different types of fiber, it is still appropriate to prescribe a diet providing 20-35 g/day of fiber from different sources (Escudero Alvarez et al. 2006). Both a high-fiber diet and the prescription of fiber are common in the primary and secondary care management of constipation since they reduce transit times (Wisten et al. 2005). Indeed, a reduced transit time has been associated with protection against colorectal cancer, by decreasing the likelihood to colonic carcinogen exposure (Lim et al. 2005).

Insoluble fibers, cellulose and hemicellulose, are known to slowly and selectively stimulate anaerobic bacterial fermentation into more distal areas of the colon. The slow, sustained effect of metabolic activity and production of short-chain fatty acids, specifically butyrate, and consequent reduction in pH and conversion of bile acids, into more distal regions, has been shown to have a strong physiological impact in biomarkers (van Loo 2004). Mechanisms for beneficial effects of fiber might include changing the activity of exogenous carcinogens through metabolic modulation and/or detoxification. Moreover, modification of immune responses could be important in producing beneficial effects of dietary fiber (Pool-Zobel et al. 2005).

Taking into account the metabolic syndrome features, pectins have been proposed as one way in which fruit consumption contributes to cardiovascular disease prevention (Marlett et al. 2002). Several mechanisms by which fiber lowers blood cholesterol have been reported. Thus, some evidences suggest that some soluble fibers bind bile acids and cholesterol during intraluminal formation of micelles, resulting in liver cell cholesterol content reduction (Anderson et al. 2000). Another reported mechanism is the inhibition of hepatic fatty acid synthesis mediated by products of fermentation, such as acetate, butyrate and propionate (Aller et al. 2004).

Body weight loss could be modulated by specific nutrients and macronutrient distribution included in energy restricted diets (Abe et al. 2006). Many conventional dietary approaches concerning weight management are based on the reduction of the dietary fat intake in order to induce weight loss, which in some cases is achieved by increasing fruit and vegetable consumption (Rodriguez et al. 2005). In this

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<table>
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<th>Study reference</th>
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<th>Population</th>
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<tr>
<td>Rodrigues et al. 2005</td>
<td>Intervention</td>
<td>Obese women (n=15)</td>
<td>Fiber content from enriched fruit diets may be involved in the favourable effects on cholesterol plasma levels.</td>
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<tr>
<td>van Gils et al. 2005</td>
<td>Longitudinal</td>
<td>Diagnosed breast cancer women (n=285526)</td>
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<td>McAnulty et al. 2005</td>
<td>Case-control</td>
<td>Smoker subjects (n=20)</td>
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<td>Jaiswal &amp; McEligot et al. 2006</td>
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<td>Maserejian et al. 2006</td>
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<td>Diagnosed oral premalignant lesions subjects (n=207)</td>
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<td>Michels et al. 2005</td>
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<td>Women in Nurses' Health Study (NHS) (n=34467)</td>
<td>Frequent consumption (5 servings/d) of fruit may reduce the risk of colorectal adenomas.</td>
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<tr>
<td>Kellen et al. 2006</td>
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<td>Healthy (n=385) and diagnosed bladder cancer subjects (n=200)</td>
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<td>Adebawo et al. 2006</td>
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<td>The consumption of a combination of fruits and vegetable may decrease decrements of blood glucose levels after glucose loading.</td>
</tr>
<tr>
<td>Bes-Rastrollo et al. 2006</td>
<td>Cross-sectional</td>
<td>Men (5094) and women (6613)</td>
<td>Fiber or fruit/vegetable consumption is inversely associated with weight gain.</td>
</tr>
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regard, it has been suggested that fiber acts as a physiologic ob- 
estacle to energy intake, displacing available calories and nu-
trients from the diet, increasing satiety and decreasing 
the absorption efficiency of the small intestine (Slavin 2005). Indeed, 
populations reporting higher-fiber diet in-
take demonstrate lower obesity rates (Slavin 2005). There-
fore, fruit can aid against body weight gain by means of its 
absorption efficiency of the small intestine (Slavin 2005). In this 
context, rich fiber foods such as fruits are often characterized by low glycemic index 
and glycaemic load (Jenkins et al. 1995) and a diet with a 
low glycemic index has been associated with lower risks of type 2 diabetes and coronary heart disease and obesity in prospective studies (Willett et al. 2002).

**Fructose-fruit effect**

Fructose provides high amounts of fructose and some resear-
chers have shown that the fructose intake may be associated with 
the prevalence of obesity, type 2 diabetes mellitus, and non-alcoholic fatty liver disease development, since high fructose levels can serve as a relatively unregulated source of acetyl-CoA (Bray et al. 2004). Indeed, studies in human subjects have demonstrated that fructose ingestion results in markedly increased rates of de novo lipogenesis (Elliott et al. 2002). However, those trials finding a positive relationship between fructose intake and non-healthy effects have been carried out by means of punctual interventions based upon high-fructose corn syrup intake (Tordoff et al. 1990) or incorporating high quantities of dairy fructose intake (Anderson et al. 1989). The oral administration of small amounts of fructose in animals and in humans appears to have an specific action increasing the hepatic glucose absorp-
tion thereby stimulating glycogen synthesis and restoring 
the ability of hyperglycaemia to regulate hepatic glu-
cose production (Petersen et al. 2001).

Some nutritionists and researchers consider fructose as a relatively safe form of sugar, being often recommended for people with diabetes and included in many weight-loss programs. This monosaccharide appears to facilitate weight loss by suppressing appetite during the postprandial period (Gaby 2005). Moreover, some scientific evidences have found an increase in hepatic gluconeogenesis during caloric restriction mediated by fructose intake (Hagopian et al. 2005). So, this monosaccharide would not be used for de novo lipogenesis when it is included in a hypocaloric diet (Hagopian et al. 2005).

Fructose presents beneficial effects as a source of fructose because of the relatively small amount of the sugar, with the conjunction of fiber and antioxidants. Reinforcing this observation, nutritional studies showed that subjects treated with a fruit-rich hypocaloric diet reached the estimated weight loss and decreased circulating cholesterol levels (Conceição de Oliveira et al. 2003; Rodriguez et al. 2005; Crujeiras et al. 2006).

**Antioxidant-fruit effect**

In aerobic organisms, reactive oxygen species (ROS) are generated constantly during mitochondrial oxidative metab-
olism (Finkel et al. 2000). These highly reactive com-
pounds will potentially alter the structure and function of several cellular components, such as lipids, proteins and nu-
cleic acids (Sies 1997). In response to free radical produc-
tion, living organisms have developed an antioxidant defence network, which should prevent the harmful effects, removing these reactive species before damage, eliminating damaged molecules and preventing mutations (Sies 1997; Halliwell 2006). An excessive and/or sustained increase in free radical production associated with diminished efficacy of the cellular defence systems results in oxidative stress, which occurs in many pathological processes and may sig-
nificantly contribute to disease onset (Halliwell 2006). It has been hypothesized that ROS play a key role in cardio-
vascular disease, cancer initiation, the aging process, in-
flammatory disease and a variety of neurological disorders 
(Mayne 2003) Also, oxidative stress has been associated with diabetes mellitus and obesity (Dandona et al. 2005; Vincent et al. 2006).

Oxidation is characterized by a steady formation of 
prooxidants balanced by a similar rate of their consumption 
by antioxidants. To maintain this equilibrium, there is a re-
quirement for the continuous supply of antioxidants, and the 
source of the first antioxidant defence is mainly the diet (Liu 2003; Pajk et al. 2006). In this context, fruits have been regarded as having considerable health benefits, due in par-
ticular to their antioxidant content, which can protect the human body against cellular oxidation reactions (Scalzo et al. 2005).

On the basis of the assumption that the antioxidant 
components of fruit may be responsible for the effects of 
such food, many studies have focused on vitamin C and 
carotenoids. However, the results of supplementation 
studies with pure vitamins are not conclusive about their 
contribution to health promotion. Natural phytochemicals 
may not be effective or safe when consumed at high doses, 
even in a pure dietary supplement form (Liu 2003). Some 
findings suggest that long-term experimental antioxidant 
vitamin supplementation increases oxidative stress, which 
may be partly related to the direct prooxidant effect of vita-
min radicals (Halliwell 2000; Versari et al. 2006).

Rather, the antioxidant effect can be produced by the 
action of less known compounds or from a combination of 
different compounds occurring in the foods with direct or 
indirect antioxidant effects. In this context, fructose has 
been proposed to produce specific effects on oxidative stress. Animal models fed with a high content of fructose have shown a significant increase in the antioxidant capacity and prevention of lipid peroxidation (Girard et al. 2005). This 
fructose component induces uric acid synthesis due to its rapid 
metabolism by fructokinase (Heuckenkamp et al. 1971). 
Uric acid has been widely recognized in the literature as a 
metabolic compound with high antioxidant power particip-
ating as in vivo scavenger (Chantzounis et al. 2005). In ad-
dition to this, a previous study suggests that urate is re-
ponsible for the increase in antioxidant capacity after con-
suming apple as fruit (Lotito et al. 2004). In agreement with 
these observations, our research group found that the anti-
oxidant capacity of plasma was associated with blood urate 
concentration in obese women, although keeping the levels in 
acceptable metabolic range (Crujeiras et al. 2006). 
Furthermore, some studies have associated antioxidant 
properties to fiber-enriched diets since these compounds en-
hance the capacity to detoxify free radicals (Diniz et al. 
2005). Numerous factors may explain the effects of dietary 
fiber on the antioxidant capacity. As mentioned earlier, fi-
ers alter fat absorption from the diet, by impairing lipid hy-
drolysis, resulting in increased fat excretion. ROS genera-
tion may be also decreased due to a reduced dietary lipid in-
take, thus ameliorating lipid peroxidation. Moreover, 
fiber secondary metabolites that arise from bacterial fermenta-
tion in the colon may have antioxidant properties (Diniz et al. 
2005).

Recently, the concept of antioxidant dietary fiber (AODF) has been introduced, since this natural product con-
tains significant amounts of natural antioxidants associated 
with the fiber matrix (Jimenez-Escalrig et al. 2001). In this 
context, fruits such as grapes, are a suitable source to obtain 
ahantioxidant dietary fiber (Saura-Calixto 1998). Reinforcing 
this idea, a significant correlation between antioxidant power in plasma and dietary fiber plus fructose evidenced the beneficial effect of fruit intake on antioxidant capacity in obese women (Crujeiras et al. 2006). Hence, it is concei-
vable that some reported antioxidant health effects of phyto-
chemicals from fruits can be also associated to the meta-
bolic effect of fructose and fiber on antioxidant defences.

Additionally, it has been described that the fruit-induced
decrease in cholesterol levels and body weight was in parallel with oxidative stress improvement when evaluated by means of prooxidant and antioxidant ratio in plasma. These outcomes suggest an indirect antioxidant effect of fruit intake mediated by weight loss and hypothalamic-related induction (Crujeiras et al. 2006). These results are in agreement with other nutritional trials that showed a decrease in oxidative damage to lipids, proteins and amino acids, after dietary restriction and weight loss in obese people over a short period and a direct influence of the hypoholesterolenic legumes diet-related effect on lipid peroxidation (Dandona et al. 2001; Crujeiras et al. 2007).

CONCLUSION

A number of epidemiological and nutritional intervention studies have associated fruit consumption with a decreased risk of suffering chronic diseases. These effects are mediated by biologically active compounds of fruit, specifically with antioxidant properties. In this context, fruit contents high level of antioxidant compounds, vitamins and polyphenols. However, evidences suggest that antioxidants are better acquired through whole-fruit consumption as compared with dietary supplements. Furthermore, other compounds like fructose and fiber have been proposed to produce specific effects on oxidative stress. Fructose could induce antioxidant mechanism by means of uric acid synthesis, a potent scavenger and fiber decreases lipid plasma levels and induce weight loss, preventing obesity and cardiovascular disease. Moreover, weight loss and decrease in circulating cholesterol produced by fruit-based diets are associated with improvement in oxidative stress. Therefore, the effects of fruit on weight loss and lipid profile could be an indirect antioxidant mechanism beside of direct antioxidant properties of fruit to prevent and improve chronic diseases and co-morbidities.

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