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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-6sulfonic 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

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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 reducetion 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

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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), total 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-6sulfonic acid) radical cation ($ABTS^{\cdot+}$) in both lipophilic and hydrophilic environments (Re *et al*. 1999). Based on TEAC 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 premalignant lesions is significantly reduced with higher consumption of fruits, particularly citrus fruit and juices (Maserejian *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 antherosclerosis (Gor-

Table 1 Content on macronutrients, as well as, on fructose, fiber, vitamins and total antioxidant capacity (TAC) of some common kinds of fruit in European and American diet.

Fruit	CHO* (g/100g)	Protein* (g/100g)	Fat* (g/100g)	Fructose# (g/100g)	Fiber* (g/100g)	Vit C* (mg/100g)	Vit E* (mg/100g)	Vit A* (μEq.retinol/100g)	TAC$ (mmol/kg)
Apple	10.5	0.3	Tr	5.0	2.3	12.4	0.4	4.0	1.3
Banana	20.8	1.2	0.3	3.8	2.5	11.5	0.23	18.0	0.6
Black grape	15.5	0.6	0.7	8.0	0.4	4.0	0.7	3.0	3.8
Cherry	13.5	0.8	0.5	5.5	1.5	8.0	0.1	3.0	2.7
Kiwifruit	12.1	1.0	0.5	4.4	1.5	94.0	-	3.0	2.3
Melon	6.0	0.6	Tr	-	0.7	25.0	0.1	3.0	1.2
Orange	8.9	0.8	Tr	2.4	2.3	50.6	0.21	49.0	8.7
Peach	9.0	0.6	0.1	0.9	1.4	8.0	0.5	17.0	1.7
Pear	11.7	0.4	0.1	6.0	2.2	5.2	0.9	2.0	2.2
Pineapple	11.5	0.5	0.1	2.3	1.2	20.0	0.1	3.0	9.9
Plum	11.0	0.6	0.2	3.5	2.1	3.0	0.7	21.0	5.1
Strawberry	7.0	0.7	0.6	2.3	2.2	60.0	0.2	1.0	11.3
Watermelon	4.5	0.4	Tr	-	0.2	5.0	0.1	18.0	0.7
White grape	16.1	0.6	Tr	8.2	0.9	4.0	0.70	3.0	2.5

Source: (Ansorena 1999; Beliz 2004).
*Source: (Mataix 2003)
$ Source: (Pellegrini *et al.* 2003)

Table 2 Recent epidemiological and experimental evidences about the potential beneficial effects of fruit consumption.

Study reference	Study	Population	Major finding
Rodriguez *et al*. 2005	Intervention	Obese women (n=15)	Fiber content from enriched fruit diets may be involved in the favourable effects on **cholesterol plasma levels**.
van Gils *et al*. 2005	Longitudinal	Diagnosed breast cancer women (n=285526)	Total or specific vegetable and fruit intake is not associated with risk for **breast cancer**.
McAnulty *et al*. 2005	Case-control	Smoker subjects (n=20)	Regular ingestion of modest amounts of blueberries may reduce the risk of **CVD** by decrease in lipid hydroperoxides.
Jaiswal McEligot *et al*. 2006	Cross-sectional	Postmenopausal women (n=586)	Improvement overall survival after **breast cancer** diagnosis with plant-based and high-fiber diet.
Maserejian *et al*. 2006	Longitudinal	Diagnosed oral premalignant lesions subjects (n=207)	Reduced risk of oral **premalignant lesions** with higher consumption of citrus fruits and juices.
Michels *et al*. 2006	Longitudinal	Women in the Nurses' Health Study (NHS) (n=34467)	Frequent consumption (5 servings/d) of fruit may reduce the risk of **colorectal adenomas**.
Kellen *et al*. 2006	Case-control	Healthy (n=385) and diagnosed bladder cancer subjects (n=200)	The effect of cigarette smoking on **bladder cancer** risk is reduced by fruit consumption.
Adebawo *et al*. 2006	Intervention	Hypertensive patients (n=20)	The consumption of a combination of fruits and vegetable may decrease of **cardiovascular risk** factors.
Gorinstein *et al*. 2006	Intervention	Hiperlipidemic patients (n=57)	Fresh red grapefruit to generally accepted diets could be beneficial for hyperlipidemic patients suffering from **coronary atherosclerosis**.
Sugiura *et al*. 2006	Intervention	Male Wistar rats (n=5)	10 weeks administration of the fruit extract revealed significant decrements of **blood glucose** levels after glucose loading.
Bes-Rastrollo *et al*. 2006	Cross-sectional	Men (5094) and women (6613)	Fiber or fruit/vegetable consumption is inversely associated with **weight gain**.
Crujeiras *et al*. 2006	Intervention	Obese women (n=15)	Antioxidant substances of fruit, with the weight reduction, could increase the **improvement of cardiovascular risk factors related to obesity**.

instein *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; Miller *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 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-fruit 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 nutriaents and macronutrient distribution included in energy restricted diets (Abete *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 regard, it has been suggested that fiber acts as a physiological obstacle to energy intake, displacing available calories and nutrients from the diet, increasing satiety and decreasing the absorption efficiency of the small intestine (Slavin 2005). Indeed, populations reporting higher-fiber diet intake demonstrate lower obesity rates (Slavin 2005). Therefore, fruit can aid against body weight gain by mean its high fiber content besides its low fat content.

Moreover, dietary fiber has been shown to delay the absorption of carbohydrates after a meal and thereby decrease the insulinemic response to dietary carbohydrates (Anderson *et al*. 1995). In this context, rich fiber foods such as fruits are often characterized by low glycaemic index and glycaemic load (Jenkins *et al*. 1981) and a diet with a low glycaemic 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

Fruit provides high amounts of fructose and some researchers 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 absorption thereby stimulating glycogen synthesis and restoring the ability of hyperglycaemia to regulate hepatic glucose 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).

Fruit 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 metabolism (Finkel *et al*. 2000). These highly reactive compounds will potentially alter the structure and function of several cellular components, such as lipids, proteins and nucleic acids (Sies 1997). In response to free radical overproduction, 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 significantly contribute to disease onset (Halliwell 2006). It has been hypothesized that ROS play a key role in cardiovascular disease, cancer initiation, the aging process, inflammatory 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).

Aerobic life 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 requirement 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 particular 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 vitamin 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 fruit 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 participating as *in vivo* scavenger (Glantzounis *et al*. 2005). In addition to this, a previous study suggests that urate is responsible for the increase in antioxidant capacity after consuming apple as fruit (Lotito *et al*. 2004). In agreement with these observations, our research group found that the antioxidant 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 attributed antioxidative properties to fiber-enriched diets since these compounds enhance 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, fibers alter fat absorption from the diet, by impairing lipid hydrolysis, resulting in increased fat excretion. ROS generation may be also decreased due to a reduced dietary lipid intake, thus ameliorating peroxidative damage. Moreover, fiber secondary metabolites that arise from bacterial fermentation 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 contains significant amounts of natural antioxidants associated with the fiber matrix (Jimenez-Escrig *et al*. 2001). In this context, fruits such as grapes, are a suitable source to obtain antioxidant 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 conceivable that some reported antioxidant health effects of phytochemicals from fruits can be also associated to the metabolic 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 hypocholesterolemic 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 hypocholesterolemic 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 as 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 compounds to prevent and improve chronic diseases and co-morbidities.

REFERENCES

Abete I, Parra MD, MA Z, Martínez JA (2006) Different dietary strategies for weight loss in obesity: role of energy and macronutrient content. *Nutrition Research Reviews* **19**, 1-19

Adebawo O, Salau B, Ezima E, Oyefuga O, Ajani E, Idowu G, Famodu A, Osilesi O (2006) Fruits and vegetables moderate lipid cardiovascular risk factor in hypertensive patients. *Lipids in Health Disease* **5**, 14

Aller R, de Luis DA, Izaola O, La Calle F, del Olmo L, Fernandez L, Arranz T, Hernandez JM (2004) Effect of soluble fiber intake in lipid and glucose levels in healthy subjects: a randomized clinical trial. *Diabetes Research and Clinical Practice* **65**, 7-11

Anderson JW, Allgood LD, Lawrence A, Altringer LA, Jerdack GR, Hengehold DA, Morel JG (2000) Cholesterol-lowering effects of psyllium intake adjunctive to diet therapy in men and women with hypercholesterolemia: meta-analysis of 8 controlled trials. *American Journal of Clinical Nutrition* **71**, 472-479

Anderson JW, O'Neal DS, Riddell-Mason S, Floore TL, Dillon DW, Oeltgen PR (1995) Postprandial serum glucose, insulin, and lipoprotein responses to high- and low-fiber diets. *Metabolism* **44**, 848-854

Anderson JW, Story LJ, Zettwoch NC, Gustafson NJ, Jefferson BS (1989) Metabolic effects of fructose supplementation in diabetic individuals. *Diabetes Care* **12**, 337-344

Ansorena D (1999) Frutas y frutos secos. In: Martínez JA, Astiasarán I (Eds) *Alimentos: Composición y Propiedades*, Universidad de Navarra, Pamplona, pp 219-241

Beecher GR (1999) Phytonutrients' role in metabolism: effects on resistance to degenerative processes. *Nutrition Reviews* **57**, S3-6

Beliz HD (2004) *Food Chemistry* (3rd Edn), Springer, Berlin

Bes-Rastrollo M, Martinez-Gonzalez MA, Sanchez-Villegas A, de la Fuente Arrillaga C, Martinez JA (2006) Association of fiber intake and fruit/vegetable consumption with weight gain in a Mediterranean population. *Nutrition* **22**, 504-511

Bray GA, Nielsen SJ, Popkin BM (2004) Consumption of high-fructose corn syrup in beverages may play a role in the epidemic of obesity. *American Journal of Clinical Nutrition* **79**, 537-543

Conceição de Oliveira M, Sichieri R, Sanchez Moura A (2003) Weight loss associated with a daily intake of three apples or three pears among overweight women. *Nutrition* **19**, 253-256

Christen WG, Liu S, Schaumberg DA, Buring JE (2005). Fruit and vegetable intake and the risk of cataract in women. *American Journal of Clinical Nutrition* **81**, 1417-1422

Crujeiras AB, Parra MD, Abete I, Martínez JA (2007) A hypocaloric diet enriched in legumes specifically mitigates lipid peroxidation in obese subjects. *Free Radical Research* **41**, 498-506

Crujeiras AB, Parra MD, Rodriguez MC, Martinez de Morentin BE, Martinez JA (2006) A role for fruit content in energy-restricted diets in improving antioxidant status in obese women during weight loss. *Nutrition* **22**, 593-599

Dandona P, Aljada A, Chaudhuri A, Mohanty P, Garg R (2005) Metabolic syndrome: a comprehensive perspective based on interactions between obesity, diabetes, and inflammation. *Circulation* **111**, 1448-1454

Dandona P, Mohanty P, Ghanim H, Aljada A, Browne R, Hamouda W, Prabhala A, Afzal A, Garg R (2001) The suppressive effect of dietary restriction and weight loss in the obese on the generation of reactive oxygen species by leukocytes, lipid peroxidation, and protein carbonylation. *The Journal of Clinical Endocrinology and Metabolism* **86**, 355-362

Darmon N, Darmon M, Maillot M, Drewnowski A (2005) A nutrient density standard for vegetables and fruits: nutrients per calorie and nutrients per unit cost. *Journal of the American Dietetic Association* **105**, 1881-1887

Diniz YS, Faine LA, Galhardi CM, Rodrigues HG, Ebaid GX, Burneiko RC, Cicogna AC, Novelli EL (2005) Monosodium glutamate in standard and high-fiber diets: metabolic syndrome and oxidative stress in rats. *Nutrition* **21**, 749-755

Elliott SS, Keim NL, Stern JS, Teff K, Havel PJ (2002) Fructose, weight gain, and the insulin resistance syndrome. *American Journal of Clinical Nutrition* **76**, 911-922

Engbers LH, van Poppel MN, Chin APM, van Mechelen W (2006) The effects of a controlled worksite environmental intervention on determinants of dietary behavior and self-reported fruit, vegetable and fat intake. *BMC Public Health* **6**, 253

Escudero Alvarez E, Gonzalez Sanchez P (2006) Dietary fibre. *Nutrición Hospitalaria* **21 Suppl 2**, 60-71, 61-72

Finkel T, Holbrook NJ (2000) Oxidants, oxidative stress and the biology of ageing. *Nature* **408**, 239-247

Gaby AR (2005) Adverse effects of dietary fructose. *Alternative Medicine Review* **10**, 294-306

Girard A, Madani S, El Boustani ES, Belleville J, Prost J (2005) Changes in lipid metabolism and antioxidant defense status in spontaneously hypertensive rats and Wistar rats fed a diet enriched with fructose and saturated fatty acids. *Nutrition* **21**, 240-248

Glantzounis GK, Tsimoyiannis EC, Kappas AM, Galaris DA (2005) Uric acid and oxidative stress. *Currurrent Pharmaceutical Design* **11**, 4145-4151

Goralczyk R, Bachmann H, Wertz K, Lenz B, Riss G, Buchwald Hunziker P, Greatrix B, Aebischer CP (2006) Beta-carotene-induced changes in RARbeta isoform mRNA expression patterns do not influence lung adenoma multiplicity in the NNK-initiated A/J mouse model. *Nutrition Cancer* **54**, 252-262

Gorinstein S, Caspi A, Libman I, Lerner HT, Huang D, Leontowicz H, Leontowicz M, Tashma Z, Katrich E, Feng S, Trakhtenberg S (2006) Red grapefruit positively influences serum triglyceride level in patients suffering from coronary atherosclerosis: studies *in vitro* and in humans. *Journal of Agricultural and Food Chemistry* **54**, 1887-1892

Gonzalez CA (2006) Nutrition and cancer: the current epidemiological evidence. *The British Journal of Nutrition* **96**, 42-45

Hagopian K, Ramsey JJ, Weindruch R (2005) Fructose metabolizing enzymes from mouse liver: influence of age and caloric restriction. *Biochimica et Biophysica Acta* **1721**, 37-43

Halliwell B (2000) The antioxidant paradox. *Lancet* **355**, 1179-1180

Halliwell B (2006) Reactive species and antioxidants. Redox biology is a fundamental theme of aerobic life. *Plant Physiology* **141**, 312-322

Halvorsen BL, Holte K, Myhrstad MC, Barikmo I, Hvattum E, Remberg SF, Wold AB, Haffner K, Baugerod H, Andersen LF, Moskaug O, Jacobs DR Jr., Blomhoff R (2002) A systematic screening of total antioxidants in dietary plants. *The Journal of Nutrition* **132**, 461-471

Heuckenkamp PU, Zollner N (1971) Fructose-induced hyperuricaemia. *Lancet* **1**, 808-809

He FJ, Nowson CA, MacGregor GA (2006) Fruit and vegetable consumption and stroke: meta-analysis of cohort studies. *Lancet* **367**, 320-326

Hu FB, Willett WC (2002) Optimal diets for prevention of coronary heart disease. *JAMA* **288**, 2569-2578

Jaiswal McEligot A, Largent J, Ziogas A, Peel D, Anton-Culver H (2006) Dietary fat, fiber, vegetable, and micronutrients are associated with overall survival in postmenopausal women diagnosed with breast cancer. *Nutrition and Cancer* **55**, 132-140

Jenkins DJ, Wolever TM, Taylor RH, Barker H, Fielden H, Baldwin JM, Bowling AC, Newman HC, Jenkins AL, Goff DV (1981) Glycemic index of foods: a physiological basis for carbohydrate exchange. *American Journal of Clinical Nutrition* **34**, 362-366

Jimenez-Escrig A, Rincon M, Pulido R, Saura-Calixto F (2001) Guava fruit (*Psidium guajava* L.) as a new source of antioxidant dietary fiber. *Journal of Agricultural and Food Chemistry* **49**, 5489-5493

Kellen E, Zeegers M, Paulussen A, Van Dongen M, Buntinx F (2006) Fruit consumption reduces the effect of smoking on bladder cancer risk. The Belgian case control study on bladder cancer. *International Journal of Cancer*

118, 2572-2578

Lampe JW (1999) Health effects of vegetables and fruit: assessing mechanisms of action in human experimental studies. *American Journal of Clinical Nutrition* **70**, 475S-490S

Lim CC, Ferguson LR, Tannock GW (2005) Dietary fibres as "prebiotics": implications for colorectal cancer. *Molecular Nutrition and Food Research* **49**, 609-619

Liu RH (2003) Health benefits of fruit and vegetables are from additive and synergistic combinations of phytochemicals. *American Journal of Clinical Nutrition* **78**, 517S-520S

Lotito SB, Frei B (2004) The increase in human plasma antioxidant capacity after apple consumption is due to the metabolic effect of fructose on urate, not apple-derived antioxidant flavonoids. *Free Radical of Biology and Medicine* **37**, 251-258

Marlett JA, McBurney MI, Slavin JL (2002) Position of the American Dietetic Association: health implications of dietary fiber. *Journal of the American Dietetic Association* **102**, 993-1000

Martinez-Gonzalez MA, Fernandez-Jarne E, Serrano-Martinez M, Marti A, Martinez JA, Martin-Moreno JM (2002) Mediterranean diet and reduction in the risk of a first acute myocardial infarction: an operational healthy dietary score. *European Journal of Nutrition* **41**, 153-160

Maserejian NN, Giovannucci E, Rosner B, Zavras A, Joshipura K (2006) Prospective study of fruits and vegetables and risk of oral premalignant lesions in men. *American Journal of Epidemiology* **164**, 556-566

Mataix J (2003) Frutas. In: Mataix J (Ed) *Tabla de Composición de Alimentos Españoles*, Instituto de Nutrición y Tecnología de Alimentos, Universidad de Granada, Granada, pp 163-175

Mayne ST (2003) Antioxidant nutrients and chronic disease: use of biomarkers of exposure and oxidative stress status in epidemiologic research. *The Journal of Nutrition* **133 Suppl 3**, 933S-940S

McAnulty SR, McAnulty LS, Morrow JD, Khardouni D, Shooter L, Monk J, Gross S, Brown V (2005) Effect of daily fruit ingestion on angiotensin converting enzyme activity, blood pressure, and oxidative stress in chronic smokers. *Free Radical Research* **39**, 1241-1248

Michels KB, Giovannucci E, Chan AT, Singhania R, Fuchs CS, Willett WC (2006) Fruit and vegetable consumption and colorectal adenomas in the Nurses' Health Study. *Cancer Research* **66**, 3942-3953

Miller ER, 3rd, Erlinger TP, Appel LJ (2006) The effects of macronutrients on blood pressure and lipids: an overview of the DASH and OmniHeart trials. *Current Atherosclerosis Reports* **8**, 460-465

Naska A, Vasdekis VG, Trichopoulou A, Friel S, Leonhauser IU, Moreiras O, Nelson M, Remaut AM, Schmitt A, Sekula W, Trygg KU, Zajkas G (2000) Fruit and vegetable availability among ten European countries: how does it compare with the 'five-a-day' recommendation? DAFNE I and II projects of the European Commission. *The British Journal of Nutrition* **84**, 549-556

Pajk T, Rezar V, Levart A, Salobir J (2006) Efficiency of apples, strawberries, and tomatoes for reduction of oxidative stress in pigs as a model for humans. *Nutrition* **22**, 376-384

Pellegrini N, Serafini M, Colombi B, Del Rio D, Salvatore S, Bianchi M, Brighenti F (2003) Total antioxidant capacity of plant foods, beverages and oils consumed in Italy assessed by three different *in vitro* assays. *The Journal of Nutrition* **133**, 2812-2819

Petersen KF, Laurent D, Yu C, Cline GW, Shulman GI (2001) Stimulating effects of low-dose fructose on insulin-stimulated hepatic glycogen synthesis in humans. *Diabetes* **50**, 1263-1268

Pool-Zobel BL, Selvaraju V, Sauer J, Kautenburger T, Kiefer J, Richter KK, Soom M, Wolfl S (2005) Butyrate may enhance toxicological defence in primary, adenoma and tumor human colon cells by favourably modulating expression of glutathione *S*-transferases genes, an approach in nutrigenomics. *Carcinogenesis* **26**, 1064-1076

Potter JD (2005) Vegetables, fruit, and cancer. *Lancet* **366**, 527-530

Re R, Pellegrini N, Proteggente A, Pannala A, Yang M, Rice-Evans C (1999) Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology and Medicine* **26**, 1231-1237

Rodriguez MC, Parra MD, Marques-Lopes I, De Morentin BE, Gonzalez A, Martinez JA (2005) Effects of two energy-restricted diets containing different fruit amounts on body weight loss and macronutrient oxidation. *Plant Foods for Human Nutrition* **60**, 219-224

Saura-Calixto F (1998) Antioxidant dietary fiber product: a new concept and a potential food ingredient. *Journal of Agricultural and Food Chemistry* **46**, 4303-4306

Saura-Calixto F, Goñi I (2006) Antioxidant capacity of the Spanish Mediterranean diet. *Food Chemistry* **94**, 442-447

Scalzo J, Mezzetti B, Battino M (2005) Total antioxidant capacity evaluation: critical steps for assaying berry antioxidant features. *Biofactors* **23**, 221-227

Sies H (1997) Oxidative stress: oxidants and antioxidants. *Experimental Physiology* **82**, 291-295

Slavin JL (2005) Dietary fiber and body weight. *Nutrition* **21**, 411-418

Sugiura M, Nakamura M, Ikoma Y, Yano M, Ogawa K, Matsumoto H, Kato M, Ohshima M, Nagao A (2006) The homeostasis model assessment-insulin resistance index is inversely associated with serum carotenoids in non-diabetic subjects. *Journal of Epidemiology* **16**, 71-78

Takase B, Etsuda H, Matsushima Y, Ayaori M, Kusano H, Hamabe A, Uehata A, Ohsuzu F, Ishihara M, Kurita A (2004) Effect of chronic oral supplementation with vitamins on the endothelial function in chronic smokers. *Angiology* **55**, 653-660

Thomson CA, Rock CL, Giuliano AR, Newton TR, Cui H, Reid PM, Green TL, Alberts DS (2005) Longitudinal changes in body weight and body composition among women previously treated for breast cancer consuming a high-vegetable, fruit and fiber, low-fat diet. *European Journal of Nutrition* **44**, 18-25

Tordoff MG, Alleva AM (1990) Effect of drinking soda sweetened with aspartame or high-fructose corn syrup on food intake and body weight. *American Journal of Clinical Nutrition* **51**, 963-969

Vainio H, Weiderpass E (2006) Fruit and vegetables in cancer prevention. *Nutrition and Cancer* **54**, 111-142

van Gils CH, Peeters PH, Bueno-de-Mesquita HB, Boshuizen HC, Lahmann PH, Clavel-Chapelon F, Thiebaut A, Kesse E, Sieri S, Palli D, Tumino R, Panico S, Vineis P, Gonzalez CA, Ardanaz E, Sanchez MJ, Amiano P, Navarro C, Quiros JR, Key TJ, Allen N, Khaw KT, Bingham SA, Psaltopoulou T, Koliva M, Trichopoulou A, Nagel G, Linseisen J, Boeing H, Berglund G, Wirfalt E, Hallmans G, Lenner P, Overvad K, Tjonneland A, Olsen A, Lund E, Engeset D, Alsaker E, Norat T, Kaaks R, Slimani N, Riboli E (2005) Consumption of vegetables and fruits and risk of breast cancer. *JAMA* **293**, 183-193

Van Loo JA (2004) Prebiotics promote good health: the basis, the potential, and the emerging evidence. *Journal of Clinical Gastroenterology* **38**, S70-75

Versari D, Daghini E, Rodriguez-Porcel M, Sattler K, Galili O, Pilarczyk K, Napoli C, Lerman LO, Lerman A (2006) Chronic antioxidant supplementation impairs coronary endothelial function and myocardial perfusion in normal pigs. *Hypertension* **47**, 475-481

Vincent HK, Taylor AG (2006) Biomarkers and potential mechanisms of obesity-induced oxidant stress in humans. *International Journal of Obesity* **30**, 400-418

Willett W, Manson J, Liu S (2002) Glycemic index, glycemic load, and risk of type 2 diabetes. *American Journal of Clinical Nutrition* **76**, 274S-280S

Wisten A, Messner T (2005) Fruit and fibre (Pajala porridge) in the prevention of constipation. *Scandinavian Journal of Caring Sciences* **19**, 71-76