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By-Products from Plant Foods are Sources of Dietary Fibre and Antioxidants

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1. Introduction

Fruit and vegetables have been recognized as important sources for a wide array of non digestible components and phytochemicals that individually, or in combination, may act synergistically to contribute to the nutritional and health benefits of these food commodities.

World Health Organization (WHO) and worldwide health authorities such as United States Department of Agriculture (USDA) promote a high consumption and variety of fruit and vegetables. In addition, the source of fibre in a healthy dietary pattern such as Mediterranean Diet has been described as an important qualitative difference on health. Fruit and vegetable related dietary fibre transports a significant amount of polyphenols and carotenoids linked to the fibre matrix through the human gut. Despite these effects and recommendations, the intake of plant foods remains low and, consequently, both dietary fibre and antioxidant compounds are usually deficient in most diets around the world.

On the other hand, the food industry processing plant foods produces large amounts of waste and residues (leaves, stems, wastewaters, etc.) that are good sources of dietary fibre and phytochemicals. Several of them contain more dietary fibre than their respective edible portion.

A variety of plant food byproducts are rich in fibre and polyphenolic compounds meeting the criteria of antioxidant dietary fibre. A broad spectrum of these will be summarized in the present work. In this chapter information on nutritional and phytochemical composition will be also included. Special attention nutritional claims criteria with reference to European Regulation has been given to quality ingredients for functional foods and/or dietary supplements. The application of byproducts in the food industry results in added value to both, the industry and the consumer. The industry benefits from economic incomes and the consumer from the excellent nutritional value of these materials with potential health claims.

2. A healthy diet: Mediterranean dietary pattern based on dietary fibre and bioactive compounds

Mediterranean Diet was declared by UNESCO as an Intangible Cultural Heritage, offering important benefits for the health, quality of life and well-being of the communities. The

Mediterranean Diet offers a nutritional model enriched by diverse cultures which over centuries has essentially maintained the same food structure and the same proportions: olive oil, fresh fruits and vegetables, grains and derivatives, fish and to a lesser extent, nuts, dairy products and meat. There is also a moderate consumption of wine, coffee and tea during meals while respecting religious rules and beliefs. Mediterranean Diet is not just a diet (mixture of food), it means a lifestyle because it also implies the way to prepare food and how foods are consumed around the same table. To eat in the Mediterranean Dietary Pattern is a moment of social meeting that complies with several functions: social, cultural and nutritional. The recognition of dietary qualities, and the positive impact on the health of the people who follow this dietary pattern, indicates the model of healthy diet we must try to encourage (UNESCO, 2010).

The definition of the Mediterranean Diet is mainly based on consumption of foods. However, despite the robust inverse association between Mediterranean Diet and mortality found in observational and epidemiological studies, it is not clear which food constituents of this dietary pattern contribute most to its health effects.

With regards to the intake of nutrients and / or food constituents, it appears that both dietary patterns are similar in terms of energy, energy profile and dietary fibre. As far as micronutrients are concerned, clear significant differences in the intake of vitamins and minerals in Northern and Southern European countries have not been reported (Elmadfa et al, 2004). However, the intake of monounsaturated fatty acids is higher in the Mediterranean area in opposition to the intake of saturated fatty acids whose values are higher in countries of Northern and Central Europe where there is a higher prevalence of chronic diseases. These facts are related to food consumption patterns that show a remarkable difference. In countries with Mediterranean diet, consumption of fruit and vegetables is significantly higher, being very important not only the quantity of these foods but also the variety of them. Moreover, there are also differences in relation to fat consumption. Mediterranean recorded high availability of olive oil and unprocessed red meat, while Central and Northern European preferably consumed fat from meat products (Naska et al., 2006). These data are in agreement with the fatty acid profile of food consumed in both dietary patterns.

On the other hand, plant foods in Mediterranean Diet, of which there is a considerable amount and variety, seems to have a significant impact on the nutritional assessment of the Mediterranean Diet, as mentioned later, defines some health indicators of this dietary pattern. Plant foods, especially fruit and vegetables contribute a large proportion of the overall dietary intake of dietary fibre and bioactive compounds and a small proportion of the overall dietary intake of energy. Therefore, the role of bioactive compounds or phytochemicals as a key factor in the health effects of the Mediterranean dietary pattern is an attractive hypothesis. The composition and the physicochemical structure of dietary fibre and phytochemicals in fruit and vegetables have specific characteristics which lend these food groups significant nutrition and health related properties. Indeed, the potential health benefits of fruit and vegetables are mainly attributed to the effects of dietary fibre and antioxidants.

It is argued that an increasing intake of 400 to 800 g/person/day of fruits and vegetables is a public health strategy of considerable importance for individuals and communities worldwide. For this reason the World Health Organization (WHO) recommends a daily intake of more than 400 g per person daily, and health authorities worldwide promote high consumption of fruit and vegetables. Currently, the Food Standards Agency recommends the consumption of five portions of fruit and vegetables daily. There is no guidance on the specific type of fruit and vegetables to consume other than a suggestion of a variety; this is because to date, there is a lack of convincing evidence for their identification. It is therefore of priority to indentify fruit and vegetables which would significantly contribute to a reduction in cardiovascular diseases and other chronic non-communicable diseases. This way we could make public health recommendations and provide scientific information to the food industry about the selection of ingredients for functional foods.

Although inconclusive, evidence has alluded to synergistic effects of combinations of polyphenols, which may be more protective against cardiovascular diseases than isolated polyphenols, and that a combination of fruits, in the context of a balanced diet and healthy lifestyle, would help to protect against these pathologies (Chong et al., 2010) Many of the putative chemoprotective phytochemicals in fruits and vegetables are coloured. Therefore, a good strategy may be guidelines based on selecting one daily serving of fruits and vegetables from each of seven colour classes, so that a variety of phytochemicals is consumed. In this context, a complementary definition of the Mediterranean Diet was recently proposed, based on the following dietary indicators: 1) monounsaturated/saturated lipid ratio; 2) intake of dietary fibre defined as food indigestible fraction; 3) intake of antioxidant capacity of the whole diet; 4) intake of phytosterols. These indicators were selected based on the scientific evidence to support the beneficial health effects and because they are differential features in Mediterranean Diet (Saura-Calixto & Goñi, 2009).

There is general consensus among scientists as to the significant role of the monounsaturated to saturated fat ratio in disease aetiology. This ratio is predictive of total mortality and is a common feature in Mediterranean countries, where is much higher than in other parts of the world including northern Europe and North America (Naska et al, 2006).

As it is indicated above, dietary fibre intake is quantitatively similar in Mediterranean and non-Mediterranean European countries (around 20 g per capita). However, there are qualitative differences arising from the fact that a large proportion of the dietary fibre intake in Mediterranean countries comes from fresh fruit and vegetables, while in Northern European countries it comes more from cereals. Consequently, the composition and properties of the dietary fibre in the Mediterranean Diet has specific characteristics related to the type of food, nutrient and phytochemicals contents and healthy properties.

There is a lack of comprehensive data on the antioxidant capacity of whole diets. This parameter is derived from the accumulative and synergistic antioxidant power of a wide variety of sources. Total dietary antioxidant capacity is probably higher in Mediterranean Diet than in other dietary patterns because of the amount and variety of plant foods rich in antioxidant phytochemicals.

Finally, the intake of phytosterols has been established as a factor in the lower cardiovascular disease death rates in Mediterranean countries and it is a specific essential dietary indicator.

The intake of bioactive compounds in recognized healthy diets such as the Mediterranean Diet may serve as a benchmark until scientific knowledge in this field is sufficiently advanced to establish daily allowances. Traditional Mediterranean foods are rich in dietary fibre and bioactive compounds and the Mediterranean Diet is a specific type of healthy diet.

3. Fruit and vegetables are source of dietary fibre and antioxidant phytochemicals

Plant foods, particularly fruit and vegetables, have been consistently identified in epidemiological research as the key components of dietary patterns that reduce risk for the development of chronic and degenerative diseases, including atherosclerotic cardiovascular diseases, insulin resistance and type II diabetes and many cancers (Hu et al., 2000; Kant et al., 2004; Mokdad et al., 2000). One of the predominant mechanisms of their protective action is due to their antioxidant activity and the capacity to scavenge free radicals. There has been increasing interest in the nutritional properties of fruit and vegetables as sources of dietary fibre and other health-promoting phytochemical compounds (Knekt et al., 2002; Kris-Etherton et al., 2004; Mennen et al., 2004; Most, 2004).

Fruit and vegetables are generally high in water, low in fat and, in addition to vitamins and minerals, contain significant amounts of dietary fibre and phytochemicals – mainly polyphenols and carotenoids - with significant biological properties, including antioxidant activity.

The composition and the physicochemical structure of dietary fibre and phytochemicals in fruit and vegetables are specific characteristics which lend significant nutrition- and health-related properties to this food group. Indeed, the potential health benefits of fruit and vegetables are mainly attributed to the effects of dietary fibre and antioxidants.

3.1 Phytochemicals

Phytochemicals or phytonutrients are bioactive substances that can be found in foods derived from plants and are not essentials for life. The human body is not able to produce them. Phenolic compounds are widely distributed throughout the plant kingdom and range from simple molecules such as phenolic acids to complex polymerised compounds (i.e. polyphenols) (Rice-Evans et al., 1996). Recently, some of their characteristics, mainly their antioxidant capacity, have given rise to research related to their protective properties on health and the mechanisms of action involved. The health benefits of antioxidant of natural origin are associated with their role in the prevention of several disorders called oxidative stress pathologies (Herrera et al., 2009). These are related to the damaging effect of oxygen free radicals, or more generally reactive oxygen species, products of normal metabolism that become harmful when they cannot be neutralized by the cellular antioxidant defense systems. In this condition of oxidative stress an uncontrolled oxidizing process may occur that damages biological molecules, disturbs cellular functions, and can potentially lead to the development of one or more diseases (Valko et al., 2007).

Dietary phytochemicals are defined as bioactive, non-nutrient plant compounds that are associated with reduced risk of chronic diseases (Liu, 2004). Prospective cohort studies consistently suggest that when consumed in whole foods, these phytochemicals may contribute to important protection against chronic diseases, such as cardiovascular diseases and certain cancer (Okarter & Liu, 2010). The additive and synergistic effects of these bioactive phytochemicals found in plant foods may be responsible for the health benefits associated with the diet; additionally, the phytochemicals present in the different groups of plant foods in the diet complement each other when they are consumed together (Adom et al., 2005; Liu, 2004; Okarter & Liu, 2010).

Plant foods phenolic compounds may provide benefits to human subjects via several mechanisms (Nijveldt et al., 2001). The best described and most well known mechanism is through their antioxidant properties and modulation of biological oxidative stress to prevent damage to cellular lipids, protein and DNA. Directly, they may scavenge superoxide and other reactive oxygen species such as hydroxyl and peroxy radicals. Overall, phenolic compounds have multiple paths for benefiting human health, most notably, through their actions as antioxidants and modifying cellular events. Their specific actions are likely to be dependent on the composition and time course of metabolites appearing in plasma (Crozier et al., 2009; Hollman et al., 1997; Manach et al., 2005). The intake of these antioxidants can lead to sustained reduction of the kind of oxidative damage to lipids, proteins and DNA that is associated with the development of chronic diseases (Evans & Halliwell 2001).

Notwithstanding the need for more research, the collected data suggest that the consumption of phenolic-rich fruits increases the antioxidant capacity of blood, and when they are consumed with high fat and carbohydrate "pro-oxidant" foods, they may counterbalance their negative effects. Given the content and availability of fat and carbohydrate in the Western diet, regular consumption of phenolic-rich foods, appears to be a prudent strategy to maintain oxidative balance and health (Burton-Freeman, 2010). Vitamins (C and E), polyphenolic compounds and carotenoids are the main groups of antioxidants present in fruit and vegetables. Vitamins are single molecules, but polyphenols and carotenoids are made up of hundreds of compounds with a wide range of structures and molecular masses.

Dietary fibre and antioxidants are generally addressed separately as groups of food constituents in both chemical and nutritional studies. However, it is a little known fact that a substantial proportion of the antioxidant polyphenols and carotenoids contained in fruit and vegetables are linked to dietary fibre (Saura-Calixto et al., 2007), and some of the postulated benefits of the fibre intake can be attributed to these associated compounds.

Most biological properties of polyphenols depend on their bioavailability; the latter is largely influenced by chemical and physical properties and plant-derived conjugation. While a small proportion of some dietary polyphenols can be absorbed through the small intestine, the majority are either not absorbed, or are excreted and become fermentable substrates for bacterial microflora in the colon along with the non digestible food fraction (Williamson & Manach, 2005). Polyphenols bound to dietary fibre can account for a substantial part of total polyphenols in foods. These polyphenols are not bioavailable in the human upper intestine and reach the colon, where they become fermentable substrates for bacterial microflora, along with the other dietary fibre components. The fermentation of polyphenols in the colon improves antioxidant status and yields different metabolites with potential systemic effects.

The majority of studies on determining the bioavailability of phenolic compounds are conducted by the analysis of blood phenolic metabolites a short time after ingestion. However, it should be noted that among the many polyphenols present in food, most of them do not reach the bloodstream in the early hours of food digestion. Nevertheless, they do the transit until the large intestine where they can be metabolized through other pathways involving the enzymatic activities of the colonic microbiota. Therefore, it is expected that the protective effects of polyphenols are broader than those listed, as will be indicated later.

3.2 Dietary fibre

Dietary fibre is a major constituent of plant foods and its importance in nutrition and health is widely recognized. Numerous clinical and epidemiological studies have addressed the role of dietary fibre in intestinal health, prevention of cardiovascular disease, cancer, obesity, and diabetes (Buttriss & Stokes, 2008). The recommended daily intake of dietary fibre is 25-35 g/person (Buttriss & Stokes, 2008).

	Male	Female	All
Italy	Not applicable	22.92 (6.94)	22.92 (6.94)
Spain	24.93 (9.12)	22.02 (7.29)	22.92 (8.01)
United Kingdom	29.12 (8.34)	23.35 (7.08)	25.52 (8.08)
Netherlands	20.00 (7.50)	20.39 (7.06)	20.27 (7.20)
Germany	26.77 (7.61)	22.55 (5.49)	23.63 (6.38)
Sweden	23.83 (7.51)	21.55 (6.41)	22.53 (7.00)
Denmark	21.33 (7.78)	19.08 (6.47)	20.06 (7.16)
Total	22.98 (8.26)	21.52 (6.90)	21.97 (7.38)

Table 1. Fibre intake (g per day) among EPIC cohort (Bingham et al., 2003). *Data are mean (SD). EPIC: European Prospective Investigation into Cancer and Nutrition. Cohort numbers: 134 012 males; 300197 females; 4340209 in total.*

Just as there are significant differences in the consumption of fruit and vegetables among European countries we also note differences in dietary fibre intake. The source of fibre in a healthy dietary pattern is an important qualitative difference. **Table 1** summarizes the daily intake of dietary fibre among European countries (Bingham et al., 2003).

The intake of dietary fibre is low and quantitatively similar in Mediterranean and non-Mediterranean European countries. These data were consistent with other published works (Elmadfa et al., 2005). Dietary fibre intake in Mediterranean countries comes from fresh fruit and vegetables, while in Northern European countries it comes more from cereals. Accordingly, the incidence of chronic diseases is higher in northern European countries.

Currently there is not a harmonized definition of dietary fibre at the European Community level. The term dietary fibre was originally defined as the portion of food which is derived from cellular walls of plants which are digested very poorly by human beings (Trowell, 1976). The recognition that other food components could have effects similar to those originating from plant cell walls led to a redefinition of dietary fibre to include all undigestible food components. The indigestible fraction of food has been defined as the part of plant foods that is not digested nor absorbed in the small intestine, reaching the colon where it is a substrate for the fermentative microbiota. As such, it comprises not only dietary fibre (traditional concept), but also other compounds of proven resistance to the action of digestive enzymes such as a fraction of dietary starch (resistant starch), protein, certain polyphenols, and other associated compounds (Saura-Calixto et al., 2000, 2007). This definition, basically physiological in nature, has been accepted by the majority of scientists working in the field. In this line, a method to quantify the food indigestible fraction in plant foods was presented. In this method, the digestible portion of the food is removed by using digestive enzymes and mimicking the digestive process in the small intestine. Then, a majority of indigestible components are isolated (Saura-Calixto et al., 2000). The value of dietary fibre includes resistant starch in this analytical method. However, resistant oligosaccharides and inulin are not included, and therefore need to be measured separately and subsequently added to the total food indigestible fraction estimate. The concept of indigestible fraction as dietary fibre is more reliable when applied to epidemiological and nutritional studies (Saura-Calixto & Goñi, 2004).

On the other hand, a number of physiological effects in human beings, e.g. decreased intestinal transit time, increased stools bulk, reduction of blood total and/or LDL cholesterol levels, and reducing post-prandial blood glucose and/or insulin levels, are often associated to the intake of dietary fibre. However, these effects vary depending on fibre component. Therefore, each fibre may have specific effects, which suggests not including physiological properties in the definition.

3.3 Dietary fibre as a carrier of bioactive compounds

Fruit and vegetables possess a higher soluble/insoluble fibre ratio than cereals, what is considered as an indicator of nutritional quality. A part of the postulated benefits of the Mediterranean dietary pattern might then be attributable to the intake of food undigestible components (Saura-Calixto et al., 2000). It is important to note at this point that the use of food dietary fibre data in nutrition may be subject to some limitations arising from the concept of dietary fibre itself and from the methodology used to determine dietary fibre in foods.

Dietary fibre does not constitute a defined chemical group but a combination of chemically heterogeneous substances. Moreover, dietary fibre, especially from fruits and vegetables, is a carrier of bioactive compounds. Dietary fibre of fruit and vegetables transports a significant amount of polyphenols and carotenoids linked to the fibre matrix through the human gut (Saura-Calixto et al., 2006, 2007). Therefore, associated phytochemicals can make a significant contribution to the health benefits attributed to the dietary fibre of fruit and vegetables. Thus, phytochemicals may be considered dietary fibre constituents in view of the similarity of their properties in terms of resistance to digestive enzymes and colonic fermentability (Saura-Calixto et al., 2006, 2007).

Physiological and physicochemical effects of dietary fibres depend on the relative amount of individual non-digestible components. Therefore, when a dietary fibre contains associated compounds with antioxidant activity, this property is conferred to the total dietary fibre complex and may be considered as antioxidant dietary fibre (Saura-Calixto et al., 1998).

In the Spanish diet, considered as Mediterranean pattern diet, fruit and vegetables provide a daily intake of 700-1000 mg of polyphenols/person/diet, a major fraction of this (600 mg/person/day) associated with dietary fibre (Saura-Calixto et al., 2007). These issues constitute an important qualitative difference in relation to other dietary patterns.

4. By-Products from plant foods as sources of dietary fibre and antioxidants

Fruit and vegetables have been recognized as important sources for a wide array of non digestible components and phytochemicals that individually, or in combination, may act synergistically to contribute to the nutritional and health benefits of these food commodities. Despite the consumption recommendations, the intake of fruit and vegetables remains low and, consequently, both dietary fibre and antioxidant compounds are usually deficient in most diets around the world.

Nowadays dietary fibre and bioactive compounds are widely used as functional ingredients in processed foods. The market in this field is competitive and the development of new types of quality ingredients is a challenge for the food industry. In this regard, it is interesting to consider not only the nutritional quality of the ingredient, but also its distribution, cost and other additional benefits, since the use of these ingredients would give added value to the production of these materials.

	Byproducts	Edible part	Reference
Agave	40% (rind and pith)	60%	Iñiguez-Covarrubias et al., 2001
Apple	11% (pulp and seed core)	89%	Ayala-Zavala et al., 2010
Artichoke	Around 60% (outer bracts, receptacles and stems)	40%	Llorach et al., 2002
Asparagus	Up to 40-50% (spear)	50-60%	Rodríguez et al., 2006
Banana	Up to 30% (peel)	70%	Schieber et al., 2001
Cactus pear cladodes	20% (spines, glochids and peel)	80%	Bensadon et al., 2010
Cactus pear fruit	45% (spines, glochids, peel and unusable pulp)	65%	Bensadon et al., 2010
Carrot	30-40% (pomace)	60-70%	Schieber et al., 2001
Cyphomandra betacea	15-35% (skin, pulp and seeds)	65-85%	Ordóñez et al., 2010
Guava	10-15% (peel and seeds)	85-90%	Schieber et al., 2001
Mandarin	16% (peels)	84%	Ayala-Zavala et al., 2010
Mango	13.5% (seeds), 11% (peels) and 17.9% (unusable pulp)	58%	Ayala-Zavala et al., 2010
Orange	66% (peel)	44%	Li et al., 2006
Papaya	6.5% (seeds), 8.5% (peels) and 32.1% (unusable pulp)	53%	Ayala-Zavala et al., 2010
Passion fruit	>75% (rind and seeds)	25%	Schieber et al., 2001
Pineapple	9.1% (core), 13.5% (peels), 14.9% (top) and 14.5% (pulp)	48%	Ayala-Zavala et al., 2010
Potato	15-40% (peel)	60-85%	Schieber et al., 2001
Tomato	3-7% (peel and seeds)	93-97%	Schieber et al., 2001
Tiger nuts ("*Chufa*")	Up to 60% (solid and liquid wastes)	40%	Sánchez-Zapata et al., 2009

Table 2. Amount of byproducts generated from fruit and vegetable processing industry.

There is a trend to find new sources of functional ingredients such as plant food byproducts that have traditionally been undervalued (Rodríguez et al., 2006). The term "byproduct" suggests that plant food wastes might be usable and have their own market (Sánchez-Zapata et al., 2009). The plant food processing industry produces large amounts of wastes and residues, estimated to be around 800 000 tons per year of fresh fruit and vegetable matter globally, without considering the wastage during processing (Ayala-Zavala et al., 2010). In India, fruit and vegetable wastes constitute about 5.6 million tons annually (Arvanitoyannis & Varzakas et al., 2008). These byproducts might reach around 60% of harvested plants. These residues are very perishable products that are difficult to manage because of environmental problems in the industries (Arvanitoyannis & Varzakas et al., 2008).

Dietary fibre does not constitute a defined chemical group but a combination of chemically heterogeneous substances. The health significance of foods fibres has led to the development of a large and potential market for fibre-rich products and ingredients (Rodríguez et al., 2006). In general, agricultural and industries residues are important sources of dietary fibre.

Table 2 shows the percentage of byproducts generated from fruit and vegetables processing industries. These byproducts are made up mainly of skins, seeds, stems, leaves, wastewaters and unusable pulp which are normally discarded (Ajila et al., 2007). The amount of byproducts might represent more than 40% of total plant food in cases such as artichoke, asparagus, cactus pear fruit, mango, orange, papaya, pineapple, red chicory and tiger nuts.

Table 3 displays the total dietary fibre content of byproducts from plant foods widely consumed. It is remarkable the important amount of fibre fraction present in byproducts ranging from 27 up to 80%, comprising both soluble and insoluble fibre compounds.

Dietary fibre of fruit and vegetables transports a significant amount of polyphenols and carotenoids linked to the fibre matrix through the human gut (Saura-Calixto et al., 2006, 2007). Therefore, associated phytochemicals can make a significant contribution to the health benefits attributed to the dietary fibre of fruit and vegetables. Moreover, phytochemicals may be considered dietary fibre constituents in view of the similarity of their properties in terms of resistance to digestive enzymes and colonic fermentability (Saura-Calixto et al., 2006, 2007).

An interesting approach to providing an added value to byproducts is their use as sources of dietary fibre and also as natural antioxidant compounds. Particularly, plant food residues are a good source of phytochemicals such as polyphenols.

The phenolic content of a wide variety of plant food byproducts are displayed in Tables 4 and 5. It can be noted that peel byproducts from grape, mango, pomegranate, apple, bambangan, cactus pear and cladodes as well as seeds of avocado, longan and mango, are remarkably the highest in polyphenol concentration. Likewise, general byproducts from asparagus, artichoke, blueberry, cranberry, buckwheat and grape seed are rich in polyphenols including proanthocyanidins. Grape antioxidant dietary fibre is the most concentrated source of polyphenols with a concentration of 19740 mg/100 g dry weight (Pérez-Jiménez et al., 2008).

Byproducts	Dietary fiber (g/100 g dry weight)	Reference
Apple	44.0	Mckee & Latner, 2000
Brewer's dried grain	60.0	Mckee & Latner, 2000
Cabbage outer leaves	40.5	Mckee & Latner, 2000
Carob	53.0	Bravo, 1994
Carrot	48.0	Mckee & Latner, 2000
Cauliflower	65.0	Mckee & Latner, 2000
Chia	56.5	Vázquez-Ovando et al., 2009
Pepper	80.4	Mckee & Latner, 2000
Cocoa hulls	60.5	Lecumberri et al., 2006
Coconut	63.2	Raghavendra et al., 2006
Coffee silverskin	69.2	Napolitano et al., 2007
Date	71.0	Mckee & Latner, 2000
Grape	77.9	Mckee & Latner, 2000
Grape antioxidant dietary fibre	73.5	Pérez-Jiménez et al., 2008
Grapefruit	58.6	Larrauri et al., 1997a
Guava	48.6	Sánchez-Zapata et al., 2009
Jack vean	55.9	Vázquez-Ovando et al., 2009
Kiwi	25.8	Mckee & Latner, 2000
Lime	64.3	Jongaroontaprangsee et al., 2007
Tangerine	52.9	Rincon et al., 2005
Mango	74.0	Larrauri et al., 1996
Oat bran	8.2	Mckee & Latner, 2000
Olive	80.0	Mckee & Latner, 2000
Orange	57-71	Vázquez-Ovando et al., 2009
Passion fruit	63.3	Pérez-Navarrete, 2003, as cited in Sánchez-Zapata et al., 2009
Peach	36.0	Mckee & Latner, 2000
Pear	43.9	Mckee & Latner, 2000
Peas	82.3	Mckee & Latner, 2000
Pineapple	70.6	Larrauri et al., 1997b
Rice bran	27.4	Mckee & Latner, 2000
Tiger nuts	59.7	Sánchez-Zapata et al., 2009

Table 3. Total dietary fibre content of byproducts from plant foods.

	Peel/skin	Pulp	General byproducts	Reference
Asparagus			284-371	Rodríguez et al., 2005
Blanched artichoke			360-440	Llorach et al., 2002
Cauliflower			110-180	Llorach et al., 2003
Chicory			77-82	Llorach et al., 2004
Grape	2890			Saura-Calixto et al., 1998
Grapefruit	155	135		Gorinstein et al., 2001
Guava	58.70			Jimenez-Escrig et al., 2001
Hazelnut	577*		127-241*	Shahidi et al., 2007
Lemon	190.0	164.0		Gorinstein et al., 2001
Lettuce			14-156	Llorach et al., 2004
Mango	7000			Larrauri et al., 1996
Orange	179.0	154.0		Gorinstein et al., 2001
Peach	133.7	41.5		Chang et al., 2000
Pomegranate	24990	2440		Li et al., 2005
Raw artichoke			300-320	Llorach et al., 2002
Tomato cherry	10.4-40	9.20-27.0		George et al., 2004

Table 4. Phenolic content (mg/100 g fresh weight) measured in solvent extracts of plant byproducts. *mg/g of extract.

A wide array of phenolic compounds has been described in plant food by-products. Almond hull extracts contain hydroxybenzoic and cinnamic acid derivatives, with minor presence of flavan-3-ols, including the presence of epicatechin and glycosylated flavonols (Rubilar et al., 2007). Five phenolic acids (gallic acid, caffeic acid, p-coumaric acid, ferulic acid, and sinapic acid) were identified in hazelnut byproducts (both free and esterified forms) (Shahidi et al., 2007).

Caffeic acid derivatives are the main phenolic compounds in artichoke heads, with a wide range of caffeoylquinic acid derivatives with chlorogenic acid (5-Ocaffeoylquinic acid) as the most important of these derivatives. Other phenolics such as the flavonoids apigenin and luteolin (both glucosides and rutinosides) as well as different cyanidin caffeoylglucoside derivatives have been identified (Llorach et al., 2002). The analysis of cauliflower byproduct extracts revealed the presence of both flavonoids and hydroxycinamic acids (caffeic acid and sinapic acid). Different combinations of flavonols such as kaempferol and quercetin with sinapic acid and glucose were the main phenolic compounds present (Llorach et al., 2003).

Analyses of lettuce byproducts revealed the occurence of both hydroxycinnamic acids and flavonoids. The flavonoid profile of lettuce byproducts was composed of flavones (luteolin derivatives) and flavonols (quercetin derivatives), whereas the chicory byproducts were composed only of kaempferol derivatives (Llorach et al., 2004).

	Peel/ skin	Pulp	Seed	General byproducts	Reference
Apple	3300	11800			Schieber et al., 2003; Wolfe & Liu et al., 2003
Asparagus				284-371	Rodríguez et al., 2005
Avocado			8820		Soong & Barlow, 2004
Bambangan peel powder	9830				Hassan et al., 2011
Banana	928	232			Someya et al., 2002
Blueberry				459*	Khanal et al., 2009
Buckwheat bran				406	Zduńczyk et al., 2006
Buckwheat hulls				448	Zduńczyk et al., 2006
Cactus pear	2760	3180	1610		Bensadón et al., 2010; Ramírez-Moreno et al., 2011
Cladodes	3710				Bensadón et al., 2010
Cranberry				448*	Khanal et al., 2009
Cyphomandra betacea				72	Ordóñez et al., 2010
Grape antioxidant dietary fibre				19740	Pérez-Jiménez et al., 2008
Grape pomace				20-200	González-Paramás et al., 2004
Grape seed				120-710	González-Paramás et al., 2004
Jackfruit		90	2770		Soong & Barlow, 2004
Longan		160	6260		Soong & Barlow, 2004
Mango	5467-9020	240	11700		Ajila et al., 2010a; Soong & Barlow, 2004
Oat bran with hulls				155	Zduńczyk et al., 2006

Table 5. Phenolic content (mg/100 g dry weight) in different plant foods byproducts. *mg proanthocyanidins/100 g dry weight.

The prominent phenolic compounds identified in peels of raw and ripe mango fruits were protocatechuic acid, gentisic acid and gallic acid. Gallic acid, syringic acid, mangiferin, ellagic acid, gentisyl-protocatechuic acid, quercetin were the phenolic compounds identified in both raw and ripe peels, while raw peel showed the presence of glycosylated iriflophenone and maclurin derivatives also (Ajila et al., 2010b). The main flavonoids found in citrus species are hesperidin, narirutin, naringin and eriocitrin. Peel and other solid residues of lemon waste mainly contained hesperidin and eriocitrin, while the latter was predominant in liquid residues (Schieber et al., 2001). Otherwise, the polyphenol profile of solvent extracts of various byproducts (barks, kernels, peels, and old and young leaves) from Brazilian mango crops showed the occurrence of xanthone C-glycosides, gallotannins, and benzophenones (Barreto et al., 2008).

Apple pomace is a good source of polyphenols which are predominantly localized in the peels and are present in the juice to a minor extent (Schieber et al., 2001). The phenolic compounds quantified in the apple skin were: the proanthocyanidins (procyanidin B1 and

B2), the flavan- 3-ols (epicatechin and catechin), the flavonols (quercetin-3-Ogalactoside, quercetin-3-O-rhamnoside, quercetin-3-O-glucoside, quercetin-3-O-rutinoside), the dihydrochalcone (phloretin-2-Oglucoside), the anthocyanin (cyanidin-3-O-galactoside), and the phenolic acid (chlorogenic acid) (Huber & Rupasinghe, 2009). Also, banana bracts are an abundant source of anthocyanins such as delphinidin, cyanidin, pelargonidin, peonidin, petunidin and malvidin (Schieber et al., 2001).

In the composition of extracts of white and red grape pomace several of these compounds were also detected but basically consisted of glycosylated flavonols (quercetin, kaempferol) (Rubilar et al., 2007). Phenolic compounds present in grape pomace antioxidant dietary fibre have been widely described (Tourino et al., 2008), comprising: hydroxybenzoic and phenolic acids and their derivatives, monomeric flavonoids (catechins and flavonols aglycones) and flavonoids such as oligomeric proanthocyanidins, flavonols, flavones, and flavanones; anthocyanin, anthocyanidins delphinidin, cyaniding, petudin, peonidin, petunidin, pelargonidin and malvidin) and their mono and acetyl glucoside derivatives were also identified as well as polimeric proanthocyanidins (types A and B).

One recognized characteristic of a healthy diet includes components that counteract oxidative stress, which is involved in the etiopathogeny and progression of chronic diseases, contributing to the process of aging (Herrera et al., 2009). Dietary fruit and vegetables provide a significant amount of compounds (vitamins, carotenoids and polyphenols) that act as physiological antioxidants. Polyphenols are the major dietary antioxidants.

Since part of the total content of antioxidant phytochemicals is linked to dietary fibre as noted above, an appreciable proportion of the total antioxidant capacity in fruit and vegetables is associated with dietary fibre. We address mainly polyphenols associated with dietary fibre in fruit and vegetables because of the important biological properties derived from them and the significant phenolic content in these foods. Table 6 summarizes the antioxidant or radical scavenging activity of plant food byproducts. Those from bambangan, cactus pear, cladodes, hazelnut and, especially grape antioxidant dietary fibre, possess a potent antioxidant capacity.

5. Application of plant food byproducts as functional ingredients

The definition of a *functional food* by the International Life of Science Institute (ILSI 1999) is "a food product can be functional if it has satisfactorily been proven that it produces a beneficial effect on one or more physiological functions, besides its conventional nutritional effects, being this relevant for improving human health and/or reducing the risk of suffering certain diseases" (Roberfroid, 2000). Dietary fibre holds all the characteristics required to be considered as an important ingredient in the formulation of functional foods due to its proven beneficial effects (Rodríguez et al., 2006).

The Regulation on Nutrition and Health Claims (European Comission 2007, EU Regulation (EC) No 1924/2006) allows claims to be made with respect to the fibre content of food (Table 7) as *source of fibre* if its levels exceed 3 g per 100 g or *high in fibre* for 6 g per 100 g (Buttriss & Stokes, 2008). The claims for dietary fibre are as follows (Table 7)

	Extract	Byproducts	Method	Reference
Bambangan peel powder	Methanol, acetone and water	44.50 µg/mL	DDPH IC_{50}	Hassan et al., 2011
Blanched artichoke	Methanol/water	0.18-0.27g TEAC/100 g FW	ABTS	Llorach et al., 2002
Buckwheat bran	Methanol and water	24.24 µmol TEAC/g DW	ABTS	Zduńczyk et al., 2006
Buckwheat hulls	Methanol and water	26.15 µmol TEAC/g DW	ABTS	Zduńczyk et al., 2006
Cactus pear	Acidic methanol, acetone and water	66.33 µmol TEAC/g DW	ABTS	Bensadón et al., 2010; Ramírez-Moreno et al., 2011
Cauliflower	Ethanol and water	0.86-3.20 g TEAC/1 kg FW	ABTS	Llorach et al., 2003
Chicory	Methanol or water	0.6-0.8 mg TEAC/g FW	ABTS	Llorach et al., 2004
Cladodes	Acidic methanol, acetone and water	57.55 µmol TEAC/g DW	ABTS	Bensadón et al., 2010
Coffee silverskin	Methanol and water	1-4 mmol TEAC/g FW	ABTS	Napolitano et al., 2007
Cyphomandra betacea	Acidic ethanol and water	12.24 µmol TEAC/g DW	ABTS	Ordóñez et al., 2010
Grape antioxidant dietary fibre	Acidic methanol, acetone, water and buthanol.	375.5 µmol TEAC/g DW	ABTS	Pérez-Jiménez et al., 2008
Hazelnut	Ethanol, water and methanol	117-148 µmol TEAC/g of extract	ABTS	Shahidi et al., 2007
Lettuce	Methanol or water	0.4-1.3 mg TEAC/g FW	ABTS	Llorach et al., 2004
Oat bran with hulls	Methanol and water	7.96 µmol TEAC/g DW	ABTS	Zduńczyk et al., 2006
Raw artichoke	Methanol/water	0.14-0.25 g TEAC/100 g FW	ABTS	Llorach et al., 2002

Table 6. Antioxidant activity or radical scavenging activity of plant food byproducts. TEAC: trolox equivalent antioxidant capacity. DW: dry weight. FW: fresh weight.

Claim	*Source of fibre*	*Increased in fibre*	*High in fibre*
Requirement	Either >3 g/100 g or >1.5 g fibre/100 kcal	>25% more than a similar food which no claim is made	Either >6 g/100 g or >3 g fibre/100 kcal

Table 7. Nutrient claims for dietary fibre based on AOAC (American Organization of Analytical Chemists) analysis (EU Regulation (EC) No 1924/2006).

Byproducts obtained when processing cereal, algae, fruit and vegetables can be added as functional ingredients, providing advantageous dietary fibre and bioactive compounds. These byproducts serve as non-caloric bulking agents, enhance water and oil retention, and improve emulsion and oxidative stability. The literature reports addition of fibre to food products such as baked goods, beverages, confectionary, dairy, meat and pasta (Elleuch et al., 2011).

Addition of byproducts in bakery products are muffin butter supplemented with peach dietary fibre (Grigelmo-Miguel et al., 1999), and cake dough enhanced with prickly pear cladode fibre (Ayadi et al., 2009) at levels up to 5%. Incorporation of cauliflower by-products into ready-to-eat snacks enhanced nutritional and textural characteristics, increasing dietary fibre levels in the finished product by over 100% (Stojceska et al., 2008).

Fibres can also be introduced into meat products. Addition of 1.5% of orange fibre or 3% of carrot fibre to dry fermented sausages does not affect its organoleptic characteristics (Eim et al., 2008; Garcia et al., 2002). Citrus fibre with associated antioxidant bioactive compounds when added to meat products inhibits lipid oxidation and decrease residual nitrite levels (Fernández-Ginés et al., 2003). Pork burgers elaborated with tiger nut fibre had higher nutritional value in terms of fibre content and better cooking characteristics such as higher cooking yield, fat and moisture retention (Sánchez-Zapata et al., 2010). Grape pomace antioxidant dietary fibre when added to minced fish (Sánchez-Alonso et al., 2007) and chicken hamburgers (Sáyago-Ayerdi et al., 2009) improves oxidative stability and thus prolong shelf life. By-product fibre addition to burgers is a promising and convenient application considering dietary fibre of burgers can be significantly increased without changes in sensory acceptance.

The addition of unripe banana flour to spaghetti increased the dietary fibre and the content of phenolic compounds. Consequently, spaghetti had a slow and low rate for enzymatic hydrolysis and an increased antioxidant capacity (Ovando-Martínez et al., 2009). Mango peel powder was incorporated into macaroni (7.5%) to increase dietary fibre from 8.6 to 17.8%, polyphenols from 0.46 to 1.80 mg/g and carotenoid content from 5 to 84 µg/g of macaroni, resulting in an enhanced nutritional quality without affecting its cooking, textural and sensory properties (Ajila et al., 2010a).

6. Conclusion

Several fruit and vegetable byproducts from food processing industries meet the criteria of antioxidant dietary fibre definition. They are certain to be an excellent source of dietary fibre and natural antioxidants if used as high-quality ingredients in functional foods or dietary supplements. Furthermore, compliance with the nutritional claims criteria recognized in the

European Regulation would be met. The applications of plant food byproducts will definitely bring about added value to both, the industry and the consumer. The industry benefits from econimic incomes and the consumer from the excellent nutritional value of these materials with potential health claims.

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8. References

Adom, K. K., Sorrells, M. E., & Liu, R. H. (2005). Phytochemicals and antioxidant activity of milled fractions of different wheat varieties. *Journal of Agricultural and Food Chemistry,* Vol. 53, No.6, (March 2005), pp. 2297-2306, ISSN 0021-8561

Ajila, C. M., Aalami, M., Leelavathi, K., & Rao, U. J. S. P. (2010a). Mango peel powder: A potential source of antioxidant and dietary fiber in macaroni preparations. *Innovative Food Science & Emerging Technologies,* Vol.11, No.1, (January 2010), pp. 219-224, ISSN 1466-8564

Alfredo, V., Gabriel, R., Luis, C., & David, B. (2009). Physicochemical properties of a fibrous fraction from chia (*Salvia hispanica* L.). *LWT - Food Science and Technology,* Vol.42, No.1 (2009), pp. 168-173, ISSN 0023-6438

Arvanitoyannis, I. S., & Varzakas, T. H. (2008). Vegetable waste treatment: Comparison and critical presentation of methodologies. *Critical Reviews in Food Science and Nutrition,* Vol.48, No.3, (March 2008), pp. 205-247, ISSN 1040-8398

Ayadi, M. A., Abdelmaksoud, W., Ennouri, M., & Attia, H. (2009). Cladodes from *Opuntia ficus indica* as a source of dietary fiber: Effect on dough characteristics and cake making. *Industrial Crops and Products,* Vol.30, No.1, (July 2009), pp. 40-47, ISSN 0926-6690

Ayala-Zavala, J., Rosas-Domínguez, C., Vega-Vega, V., & González-Aguilar, G. A. (2010). Antioxidant enrichment and antimicrobial protection of fresh-cut fruits using their own byproducts: Looking for integral exploitation. *Journal of Food Science,* Vol.75, No.8 (2010), pp. R175-R181, ISSN 1750-3841

Bensadón, S., Hervert-Hernández, D., Sáyago-Ayerdi, S., & Goñi, I. (2010). By-products of *Opuntia ficus-indica* as a source of antioxidant dietary fiber. *Plant Foods for Human Nutrition (Formerly Qualitas Plantarum),* Vol.65, No.3, (September and 2010), pp. 210-216, ISSN 0921-9668

Bingham, S. A., Day, N. E., Luben, R., Ferrari, P., Slimani, N., Norat, T., Clavel-Chapelon, F., Kesse, E., Nieters, A., Boeing, H., Tjonneland, A., Overvad, K., Martinez, C., Dorronsoro, M., Gonzalez, C. A., Key, T. J., Trichopoulou, A., Naska, A., Vineis, P., Tumino, R., Krogh, V., Bueno-de-Mesquita, H. B., Peeters, P. H., Berglund, G., Hallmans, G., Lund, E., Skeie, G., Kaaks, R., Riboli, E., & European Prospective Investigation into Cancer and Nutrition. (2003). Dietary fibre in food and protection against colorectal cancer in the European prospective investigation into cancer and nutrition (EPIC): An observational study. *Lancet,* Vol.361, No.9368, (May 2003), pp. 1496-1501, ISSN 0140-6736

Bravo, L., Grades, N., & Saura-Calixto, F. (1994). Composition and potential uses of mesquite pods (*Prosopis pallida* L): Comparison with carob pods (*Ceratonia siliqua* L). *Journal of the Science of Food and Agriculture,* Vol.65, No.3 (1994), pp. 303-306, ISSN 1097-0010

Burton-Freeman, B. (2010). Postprandial metabolic events and fruit-derived phenolics: A review of the science. *The British Journal of Nutrition,* Vol.104 Suppl 3, (October 2010), pp. S1-14, ISSN 1475-2662, 0007-1145

Buttriss, J. L., & Stokes, C. S. (2008). Dietary fibre and health: An overview. *Nutrition Bulletin,* Vol.33, No.3 (2008), pp. 186-200, ISSN 1467-3010

Chang, S., Tan, C., Frankel, E. N., & Barrett, D. M. (2000). Low-density lipoprotein antioxidant activity of phenolic compounds and polyphenol oxidase activity in selected clingstone peach cultivars. *Journal of Agricultural and Food Chemistry,* Vol.48, No.2, (February 2000), pp. 147-151, ISSN 0021-8561

Chong, M. F., Macdonald, R., & Lovegrove, J. A. (2010). Fruit polyphenols and CVD risk: A review of human intervention studies. *The British Journal of Nutrition,* Vol.104 Suppl 3, (October 2010), pp. S28-39, ISSN 1475-2662, 0007-1145

Crozier, A., Jaganath, I. B., & Clifford, M. N. (2009). Dietary phenolics: Chemistry, bioavailability and effects on health. *Natural Product Reports,* Vol.26, No.8, (Aug and 2009), pp. 1001-1043, ISSN 0265-0568

Eim, V. S., Simal, S., Rosselló, C., & Femenia, A. (2008). Effects of addition of carrot dietary fibre on the ripening process of a dry fermented sausage (sobrassada). *Meat Science,* Vol.80, No.2, (October 2008), pp. 173-182, ISSN 0309-1740

Elleuch, M., Bedigian, D., Roiseux, O., Besbes, S., Blecker, C., & Attia, H. (2011). Dietary fibre and fibre-rich by-products of food processing: Characterisation, technological functionality and commercial applications: A review. *Food Chemistry,* Vol.124, No.2, (January 2011), pp. 411-421, ISSN 0308-8146

Elmadfa, I., Rust, P., Majchrzak, D., Wagner, K. H., Genser, D., Lettner, R., & Pinter, M. (2004). Effects of beta-carotene supplementation on free radical mechanism in healthy adult subjects. *International Journal for Vitamin and Nutrition Research,* Vol.74, No.2, (March 2004), pp. 147-152, ISSN 0300-9831

Elmadfa, I., Weichselbaum, E., Konig, J., de Winter A-M, R., Trolle, E., Haapala, I., Uusitalo, U., Mennen, L., Hercberg, S., Wolfram, G., Trichopoulou, A., Naska, A., Benetou, V., Kritsellis, E., Rodler, I., Zajkas, G., Branca, F., D'Acapito, P., Klepp, K. I., Ali-Madar, A., De Almeida, M. D., Alves, E., Rodrigues, S., Sarra-Majem, L., Roman, B., Sjostrom, M., Poortvliet, E., & Margetts, B. (2005). European nutrition and health report 2004. *Forum of Nutrition,* Vol.(58), No.58 (2005), pp. 1-220, ISSN 1660-0347, 0067-8198

Evans, P., & Halliwell, B. (2001). Micronutrients: Oxidant/antioxidant status. *The British Journal of Nutrition,* Vol.85 Suppl 2, (May 2001), pp. S67-74, ISSN 0007-1145

Fernández-Ginés, J. M., Fernández-López, J., Sayas-Barberá, E., Sendra, E., & Pérez-Alvarez, J. A. (2003). Effect of storage conditions on quality characteristics of bologna sausages made with citrus fiber. *Journal of Food Science,* Vol.68, No.2 (2003), pp. 710-714, ISSN 1750-3841

García, M. L., Dominguez, R., Galvez, M. D., Casas, C., & Selgas, M. D. (2002). Utilization of cereal and fruit fibres in low fat dry fermented sausages. *Meat Science,* Vol.60, No.3, (March 2002), pp. 227-236, ISSN 0309-1740

George, B., Kaur, C., Khurdiya, D. S., & Kapoor, H. C. (2004). Antioxidants in tomato (*Lycopersium esculentum*) as a function of genotype. *Food Chemistry,* Vol.84, No.1, (January 2004), pp. 45-51, ISSN 0308-8146

Gorinstein, S., Martín-Belloso, O., Park, Y., Haruenkit, R., Lojek, A., Cíz, M., Caspi, A., Libman, I., & Trakhtenberg, S. (2001). Comparison of some biochemical characteristics of different citrus fruits. *Food Chemistry,* Vol.74, No.3, (August 2001), pp. 309-315, ISSN 0308-8146

Grigelmo-Miguel, N., Carreras-Boladeras, E., & Martín-Belloso, O. (1999). Development of high-fruit-dietary-fibre muffins. European Food Research and Technology, Vol. 210, No. 2, (December 1999), pp. 123-128, ISNN 1438-2377, 1438-2385

Hassan, F. A., Ismail, A., Hamid, A. A., Azlan, A., & Al-sheraji, S. (2011). Characterisation of fibre-rich powder and antioxidant capacity of *Mangifera pajang* K. fruit peels. *Food Chemistry,* Vol.126, No.1, (May 2011), pp. 283-288, ISSN 0308-8146

Herrera, E., Jimenez, R., Aruoma, O. I., Hercberg, S., Sanchez-Garcia, I., & Fraga, C. (2009). Aspects of antioxidant foods and supplements in health and disease. *Nutrition Reviews,* Vol.67 Suppl 1, (May 2009), pp. S140-144, ISSN 1753-4887, 0029-6643

Hollman, P. C., van Trijp, J. M., Buysman, M. N., van der Gaag, M. S., Mengelers, M. J., de Vries, J. H., & Katan, M. B. (1997). Relative bioavailability of the antioxidant flavonoid quercetin from various foods in man. *FEBS Letters,* Vol.418, No.1-2, (November 1997), pp. 152-156, ISSN 0014-5793

Hu, F. B., Rimm, E. B., Stampfer, M. J., Ascherio, A., Spiegelman, D., & Willett, W. C. (2000). Prospective study of major dietary patterns and risk of coronary heart disease in men. *The American Journal of Clinical Nutrition,* Vol.72, No.4, (October 2000), pp. 912-921, ISSN 0002-9165

Jiménez, J. P., Serrano, J., Tabernero, M., Arranz, S., Díaz-Rubio, M. E., García-Diz, L., Goñi, I., & Saura-Calixto, F.Effects of grape antioxidant dietary fiber in cardiovascular disease risk factors. *Nutrition,* Vol.24, No.7-8, (/7, 2008, pp. 646-653, ISSN 0899-9007

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,* Vol.49, No.11, (November 2001), pp. 5489-5493, ISSN 0021-8561

Jongaroontaprangsee, S., Tritrong, W., Chokanaporn, W., Methacanon, P., Devahastin, S., & Chiewchan, N. (2007). Effects of drying temperature and particle size on hydration properties of dietary fiber powder from lime and cabbage by-products. *International Journal of Food Properties,* Vol.10, No.4 (2007), pp. 887-897, ISSN 1094-2912

Kant, A. K., Graubard, B. I., & Schatzkin, A. (2004). Dietary patterns predict mortality in a national cohort: The national health interview surveys, 1987 and 1992. *The Journal of Nutrition,* Vol.134, No.7, (July 2004), pp. 1793-1799, ISSN 0022-3166

Khanal, R. C., Howard, L. R., Brownmiller, C. R., & Prior, R. L. (2009). Influence of extrusion processing on procyanidin composition and total anthocyanin contents of blueberry pomace. *Journal of Food Science,* Vol.74, No.2, (March 2009), pp. H52-58, ISSN 1750-3841, 0022-1147

Knekt, P., Kumpulainen, J., Jarvinen, R., Rissanen, H., Heliovaara, M., Reunanen, A., Hakulinen, T., & Aromaa, A. (2002). Flavonoid intake and risk of chronic diseases. *The American Journal of Clinical Nutrition,* Vol.76, No.3, (September 2002), pp. 560-568, ISSN 0002-9165

Kris-Etherton, P. M., Lefevre, M., Beecher, G. R., Gross, M. D., Keen, C. L., & Etherton, T. D. (2004). Bioactive compounds in nutrition and health-research methodologies for establishing biological function: The antioxidant and anti-inflammatory effects of flavonoids on atherosclerosis. *Annual Review of Nutrition,* Vol.24, (2004), pp. 511-538, ISSN 0199-9885

Larrauri, J. A., Rupérez, P., Borroto, B., & Saura-Calixto, F. (1996). Mango peels as a new tropical fibre: Preparation and characterization. *Lebensmittel-Wissenschaft Und-Technologie,* Vol.29, No.8, (December 1996), pp. 729-733, ISSN 0023-6438

Larrauri, J. A., Rupérez, P., Borroto, B., & Saura-Calixto, F. (1997). Seasonal changes in the composition and properties of a high dietary fibre powder from grapefruit peel. *Journal of the Science of Food and Agriculture,* Vol.74, No.3 (1997), pp. 308-312, ISSN 1097-0010

Larrauri, J. A., Rupérez, P., & Calixto, F. S. (1997). Pineapple shell as a source of dietary fiber with associated polyphenols. *Journal of Agricultural and Food Chemistry,* Vol.45, No.10, (October 1997), pp. 4028-4031, ISSN 0021-8561

Lecumberri, E., Mateos, R., Ramos, S., Alia, M., Ruperez, P., Goya, L., Izquierdo-Pulido, M., & Bravo, L. (2006). Characterization of cocoa fiber and its effect on the antioxidant capacity of serum in rats. *Nutricion Hospitalaria: Organo Oficial De La Sociedad Espanola De Nutricion Parenteral y Enteral,* Vol.21, No.5, (Sep-Oct 2006), pp. 622-628, ISSN 0212-1611

Li, Y., Guo, C., Yang, J., Wei, J., Xu, J., & Cheng, S. (2006). Evaluation of antioxidant properties of pomegranate peel extract in comparison with pomegranate pulp extract. *Food Chemistry,* Vol.96, No.2, (May 2006), pp. 254-260, ISSN 0308-8146

Liu, R. H. (2004). Potential synergy of phytochemicals in cancer prevention: Mechanism of action. *The Journal of Nutrition,* Vol.134, No.12 Suppl, (December 2004), pp. 3479S-3485S, ISSN 0022-3166

Llorach, R., Espin, J. C., Tomas-Barberan, F. A., & Ferreres, F. (2003). Valorization of cauliflower (*Brassica oleracea* L. var. botrytis) by-products as a source of antioxidant phenolics. *Journal of Agricultural and Food Chemistry,* Vol.51, No.8, (April 2003), pp. 2181-2187, ISSN 0021-8561

Llorach, R., Tomas-Barberan, F. A., & Ferreres, F. (2004). Lettuce and chicory byproducts as a source of antioxidant phenolic extracts. *Journal of Agricultural and Food Chemistry,* Vol.52, No.16, (August 2004), pp. 5109-5116, ISSN 0021-8561

Llorach, R., Espín, J. C., Tomás-Barberán, F. A., & Ferreres, F. (2002). Artichoke (*Cynara scolymus* L.) byproducts as a potential source of health-promoting antioxidant phenolics. *Journal of Agricultural and Food Chemistry,* Vol.50, No.12, (June 2002), pp. 3458-3464, ISSN 0021-8561

Manach, C., Williamson, G., Morand, C., Scalbert, A., & Remesy, C. (2005). Bioavailability and bioefficacy of polyphenols in humans. I. Review of 97 bioavailability studies. *The American Journal of Clinical Nutrition,* Vol.81, No.1 Suppl, (January 2005), pp. 230S-242S, ISSN 0002-9165

Mennen, L. I., Sapinho, D., de Bree, A., Arnault, N., Bertrais, S., Galan, P., & Hercberg, S. (2004). Consumption of foods rich in flavonoids is related to a decreased cardiovascular risk in apparently healthy French women. *The Journal of Nutrition,* Vol.134, No.4, (April 2004), pp. 923-926, ISSN 0022-3166

Mokdad, A. H., Marks, J. S., Stroup, D. F., & Gerberding, J. L. (2004). Actual causes of death in the United States, 2000. *JAMA: The Journal of the American Medical Association,* Vol.291, No.10, (March and 2004), pp. 1238-1245

Most, M. M. (2004). Estimated phytochemical content of the dietary approaches to stop hypertension (DASH) diet is higher than in the control study diet. *Journal of the American Dietetic Association,* Vol.104, No.11, (November 2004), pp. 1725-1727, ISSN 0002-8223

Napolitano, A., Fogliano, V., Tafuri, A., & Ritieni, A. (2007). Natural occurrence of ochratoxin A and antioxidant activities of green and roasted coffees and corresponding byproducts. *Journal of Agricultural and Food Chemistry,* Vol.55, No.25, (December 2007), pp. 10499-10504, ISSN 0021-8561

Naska, A., Fouskakis, D., Oikonomou, E., Almeida, M. D., Berg, M. A., Gedrich, K., Moreiras, O., Nelson, M., Trygg, K., Turrini, A., Remaut, A. M., Volatier, J. L., Trichopoulou, A., & DAFNE participants. (2006). Dietary patterns and their socio-demographic determinants in 10 European countries: Data from the DAFNE databank. *European Journal of Clinical Nutrition,* Vol.60, No.2, (February 2006), pp. 181-190, ISSN 0954-3007

Nijveldt, R. J., van Nood, E., van Hoorn, D. E., Boelens, P. G., van Norren, K., & van Leeuwen, P. A. (2001). Flavonoids: A review of probable mechanisms of action and potential applications. *The American Journal of Clinical Nutrition,* Vol.74, No.4, (October 2001), pp. 418-425, ISSN 0002-9165

Okarter, N., & Liu, R. H. (2010). Health benefits of whole grain phytochemicals. *Critical Reviews in Food Science and Nutrition,* Vol.50, No.3, (March 2010), pp. 193-208, ISSN 1549-7852, 1040-8398

Ordóñez, R. M., Cardozo, M. L., Zampini, I. C., & Isla, M. I. (2010). Evaluation of antioxidant activity and genotoxicity of alcoholic and aqueous beverages and pomace derived from ripe fruits of *Cyphomandra betacea sendt*. *Journal of Agricultural and Food Chemistry,* Vol.58, No.1, (January 2010), pp. 331-337, ISSN 0021-8561

Ovando-Martinez, M., Sáyago-Ayerdi, S., Agama-Acevedo, E., Goñi, I., & Bello-Pérez, L. A. (2009). Unripe banana flour as an ingredient to increase the undigestible carbohydrates of pasta. *Food Chemistry,* Vol.113, No.1, (March 2009), pp. 121-126, ISSN 0308-8146

Raghavendra, S. N., Ramachandra Swamy, S. R., Rastogi, N. K., Raghavarao, K. S. M. S., Kumar, S., & Tharanathan, R. N. (2006). Grinding characteristics and hydration properties of coconut residue: A source of dietary fiber. *Journal of Food Engineering,* Vol.72, No.3, (February 2006), pp. 281-286, ISSN 0260-8774

Ramírez-Moreno, E., Hervert-Hernández, D., Sanchez-Mata, M. C., Díez Marqués, C., & Goñi, I. (2011) Assessment of nutritional properties on pulp and seeds of cactus pear: bioaccessibility of polyphenols and antioxidant capacity. *International Journal of Food Science and Nutrition*, in press, ISSN 0963-7486, 1465-3478.

Rice-Evans, C. A., Miller, N. J., & Paganga, G. (1996). Structure-antioxidant activity relationships of flavonoids and phenolic acids. *Free Radical Biology & Medicine,* Vol.20, No.7 (1996), pp. 933-956, ISSN 0891-5849

Rodríguez, R., Jiménez, A., Fernández-Bolaños, J., Guillén, R., & Heredia, A. (2006). Dietary fibre from vegetable products as source of functional ingredients. *Trends in Food Science & Technology,* Vol.17, No.1, (January 2006), pp. 3-15, ISSN 0924-2244

Sánchez-Alonso, I., Jiménez-Escrig, A., Saura-Calixto, F., & Borderías, A. J. (2007). Effect of grape antioxidant dietary fibre on the prevention of lipid oxidation in minced fish: Evaluation by different methodologies. *Food Chemistry,* Vol.101, No.1 (2007), pp. 372-378, ISSN 0308-8146

Sanchez-Zapata, E., Fuentes-Zaragoza, E., Fernandez-Lopez, J., Sendra, E., Sayas, E., Navarro, C., & Perez-Alvarez, J. A. (2009). Preparation of dietary fiber powder from tiger nut (*Cyperus esculentus*) milk ("horchata") byproducts and its physicochemical properties. *Journal of Agricultural and Food Chemistry,* Vol.57, No.17, (September 2009), pp. 7719-7725, ISSN 1520-5118, 0021-8561

Sanchez-Zapata, E., Munoz, C. M., Fuentes, E., Fernandez-Lopez, J., Sendra, E., Sayas, E., Navarro, C., & Perez-Alvarez, J. A. (2010). Effect of tiger nut fibre on quality characteristics of pork burger. *Meat Science,* Vol.85, No.1, (May 2010), pp. 70-76, ISSN 1873-4138, 0309-1740

Saura-Calixto, F. (1998). Antioxidant dietary fiber product: A new concept and a potential food ingredient. *Journal of Agricultural and Food Chemistry,* Vol.46, No.10, (October 1998), pp. 4303-4306, ISSN 0021-8561

Saura-Calixto, F., & Goñi, I. (2006). Antioxidant capacity of the Spanish Mediterranean diet. *Food Chemistry,* Vol.94, No.3, (February and 2006), pp. 442-447, ISSN 0308-8146

Saura-Calixto, F., Serrano, J., & Goñi, I. (2007). Intake and bioaccessibility of total polyphenols in a whole diet. *Food Chemistry,* Vol.101, No.2 (2007), pp. 492-501, ISSN 0308-8146

Saura-Calixto, F., Garcia-Alonso, A., Goni, I., & Bravo, L. (2000). In vitro determination of the indigestible fraction in foods: An alternative to dietary fiber analysis. *Journal of Agricultural and Food Chemistry,* Vol.48, No.8, (August 2000), pp. 3342-3347, ISSN 0021-8561

Saura-Calixto, F., & Goni, I. (2009). Definition of the Mediterranean diet based on bioactive compounds. *Critical Reviews in Food Science and Nutrition,* Vol.49, No.2, (February 2009), pp. 145-152, ISSN 1549-7852, 1040-8398

Sáyago-Ayerdi, S. G., Brenes, A., & Goñi, I. (2009). Effect of grape antioxidant dietary fiber on the lipid oxidation of raw and cooked chicken hamburgers. *LWT - Food Science and Technology,* Vol.42, No.5, (June 2009), pp. 971-976, ISSN 0023-6438

Schieber, A., Stintzing, F. C., & Carle, R. (2001). By-products of plant food processing as a source of functional compounds -- recent developments. *Trends in Food Science & Technology,* Vol.12, No.11, (November 2001), pp. 401-413, ISSN 0924-2244

Schieber, A., Hilt, P., Streker, P., Endreß, H., Rentschler, C., & Carle, R. (2003). A new process for the combined recovery of pectin and phenolic compounds from apple pomace. *Innovative Food Science & Emerging Technologies,* Vol.4, No.1, (March 2003), pp. 99-107, ISSN 1466-8564

Shahidi, F., Alasalvar, C., & Liyana-Pathirana, C. M. (2007). Antioxidant phytochemicals in hazelnut kernel (*Corylus avellana* L.) and hazelnut byproducts. *Journal of Agricultural and Food Chemistry,* Vol.55, No.4, (February 2007), pp. 1212-1220, ISSN 0021-8561

Someya, S., Yoshiki, Y., & Okubo, K. (2002). Antioxidant compounds from bananas (*Musa cavendish*). *Food Chemistry,* Vol.79, No.3, (November 2002), pp. 351-354, ISSN 0308-8146

Soong, Y., & Barlow, P. J. (2004). Antioxidant activity and phenolic content of selected fruit seeds. *Food Chemistry,* Vol.88, No.3, (December 2004), pp. 411-417, ISSN 0308-8146

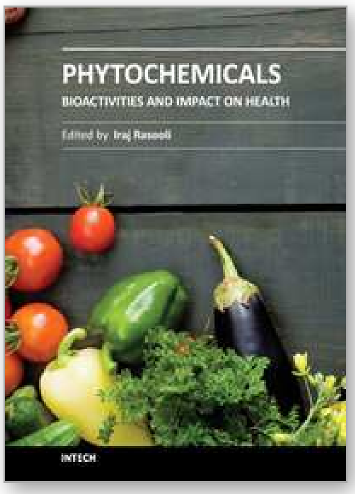
Trowell, H., Southgate, D. A., Wolever, T. M., Leeds, A. R., Gassull, M. A., & Jenkins, D. J. (1976). Letter: Dietary fibre redefined. *Lancet,* Vol.1, No.7966, (May 1976), pp. 967,

Valko, M., Leibfritz, D., Moncol, J., Cronin, M. T., Mazur, M., & Telser, J. (2007). Free radicals and antioxidants in normal physiological functions and human disease. *The International Journal of Biochemistry & Cell Biology,* Vol.39, No.1 (2007), pp. 44-84, ISSN 1357-2725

Williamson, G., & Manach, C. (2005). Bioavailability and bioefficacy of polyphenols in humans. II. review of 93 intervention studies. *The American Journal of Clinical Nutrition,* Vol.81, No.1 Suppl, (January 2005), pp. 243S-255S, ISSN 0002-9165

Wolfe, K. L., & Liu, R. H. (2003). Apple peels as a value-added food ingredient. *Journal of Agricultural and Food Chemistry,* Vol.51, No.6, (March 2003), pp. 1676-1683, ISSN 0021-8561, 0021-8561

Zduńczyk, Z., Flis, M., Zieliński, H., Wróblewska, M., Antoszkiewicz, Z., & Juśkiewicz, J. (2006). In vitro antioxidant activities of barley, husked oat, naked oat, triticale, and buckwheat wastes and their influence on the growth and biomarkers of antioxidant status in rats. *Journal of Agricultural and Food Chemistry,* Vol.54, No.12, (June 2006), pp. 4168-4175, ISSN 0021-8561



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