Apples: An Important Source of Antioxidants in the American Diet

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This work supported in part by the New York Apple Research and Development Program and New York Apple Research Association.

Apples contain a significant amount of phytochemicals. Apple skins are a rich source of quercetin which is known to have strong antioxidant and anticancer activities. Different apple cultivars exhibit differing amounts of phytochemicals and antioxidant activity. Based on the high antioxidant activity of apples, Americans should consume more apples, or at least one apple a day, to increase the total antioxidant content of their diet.

Over the past two decades, many scientists have demonstrated that diet plays an important role in the morbidity and mortality associated with the major diseases in the United States, such as cardiovascular disease, cancer, hypertension and obesity. Cancer and cardiovascular disease combined account for about 70 percent of all U.S. deaths. Scientists estimate that one-third of all cancer cases and one-half of cardiovascular diseases and hypertension can be attributed to diet (Buring and Hennekens, 1995).

The Health Benefits of Antioxidants and Phytochemicals

Antioxidants are substances or compounds that quench or stabilize free radicals, so they can prevent the oxidation of other molecules. Free radicals, formed in the ordinary process of oxygen metabolism, are very reactive chemical species that could damage cellular machinery. Abundant scientific evidence indicates that certain naturally occurring non-nutritive chemical components, commonly referred to as phytochemicals, nutraceuticals, or functional compounds, have antioxidant activity. Phytochemicals are found in fruits, vegetables, herbs, spices, and cereals, and prevent or reduce the risk of some chronic diseases such as cancers and cardiovascular disease. Polyphenols are one of the phytochemical groups whose important biochemical properties include antioxidant activity. For example, some polyphenols scavenge free radicals, e.g. superoxide ions, singlet oxygen and lipid peroxyl radicals. Polyphenols inhibit lipoxygenase and cyclo-oxygenase (Laughton et al., 1991) as well as lipid peroxidation and also have diverse effects on immune and inflammatory cell functions (Decharneux et al., 1992). Some polyphenols also display antihemolytic activities, inhibit oxidation of low-density lipoprotein (LDL) by macrophages, and prevent cytotoxicity of oxidized LDL on lymphoid cell lines (Negre-Salvayre and Salvayre, 1992). In addition, some polyphenols, such as flavonoids, have been reported to affect capillary permeability, cellular secretory processes, cell membrane receptors, and carriers. Mutagenic, antiviral, antibacterial, and antifungal properties of flavonoids have also been demonstrated. Flavonoids in regu-

Apples are high in antioxidants which help explain why “an apple a day keeps the doctor away.”

larly consumed foods such as tea, onions, and red wine may reduce the risk of coronary heart disease in elderly men (Hertog et al., 1993).

There is also a large body of evidence that shows that supplementing the diet with micronutrients has positive health benefits. Many of these micronutrients can be derived from plants. In addition, plant macro components such as fiber may reduce cancers of the colon and other tissues. In 1982, the National Research Council advised that cancer risk might be reduced by increasing the consumption of carotene-rich fruits and cruciferae family vegetables. That recommendation has been substantiated by strong epidemiological evidence including a recent study that demonstrated that persons with a low fruit and vegetable intake experienced twice the risk of cancer (Block et al., 1992). Some polyphenols have been shown to exhibit synergistic interactions with other nutrients. Therefore, phytochemicals will play an increasingly important role in optimal nutrition as this new era in the food and nutritional sciences develops. As consumers become more aware of the anticancer potential of some plant foods, the demand will grow for natural and processed foods that manifest these health benefits.

TABLE 1

Antioxidant Activity of Various NY Apple Cultivars

Variety	Antioxidant Activity* (%)	Total Phenolics (mg/100g)
Fuji	98.3	101.9
Spartan	81.5	83.6
Pioneer McIntosh	76.0	106.7
Delicious	75.7	123.8
Liberty	72.5	101.0
Granny Smith	72.1	134.5
Jonathan	72.0	108.1
Northern Spy	61.5	137.6
Cox Orange Pippin	58.9	128.9
Rome Spuree	57.2	107.4
NY 674	51.9	85.8
Freedom	51.2	123.4
Idared	50.9	78.1
Red Cort	49.4	86.8
Gala	47.7	85.2
RI Greening	44.6	132.7
Crispin	40.9	83.7
Rubinette	34.5	88.2
Jonagold	24.2	139.7
Jonamac	19.4	82.4
Empire	<10	50.9
Golden Delicious	<10	82.2
Gingergold	<10	64.9

*Antioxidant activity of 66 mg of apple tissue relative to that of 30 ppm α-tocopherol.

TABLE 2

Concentration of phenolics in fresh apples grown in NY State.

Penolics	Golden Delicious	Cortland	Monroe	R.I. Greening	Empire	NY674	*Average*
	(mg/100g apple tissue with skins)						
Chlorogenic acid	8.48	5.36	10.08	14.28	11.52	4.40	*9.02*
Epicatechin	7.12	8.32	10.72	19.16	2.28	4.32	*8.65*
Procyanidin B2	6.28	11.32	8.32	21.68	3.44	5.04	*9.34*
Quercetin glycosides							
arabinoside	2.16	2.40	4.44	2.88	2.76	1.56	
xyloside	1.68	1.08	2.28	1.92	2.16	1.20	
glucoside	2.40	1.56	2.40	12.0	2.40	0.36	*15.84*
galactoside	4.20	3.36	4.80	4.32	4.20	1.92	
hamnoside	3.84	2.28	3.12	4.08	3.84	2.40	
Phloretin glycosides							
glucoside	1.80	1.44	2.40	2.08	2.80	1.84	
xyloglucoside	1.92	3.20	4.92	5.88	1.72	3.56	*16.78*
Total	**39.88**	**40.32**	**53.48**	**77.48**	**37.12**	**26.60**	***59.63***

Various stone fruits and berries are reported to contain significant amounts of phytochemicals. In apples, there are several classes of polyphenols; flavonol glycosides, phenolic acids, catechins, dihydrochalcones, and procyanidins. Most of these compounds are known to have antioxidant activity. In less significant amounts, glutathione and ascorbic acid are the other antioxidants that occur in apples.

Antioxidant Activity of Apples

Apples are one of the major fruits consumed by Americans. Among fresh fruits consumed in 1996, bananas ranked first (28 pounds), and apples second (19.3 pounds)—more than oranges, grapes, or grapefruits. When fresh and processed products are combined, the per capita consumption of apples (47 pounds) exceeds that of bananas. Therefore, the contribution of apples to antioxidant activity in the American diet could be significant. Our main interests in this research were to evaluate the antioxidant activity in various apple cultivars and their antioxidant contribution to the American diet. The importance of the antioxidant activity measurement is that it should measure total antioxidant activity derived from whole fresh apples as they are consumed by consumers.

We analyzed antioxidant activity of apples based on coupled oxidation of linoleic acid and b-carotene and expressed the results as relative percent of 30 ppm α-tocopherol equivalent (100 percent). Flavonoids were extracted, isolated, and analyzed by an HPLC method developed in our laboratory and total phenolic contents were analyzed by the colorimetric method using the Folin-Ciocalteau reagent.

Table 1 shows the antioxidant activity and total phenolic content of various apple cultivars grown in New York State in 1997. There was a wide range of antioxidant activity among the 24 apple cultivars studied. Based on their antioxidant activity, the cultivars can be divided into three groups: the high activity group with more than 60 percent activity, the medium activity group with activity between 40–60 percent, and the low activity group with below 40 percent activity. Among the apple cultivars studied, well-known apple cultivars such as Fuji, McIntosh, Delicious, Granny Smith and Jonathan apples belong to the high activity group. Apple cultivars such as Idared, Gala, RI Greening and Crispin belong to the medium activity group. Jonagold, Empire and Golden Delicious apples are relatively low in antioxidant activity. The difference in antioxidant activity among various apple cultivars might be due to the difference in composition and concentration of phenolic compounds and also due to unknown synergistic effects among phenolics and other constituents. Apples, like other fruits, vary in chemical composition, even within the same variety. Some of the variables include maturity, location produced, agricultural practices, and other environmental factors. Therefore, we expect the antioxidant activity, as expressed in Table 1, to vary from year to year. We did observe variations in the 1998 and 1999 crops. It has been frequently reported that total phenolic content correlates with certain antioxidant activity. However, we found

that only 10 out of 24 apple cultivars showed some correlation (r^2=0.66) between antioxidant activity and the total phenolics content; other apple cultivars showed no direct correlation. This may be due to the fact that the total phenolic analysis using the Folin-Ciocalteau reagents includes many more compounds than just the biologically active flavonoids, and/or some phenolics that do not have the same antioxidant activity as others.

The composition and concentration of the major apple polyphenols observed in this study are shown in Table 2. Different apple cultivars showed different concentrations of polyphenols. The average concentrations of each phenolic are: phloretin glycosides, 16.78 mg; quercetin glycosides, 15.84 mg; procyanidin B2, 9.34 mg; chlorogenic acid, 9.02 mg; and epicatechin, 8.65 mg/100 g fresh apples. Most of these compounds are reported to have antioxidant activity. Among these, in particular, quercetin is the most powerful antioxidant. It was reported that quercetin reduces the carcinogenic activity of several food mutagens, inhibits enzymatic activities associated with several types of tumor cells, enhances the antiproliferative activity of the anticancer agents, and inhibits the growth of transformed tumorigenic cells (Leighton et al., 1992).

Consumption and Diet

Although there have been many scientific reports on the biological activity of selected phytochemicals in plant foods in recent years, these major questions still remain: Which plant foods consumed by Americans today contribute health benefits and how much? Which chemical constituents are responsible for such benefits? What kind of guidelines can we provide to consumers to help them select and consume the beneficial plant foods?

The nutritional value and health-related biological activity of various fruits and vegetables depend not only on the concentration of certain nutrients and phytochemicals but also on the amount of such foods consumed in the diet. No matter how high the concentration of a certain bioactive compound in a food, if the amount of consumption of that food is low, the contribution of the bioactive compound in the diet is negligible. For example, spinach and Brussels sprouts are relatively high in major vitamins and minerals, but their contribution to our diet is low because the amounts we consume are very small. On the other hand, tomatoes are relatively low in concentration of vitamins and minerals but make a major contribution to the U.S. diet because of large per capita consumption. Likewise, apple phenolics may contribute significantly to our diet. Among the major fresh fruits consumed in the U. S., per capita consumption of banana is 28 pounds, apples 19.3 pounds, oranges 12.8 pounds, followed by grapes (6.9 pounds), grapefruit (5.8 pounds), strawberries (4.4 pounds), peaches (4.3 pounds), and pears (3.1 pounds). For a rough estimate, if we consider per capita consumption of fresh and processed apples as 47 pounds, the actual antioxidant contribution of apples exceeds that of any other major fruit in the American diet.

If we eat one apple (approximately 150 g) each day, we may be able to get about 1 g of polyphenols with a significant amount of healthy antioxidant activity. The daily human consumption of polyphenols in the average diet has been estimated to be about 1 g. Since we do not yet know the daily antioxidant requirement, we have to be prudent before drawing any conclusions. However, the evidence shown here is that apples contain important antioxidants such as quercetin that exhibits significantly high antioxidant activity. Since quercetins are mainly located in apple skins, consumption of apples with skins is highly desirable in order to maximize apple antioxidant activity. We are in the process of elucidating the anticancer activity of fresh apples.

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