Apple Peels are Rich in Phytochemicals and Have High Antioxidant Activity

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Apples are an important source of phenolic compounds in the European and North American diet, and may exert a chemoprotective effect healthwise. When studied for nutritional quality, apple peels rate very highly in phytochemical content. In the manufacture of applesauce, peels are frequently considered a waste product. This study indicates that apple peels show potential as a value-added ingredient because of their high phenolic content, and may possess more bioactivity than apple flesh.

The leading causes of death in the United States are cardiovascular disease and cancer. It has been estimated that 32 percent of deaths from cancer could be avoided by dietary modifications. Fruits and vegetables contain many phytochemicals, including phenolics, which may exert chemoprotective effects through a variety of mechanisms. Increased intake of fruits and vegetables has also been associated with reduced risk of coronary heart disease (CHD) and stroke. Flavonoids, a class of phenolic compounds commonly found in fruits and vegetables, have been linked to reduced risk of mortality from CHD. Such findings have led the National Research Council (NRC) to recommend consuming five or more servings of fruits and vegetables a day.

Apples are very significant part of the diet. From a Dutch Food Consumption Survey and previously analyzed flavonoid contents of fruits, vegetables, and beverages, it was determined that apples are the third largest contributors of flavonoids in the Dutch diet behind tea and onions. In Finland, along with onions, they are the top contributors. Twenty-two percent of the fruit phenolics consumed in the United States are from apples, making them the largest source.

Consumption of apples has been linked to the prevention of chronic disease. Apple intake has been negatively associated with lung cancer incidence in two separate studies, and has also been related to reduced cardiovascular disease. Coronary and total mortality, symptoms of chronic obstructive pulmonary disease, and the risk of thrombotic stroke have all been inversely associated with apple consumption.

Apples are a good source of phenolic compounds. The total extractable phenolic content has been investigated and ranges from 110-357 mg / 100 g fresh apple. Previously, our research group found that peeled and unpeeled apples have high antioxidant activity and inhibit the growth of human cancer cells *in vitro*. Vitamin C was responsible for less than 0.4 percent of the antioxidant activity, indicating that other factors, such as phenolics, were the main contributors. The antioxidant and antiproliferative activities of unpeeled apples were greater than that of peeled apples. It is also known that the concentration of total phenolic compounds is much greater in the peel of apples than in the flesh. Both suggest that apple peels may possess more bioactivity than the flesh.

Apple peels are a waste product of applesauce and canned apple manufacturing. The National Agriculture Statistics Service (NASS) reported that 216 million pounds of apples were processed in this manner in New York State in 2000. We estimate that 16 million pounds of peels were generated. If apple peels show potential to improve health when consumed, their utilization should be investigated.

Therefore, the object of this study was to evaluate the nutritional quality of apple peels. Total phenolic content, anthocyanin content, antioxidant activity and antiproliferative effects of apple peels were quantified and the results compared those of the apple flesh and flesh + peel. Four apple varieties (Rome Beauty, Idared, Cortland, and Golden Delicious) commonly used in applesauce manufacture in New York State were evaluated.

Phytochemical Content

The total phenolic content of the flesh, flesh + peel, and peel of the four apple varieties was determined (Figure 1). Of the peels, the total phenolic content of the Idared peels was highest at 588.9 ± 83.2 mg gallic acid equivalents / 100 g peels, followed by Rome Beauty, Cortland, and Golden Delicious apples. The peel phenolic content was not significantly different for Idared and Rome Beauty apples ($p < 0.05$). Rome Beauty flesh + peel phenolics were the highest at 159.0 ± 15.1 mg gallic acid equivalents / 100 g flesh + peel. The phenolic content for the flesh + peel of all the varieties was similar. Total phenolic content of the flesh was highest for Cortland (103.2 ± 12.3 mg gallic acid equivalents / 100 g flesh), followed by Golden Delicious, Rome Beauty, and

Idared apples. The total phenolic content was highest in the peel, followed by the flesh + peel and the flesh for all four apple varieties. The flesh and flesh + peel values were statistically similar for Idared, Cortland, and Golden Delicious apples ($p > 0.05$).

We have shown that apple peels possessed the highest content of phenolic compounds compared to other edible parts of the apple. The total phenolic contents for the flesh and flesh + peel samples were comparable to those previously reported. Other research groups have also noted that apple peels had higher phenolic contents than the flesh. The nature and distribution of these phytochemicals between the flesh and the peel of the apple is also different. Among others, the flesh contains catechins, procyanidins, phloridzin, phloretin glycosides, caffeic acid and chlorogenic acid. The peel possesses all of these compounds and has additional flavonoids not found in the flesh, such as quercetin glycosides.

The anthocyanins in the apple peels were quantified (Figure 2). Anthocyanins are phenolic compounds with high antioxidant activity that give many fruits and vegetables their red or purple color. The anthocyanin content of the flesh and flesh + peel was not analyzed as apple flesh of these varieties does not contain anthocyanins. The measured anthocyanin contents of the apple peels were related to their appearances. The deep red Idared apple peels contained the most anthocyanins, with 26.8 ± 6.5 mg cyanidin 3-glucoside equivalents / 100 g, followed by Cortland and Rome Beauty. The Cortland apples were bright red with green patches; the Rome Beauty apples were pink. The peels from these two varieties had similar values ($p > 0.05$). Golden Delicious apple peels contained only a trace amount of anthocyanins, as expected by their lack of red pigmentation. The red color of apple peels is due to the presence of cyanidin 3-galactoside.

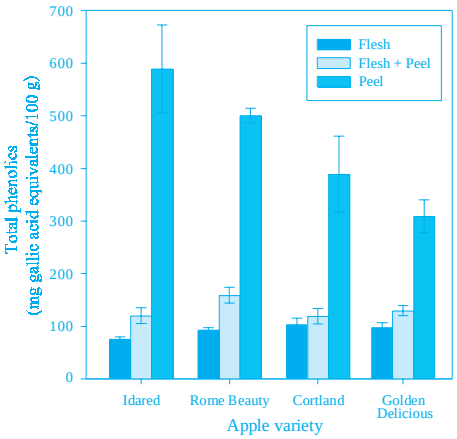

Figure 1. Total phenolic content of apples.

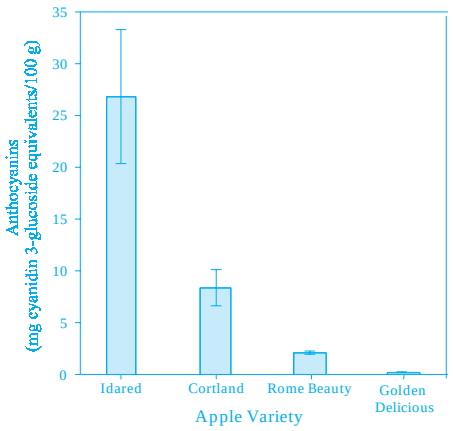

Figure 2. Anthocyanin content of apple peels.

Total Antioxidant Activity

The total antioxidant activity of the apple flesh, flesh + peel, and peel of the four apple varieties was determined using the Total Oxyradical Scavenging Activity (TOSC) assay. The degree of inhibition of an oxidizing reaction by apple extracts was measured in this test. The total antioxidant activity of the peels was greater than that of the flesh or flesh + peel for all varieties (Figure 3). Idared peels possessed the greatest activity, with 312.2 ± 9.8 µmol vitamin C equivalents / g peel, followed by the peels of Rome Beauty, Cortland, and Golden Delicious apples. The flesh + peel of Rome Beauty apples had the highest antioxidant activity (131.6 ± 0.8 µmol vitamin C equivalents / g flesh + peel) when compared to that component of the other apples. In descending order, the flesh components had total antioxidant activities of 68.0 ± 1.5 (Rome Beauty), 50.4 ± 2.2 (Cortland), 46.9 ± 1.6 (Idared), and 43.5 ± 0.4 (Golden Delicious) µmol vitamin C equivalents / g flesh. The antioxidant activity was highest from the peels in all varieties, followed by the flesh + peel and the flesh.

To our knowledge, this is the first time the total antioxidant activity of apple peels has been measured. The peels of the apple varieties under investigation exhibited high antioxidant activity compared to the flesh and flesh + peel. These antioxidant activities were high in relation to those of other fruits and vegetables tested by our research group. The peels from one average-sized Idared apple have an antioxidant activity equivalent to 820 mg vitamin C. The antioxidant activity of the edible portion of apples has been ascertained in the past using the oxygen radical absorbance capacity assay (ORAC) and compared to other fruits. They have been ranked ninth out of 12 fruits, and eighth out of 20 fruits. Apple antioxidant activity was found to be related to the total phenolic content. Apple extracts have also been shown to have the ability to bind to plasma low density and very low density lipoproteins and inhibit the their oxidation. Oxidation of these lipoproteins is thought to be an important step in the progression of atherosclerosis.

Inhibition of Cancer Cell Proliferation

The effect of apple flesh, flesh + peel and peels on the growth of $HepG_2$ human liver cancer cells *in vitro* was investigated. The cancer cells were exposed to various concentrations of apples in the form of apple extracts and incubated for 96 hours. After this time, their growth was compared to untreated cells. Figure 4 shows the EC_{50} of the antiproliferative activity of different apple varieties. Lower EC_{50} values represent higher antiproliferative activity. The peels of each apple variety inhibited the growth of $HepG_2$ cells more than the flesh or flesh + peel, and the peels had low EC_{50} values compared to the flesh and flesh + peel components. The flesh + peel and flesh samples showed inhibitory effects in most cases, though they showed much less antiproliferative activity than the peels. Liu et al. likewise reported antiproliferative effects from phytochemical extracts of Fuji, Gala, and Red Delicious apples on human liver cancer cells. Of the four varieties, Rome Beauty apples had the lowest EC_{50} values of the peel and flesh + peel components at 12.4 ± 0.4 and 26.5 ± 0.3 mg apple / mL, respectively, indicating the most antiproliferative activity of the varieties examined.

Summary

Consumption of fruits and vegetables has been associated with reduced risk of chronic diseases. These benefits are hypothesized to be due to the high content of antioxidants in fruits and vegetables. Apples are commonly eaten and are large contributors of phenolic compounds in European and North American diets. The peels of apples, in

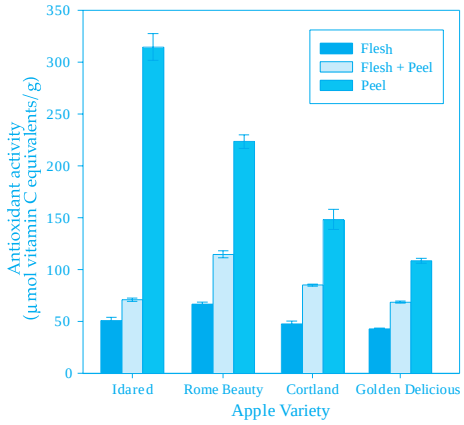

Figure 3. The antioxidant activity of apples.

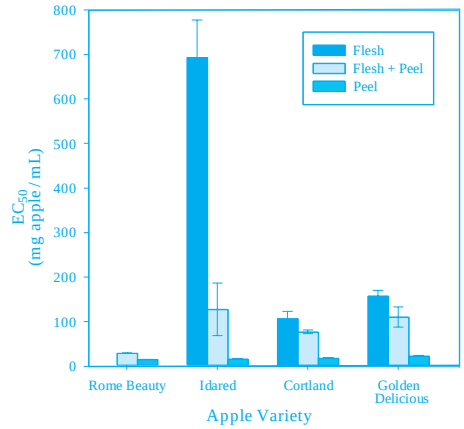

Figure 4. EC_{50} of inhibition of $HepG_2$ human liver cancer cell proliferation by phytochemical extracts of apples.

particular, are high in these phytochemicals. During applesauce and canned apple manufacture, the antioxidant-rich peels of apples are discarded. To determine if a useful source of antioxidants is being wasted, the phytochemical content, antioxidant activity, and antiproliferative activity of the peels of four varieties of apples (Rome Beauty, Idared, Cortland, and Golden Delicious) commonly used in applesauce production in New York State were investigated. The values of the peels were compared to those of the flesh and flesh + peel components of the apples. Within each variety, the total phenolic content was highest in the peels, followed by the flesh + peel and the flesh. The peels all had significantly higher total antioxidant activities than the flesh + peel and flesh of the apple varieties examined. Apple peels were also shown to more effectively inhibit the growth of $HepG_2$ human liver cancer cells than the other apple components.

Our results show that eating apple peels may have health benefits for consumers. They are often discarded in the production of other products, but clearly possess high levels of antioxidant and bioactive compounds. Waste apple peels from applesauce and canned apple manufacturing should be regarded as a valuable commodity. We believe they show potential as a functional food or value-added ingredient in the future. As part of a diet rich in fruits, vegetables and grains, apples and their peels may assist in the prevention of chronic disease.

Rui Hai Liu directs Kelly Wolfe, a graduate student, on the extraction of apple phytochemicals in Liu's laboratory in Ithaca.

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Rui Hai Liu is an assistant professor of food science in Ithaca whose research program focuses on diet and cancer, functional foods/ nutraceuticals for chronic disease prevention, and herbal remedies for cancer and hepatitis. He studies the health benefits of phytochemicals in fruits and vegetables. Kelly Wolfe is a graduate student working with Liu.