

# Antioxidant Content of Whole Grain Breakfast Cereals, Fruits and Vegetables

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Harold E. Miller, PhD, Fred Rigelhof, Leonard Marquart, PhD, RD, Aruna Prakash, PhD, and Mitch Kanter, PhD

*General Mills, Inc., Minneapolis, Minnesota*

**Key Words:** antioxidant, whole grain, breakfast cereal, fruit, vegetable, diphenylpicrylhydrazyl, DPPH.

**Background:** Considerable scientific evidence suggests that whole grains, as commonly consumed in the United States and Europe, reduce risk for chronic disease including cancer and heart disease. Whole grains provide a wide range of nutrients and phytochemicals that may work synergistically to optimize human health. Fruits and vegetables provide protection against age related diseases. It is believed their high content of antioxidant compounds is key to such protection.

**Objective:** This research compares the antioxidant activity of whole grain, ready-to-eat (RTE) breakfast cereals to that of fruits and vegetables.

**Method:** Antioxidant activity was determined by dispersing finely ground samples in a 50% aqueous methanol solution of the stable free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH). DPPH, which forms a deep purple solution, reacts with antioxidants and color loss at 515 nm correlates to antioxidant content, which is expressed as Trolox equivalents/100 grams (TE).

**Results:** Whole grain breakfast cereals analyzed in this study contained from 2200-3500 TE. By comparison, fruits generally ranged from 600-1700 TE, with a high of 2200 TE for red plums. Berries averaged 3700 TE and vegetables averaged 450 TE with a high of 1400 TE for red cabbage. A 41 gram average serving of RTE breakfast cereal provides 1120 TE, while an average 85 gram serving of vegetables or fruits provides 380 and 1020 TE, respectively.

**Conclusion:** Whole grain breakfast cereals, fruits and vegetables are all important dietary sources of antioxidants.

## INTRODUCTION

Experimental and epidemiological studies indicate that consumption of grains, fruits and vegetables is related to lower incidence of aging diseases [1–7]. These foods contain a wide variety of phytonutrients, including antioxidants, that occur in all parts of higher plants [8–11]. It is generally suggested that antioxidants in fruits, vegetables, tea and red wine are key to explaining how these foods function to reduce the incidence of chronic diseases, including heart disease and some cancers [8,12–16]. Antioxidants in grains and grain products are known, but their potential contribution to health through the diet has essentially been ignored. Free radicals are believed to trigger the initiation phase of several diseases. The ability of natural antioxidants to react with free radicals makes them of special interest. Naturally occurring antioxidants number in the thousands, and the average diet may include hundreds of antioxidant compounds. Some natural antioxidants such as Vitamin C, Vitamin E and  $\beta$ -carotene have been studied extensively.

Plant antioxidants include a variety of structural types with a wide range of antioxidant activity. Phenolic acids are common antioxidants, ubiquitous in fruits, vegetables, legumes and grains. They exist primarily as substituted benzoic and cinnamic acid compounds [17]. Flavonoids are more concentrated in fruits and vegetables, but are also found in grains. They number in the thousands and have a basic three-ring structure in common, but activity varies greatly dependent primarily on number and location of hydroxyl groups [14]. Enzymatic hydroxylation, O-methylation, O-glycosylation or esterification can modify the basic structures of phenolic acids and flavonoids. The compounds may be absorbed directly during digestion or after hydrolysis. After absorption, sulfate, phosphate or glucuronide derivatives may be formed. Such transformations complicate direct analysis of bioavailability.

Typically, phenolic acids and flavonoids are water soluble compounds, but lipid soluble derivatives are common to grains such as the caffeic and ferulic acid esters of C<sub>20–28</sub> chain mono and dialcohols [18]. Tocopherols and tocotrienols are also lipid

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Address reprint requests to: Harold E. Miller, Ph.D., General Mills, Inc., 9000 Plymouth Ave., Minneapolis, MN 55427.

soluble and are common to vegetables and grains. Although  $\alpha$ -tocopherol has the highest vitamin E activity, all tocopherols and tocotrienols have similar or better antioxidant activity. In addition to these well-known antioxidants, grains contain several unique structural types. Avenanthramides (N-cinnamoyl-anthranilate alkaloids) and avenalamic acids (ethylenic homologues of cinnamic acids) are only found in oats [19,20]. Avenanthramides occur in relatively high concentration (500–1000 PPM) and have high antioxidant activity [21]. Fat-soluble ferulic and caffeic acid esters of long chain mono and dialcohols are common to grains [18, 22] and could function to protect lipid membranes and spare vitamin E. These esters are equal to tocopherols as antioxidants that prevent lipid oxidation [23]. In addition to soluble antioxidants, a significant amount of grain phenolics are covalently bound to cell wall polysaccharides [18, 24] and may be important to human health in this form via digestive processes. A recent study [25] showed that both high molecular weight (>3500) and low molecular weight (<3000) aqueous extracts of grain had significant antioxidant activity. Activity of extracts increased when grain products were first treated by hydrolytic and enzymatic conditions that mimic digestion.

Known antioxidants are of specific interest, but studies of the antioxidant activity of extracts show that known compounds account for only a fraction of total activity [26, 27]. A large share of biologically important compounds may be unknown. It is also possible that antioxidant activity in general is important and not just that of a few compounds. The typical diet contains a mixture of hundreds of antioxidant compounds, and composition changes daily depending on foods consumed.

Many grain antioxidants are the same or similar to those contained in fruits and vegetables, but many are unique. Structural diversity of antioxidant compounds may increase the likelihood of protection in complex biological systems. Highly reactive free radicals and oxygen species are continually present in biological systems from a wide variety of sources. Free radicals are essential to metabolic processes, but can also damage cellular material at the molecular level. Protein, lipids, lipid membranes and DNA, if oxidized, can initiate degenerative disease. Antioxidants scavenge free radicals and reactive oxygen species and, by this means alone, can be extremely important in inhibiting oxidative mechanisms that lead to degenerative diseases such as heart disease, cancer, cataracts, brain dysfunction and arthritis [28].

Antioxidant content of food and plant extracts has been determined by several methods. A simple method used to measure antioxidant content of extracts involves 2,2-diphenyl-1-picrylhydrazyl, a stable free radical, as the detection agent. However, extraction efficiency is an important variable for any comparison of activity between products. Grain antioxidants are difficult to extract since solubility ranges from water-soluble to lipid soluble and many are covalently bound to cell wall material. Also, most of the antioxidants in grains are

contained in the bran and germ, which have a thick walled, cellular structure that inhibits extraction.

There is a need for quantitative data on the antioxidant content of grain products. Such information will increase understanding of the function of whole grain products in the diet to reduce chronic disease. The objective of this paper is to provide new data regarding the antioxidant content of whole grain products such as bread and ready-to-eat breakfast cereals as compared to refined grain products, fruits and vegetables. These results demonstrate the potential value of cereal products as a dietary source of antioxidants.

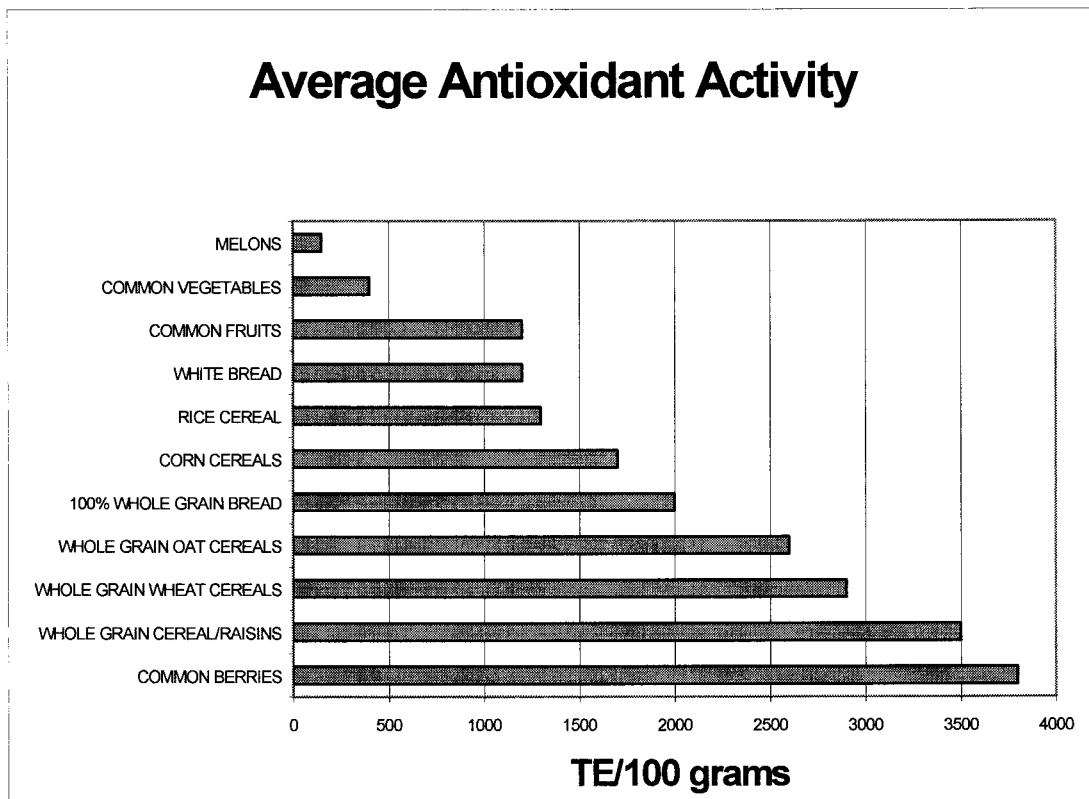
## **MATERIALS AND METHODS**

### **Materials**

Antioxidant activity was determined for a variety of grain products, fruits and vegetables. Fruits and vegetables were purchased at a local grocery and the edible portions were analyzed fresh within one to seven days. Potatoes and cucumbers were analyzed with their skins, but carrots were peeled. All the breakfast cereals were General Mills brands and were about one month old when analyzed. Distilled water and HPLC grade methanol were used as solvents. The reagents, (S)-(-)-6-Hydroxy-2,5,7,8-trimethylchroman-2-carboxylic acid (TROLOX) and 2,2-Diphenyl-1-picrylhydrazyl (95%) were purchased from Aldrich Chemical Company.

### **Methods**

All samples were first treated to obtain a finely ground, homogeneous material. Standard procedure was to grind in a kitchen type blender, first with a blade attachment and then with a roto-stat attachment. The roto-stat attachment was useful in producing a uniform, small particle-size material from coarse or fibrous samples. In the case of breakfast cereals that contained particulates such as raisins, the entire contents of the box were first ground cryogenically to give a homogeneous material for further processing. A 250-mg sub-sample of homogeneous material was then ground to a very fine powder using a Wig-L-Bug ball mill (Crescent Dental Mfg. Co.) set at 5000 rpm for 30 seconds. The ball mill worked equally well for wet or dry samples. Distilled water was added to samples such as bread that would otherwise pack in the ball mill. A weighed portion of the pulverized sample (about 10 to 100 mg depending on activity) was then added to a 125 mL Erlenmeyer flask that contained 50 mL of 101  $\mu$ molar DPPH in 50% aqueous methanol. The reaction flask was stoppered and placed in a rotating incubator at 100°F. After four hours, the mixture was filtered, and the absorption at 515 nm recorded using a Milton Roy 21D spectrophotometer. Absorption values were taken on a DPPH blank solution at zero time and again after four hours at 100°F. A 5% decrease in absorption was typical for the blank



**Fig. 1.** The average antioxidant activity is compared for different foods. Averages compared are from analysis of 3 melons, 20 vegetables, 12 fruit, 2 white breads, 1 rice cereal, 3 corn cereals, 2 whole grain breads, 3 whole grain oat cereals, 3 whole wheat cereals, 2 whole grain cereals with raisins and 5 berries.

and readings were corrected proportionately. DPPH concentration was selected to give an initial reading of 1.0 and sample size was adjusted to give about 0.5 reduction in absorption from the initial reading. Using standard curves for the reaction of Trolox with DPPH, the data was then converted to activity in terms of  $\mu$ moles Trolox Equivalents/100 grams sample (TE).

## RESULTS

### Antioxidant Comparisons

Antioxidant content was determined using the DPPH reaction. Fig. 1 demonstrates the range of activity observed for commonly consumed fruits, vegetables and grain products. The results are similar to previous reports [29–31] even though variety differences, seasonal effects, processing and methodology are significant variables. RTE cereals are about 3% moisture, breads about 35% moisture and fruits and vegetables around 80% to 90% moisture. The average antioxidant activity of cereal products is equal to or exceeds most vegetables or fruits. Melons have very low antioxidant activity, and berries have relatively high activity. Vegetables are relatively low in general. Fruits and vegetables are recognized as good sources

of antioxidants, but whole grain breakfast cereals have significantly higher content on an equal weight basis. Whole grain bread was 2000 TE, compared to white bread at 1200 TE, indicating the contribution of bran and germ. On a dry weight basis, the values would be about 3,000 and 1,800 TE, respectively. Assuming that bran and germ are 15% of wheat grain and that the difference between whole wheat and white bread is that white bread contains no bran or germ, we estimate that the bran/germ is about 8,000 TE in this example. Consistent with this estimate, we have analyzed bran products that were as high as 8,500 TE and commercial wheat germ was 5,000 TE. Note that bran products often contain residual starch and thus are ‘diluted’ to some extent. In addition, there are significant differences between red and white wheat bran. Samples of red and white bran prepared by the same milling procedure (Buhler Mill) averaged about 5,500 TE and 4,100 TE, respectively. The flour fraction averaged about 900 TE. Although grain antioxidants are more concentrated in the bran fraction, it is noteworthy that even the starchy fraction of grains has a relatively high antioxidant content (800 to 1000 TE) as compared to vegetables and many fruits. Whole grain oat and wheat cereals were 2600 TE and 2900 TE, respectively, compared to 1300 TE for a cereal from white rice with the bran and germ removed. The

**Table 1.** Antioxidant Content of Fresh Vegetables<sup>1</sup>

Product	TE/100 grams
Red cabbage	1400
Garlic	1300
Beets	800
Mushrooms	700
Broccoli flowers	600
Spinach	500
Brussels sprouts	500
Sweet corn	500
White potato	400
Red potato	350
Peas	300
Cauliflower	200
Carrots	200
Green beans	200
Yellow onions	200
Tomato	200
Head lettuce	150
Green cabbage	150
Cucumber	100
Celery	50

<sup>1</sup> All products were purchased from a local supermarket and the edible portions analyzed fresh. Potatoes and cucumbers were analyzed with skins; carrots were peeled.

wheat- and oat-based breakfast cereals studied here contain the whole grain. RTE corn cereal products, made from degerminated grain, were of intermediate value at 1900 TE. Cereals with added raisins averaged higher values due to the high antioxidant activity of raisins [28].

### Antioxidant Content

The antioxidant content of common fruit and vegetable products is summarized in Tables 1 and 2. These products represent a wide range of activity, with vegetable products being the lowest on average. Interestingly, commercial button

**Table 2.** Antioxidant Content of Fresh Fruit<sup>1</sup>

Product	TE/100 grams
Red plum	2200
Black plum	2000
Red grape	1700
Red apple	1400
Green grape	1200
Nectarine	1200
Banana	1100
Kiwi	1000
Pineapple	1000
Sweet cherry	800
Orange	600
Pear	600
Cantaloupe	200
Honeydew melon	100
Watermelon	100

<sup>1</sup> All products were purchased at a local supermarket and the edible portions analyzed fresh. Apples were analyzed with skins.

mushrooms, which are white and see little daylight, are higher in antioxidants than most vegetables and many fruits. The vegetables, red cabbage, garlic and beets, are relatively high in antioxidants compared to cucumber, celery, carrots, green beans and green cabbage. The difference between red and green cabbage is striking. Apparently, the purple cabbage pigment contributes a high level of antioxidant activity. Many popular vegetables tend to be relatively low in antioxidants. The average value of antioxidants for the vegetables in Table 1 is 440 TE. Red plums at 2200 TE had the highest antioxidant value of the fruits summarized in Table 2. The antioxidant activity of melons is much lower than any of the other fruits. The average for all fruits except melons is 1230 TE. Fruits average nearly three times the antioxidant concentration of vegetables.

The antioxidant content for RTE breakfast cereals is summarized in Table 3. These products also have a wide range of antioxidant activity. Breakfast cereals are equal or higher than any of the vegetables and the majority of fruits. Average value for all cereal products in Table 3 is 2700 TE. Whole-grain-wheat- and oat-based products average higher in antioxidants than products from refined rice or corn ingredients. Regardless, all breakfast cereals are good sources of antioxidants compared to common fruits and vegetables. Table 4 compares some of the richest antioxidant sources. Berries and dried fruit compose a relatively small part of the average diet, but they are important antioxidant sources. Highly pigmented berries have the highest antioxidant activity. Gooseberries, which have a light green flesh, are the lowest. Dried fruits essentially reflect the effect of concentration by drying with little loss of activity due to processing. Grapes are concentrated during drying from about 19% solids to about 82% solids, a 4.3 fold concentration. Red grapes analyzed at 1700 TE, which gives a calculated value of 7300 TE when multiplied by a 4.3 concentration factor. This compares to dark raisins that analyzed at 6400 TE.

Antioxidant content of vegetables, fruits and breakfast cereals was previously reported by Prior and others using the oxygen radical absorbing capacity (ORAC) method [28–31]. To remove differences in ORAC and DPPH methods, we give antioxidant results divided by the antioxidant content in RTE breakfast cereals in Table 5. Their results were similar to our observations with DPPH as shown in Table 5. Considering possible experimental variation between these two sets of data, the results are remarkably similar. The antioxidant content of cereals, on average, is 2 to 3 times higher than fruits, 2.5 to 6 times higher than vegetables and about 0.75 times that of berries. Dried fruit averaged 2 to 3 times the antioxidant content of breakfast cereals.

Table 6 summarizes ORAC data from a conference presentation by Prior [31]. He reported that an average 41 gram serving of breakfast cereal contained about the same antioxidant activity as an average daily intake of fruit or vegetables (560, 580 and 640 TE, respectively).

**Table 3.** Antioxidant Content of RTE Breakfast Cereals<sup>1</sup>

Product	TE/100 grams
Multi-Bran Chex®	3900
Basic 4®	3600
Crispy Wheaties 'N Raisins® <sup>2</sup>	3500
Raisin Nut Bran®	3100
Wheat Chex® <sup>2</sup>	3000
Whole Grain Total® <sup>2</sup>	2800
Wheaties® <sup>2</sup>	2800
Multigrain Cheerios® <sup>2</sup>	2700
Oatmeal Crisp/Raisin® <sup>2</sup>	2700
Apple Cinnamon Cheerios®	2700
Cheerios® <sup>2</sup>	2600
Honey Nut Cheerios®	2200
Oatmeal Crisp/Apple Cinnamon® <sup>2</sup>	2200
Country Corn Flakes®	2000
Corn Chex®	1600
Kix®	1400
Rice Chex®	1300

<sup>1</sup> Products were about one month old when analyzed. For cereals containing particulates, the entire product was ground homogeneously.

<sup>2</sup> Whole grain product.

### Antioxidant Consumption

Calculated average daily intake of antioxidant activity from RTE breakfast cereals, fruits and grains is compared in Table 7. These values were calculated by multiplying average antioxidant activity, determined by DPPH analysis, times the average per capita daily intake of food types taken from the USDA Continuing Survey of Food Intakes by Individuals, 1994–96. From these calculations, it can be seen that breakfast cereals contribute significant antioxidant activity, but less than fruits and vegetables. This is not surprising, since average daily consumption of RTE breakfast cereals is only 16 grams per day, compared to 189 and 79 grams per day respectively for vegetables and fruits. Breakfast cereal consumption averages only about a half serving/day/individual. Table 8 compares the amount of antioxidant available from an average serving of whole grain breakfast cereal, fruits or vegetables. In this case, cereals provide about the same amount of antioxidants as fruits and at least double vegetables. Both sets of data illustrate that breakfast cereals provide a significant amount of daily antioxidants consumed relative to fruits and vegetables.

Antioxidant activity of breakfast cereals is not substantially diminished during normal room temperature storage. Two puffed oat cereals with five months difference in age were analyzed. The one month old sample was 2600 TE and the six month old product was 2500 TE. This small difference is not surprising, since most of the antioxidants are dispersed in a dry, solid matrix with little oxidative exposure. In a separate study, breakfast cereals were stored at 100°F. After eight weeks at 100°F (roughly equivalent to eight months at room temperature), there was less than 10% loss of antioxidant activity. Lipid soluble antioxidants are likely most vulnerable. Some loss of activity should occur, but these results indicate it is slight over the normal shelf life of breakfast cereals.

**Table 4.** Antioxidant Content of Berries, Dried Fruit and Juices<sup>1</sup>

Product	TE/100 grams
<b>Berries</b>	
Blackberries	5500
Raspberries	5100
Blueberries	3300
Strawberries	3100
Gooseberries	1900
<b>Dried Fruits</b>	
Dates	6600
Raisins	6400
Prunes	5800
<b>Juices</b>	
Concord grape juice	1500
Grapefruit juice	400
Orange juice (from concentrate)	400
Apple juice (from concentrate)	300
V-8™ juice	600

<sup>1</sup>All berries were purchased from a local supermarket and analyzed fresh.

### DISCUSSION

Data reported in this paper show the high antioxidant content of whole grain products relative to fruits, vegetables and refined grain products. Antioxidant activity is one of several factors that probably contribute to mechanisms responsible for the observed efficacy of whole grains in the daily diet to reduce chronic disease. Whole grain products contain biologically active antioxidants that could act independently or synergistically with fiber to reduce disease. The amount of antioxidant material, as measured by ORAC or DPPH, shows relative potential of different foods to provide antioxidants for prevention of chronic diseases. The relative activity of many antioxidants and antioxidant extracts has been studied under different model conditions. The activity for individual compounds varies significantly depending on the model system. Also, antioxidant activity is quite low for many compounds. The biological significance of the different compounds and different activities is essentially unknown. Antioxidants with a low redox potential may still be important if they can interact with high-energy free radicals.

Epidemiological data indicates vegetables are important to good health. However, antioxidant content may not be the most important health factor for vegetables. Some breakfast cereals

**Table 5.** Relative Antioxidant Content of Fruits, Grains and Vegetables [29, 30, 31]

Product	USDA	General Mills
Dried Fruit	3.1	2.1
Berries	1.3	1.4
RTE Cereals	1.0	1.0
Fruit	0.36	0.45
Vegetables	0.43	0.16
Melons	0.07	0.05

**Table 6.** Antioxidant Consumption Comparisons [30]

Product	TE Content
RTE breakfast cereal <sup>1</sup>	563
Fruits <sup>2</sup>	584
Vegetables <sup>2</sup>	640

<sup>1</sup> 41 gram serving<sup>2</sup> Average day consumption

have remarkably high antioxidant content, and even the most refined products from rice and corn are higher than essentially all vegetables and a majority of fruits. Whole grain products are generally recognized as healthful foods and important to a balanced diet. Antioxidant content provides additional insight into how grain-based products may deliver health benefits for humans. Antioxidant content is but one nutritional attribute of foods, and a well balanced diet should contain a wide variety of foods.

The modified DPPH procedure described in this paper was developed especially for use with cereal products that contain difficult-to-extract antioxidants. Stirring finely ground sample four hours in warm solvent facilitates interaction of DPPH with antioxidant molecules that are not readily soluble. Also, grinding does increase the ability of DPPH to react with antioxidants. An oat cereal was coarsely ground with a high speed Stein mill and then ball milled for 15 seconds and 60 seconds. Antioxidant activity observed was 2280, 2650 and 2810 TE, respectively. The 60 second ball milled sample had over 20% more apparent activity than the Stein milled material.

The reaction of DPPH with antioxidants has been studied and the stoichiometry characterized [32–36]. DPPH has long been recognized as a convenient reagent to quantify antioxidants in complex biological systems and has been widely used for this purpose in recent years [37–41]. The DPPH technique outlined above can be adapted to a variety of situations. It is a convenient screening tool for quickly determining antioxidant content of food products and food ingredients. Information about antioxidant content differences may be of value in helping interpret efficacy results for products tested in biological models for chronic disease. It is unknown if 50% aqueous methanol solvent facilitates reaction of DPPH with lipid soluble antioxidants as they exist in grain. However, pure vitamin E or 70% vitamin E in soy oil was analyzed in 50% aqueous methanol and reacted 1:2, vitamin E: DPPH on a molar basis, as previously reported [33]. The ORAC method is a different

**Table 7.** Daily Antioxidant Consumption Per Capita

Product	Grams/day <sup>1</sup>	TE Content
RTE breakfast cereal	16	480
Vegetables	189 <sup>2</sup>	600
Fruit	79	760

<sup>1</sup> USDA Continuing Survey of Food Intake by Individuals, 1994–1996 <sup>2</sup> Includes 61 grams of potato products (24 grams fried) with estimated corrections for peeling and cooking

**Table 8.** Antioxidants in Average Servings of Foods

Product	Serving (gm)	TE Content
Whole grain RTE cereal	30	840 <sup>1</sup>
	55	1540 <sup>1</sup>
Vegetables	85	380
Fruit	85	1020

<sup>1</sup> Average for eight whole grain RTE breakfast cereals

technique for sample preparation and analysis, but the results show a similar relationship of activity. Our studies with DPPH concur with the ORAC data that RTE breakfast cereals are an excellent dietary source for antioxidants.

Bioavailability of natural antioxidants in foods has had limited but interesting investigation [27,42–48]. Absorption of vitamin E, vitamin C and carotenoids is well established. Bioavailability of flavonoids has been demonstrated for a few of the many known compounds. Studies with wine and tea show that flavonoids and catechins are absorbed, and there is good evidence for absorption of complex polyphenols in tea. Considerable differences in absorption have been reported. A confounding factor is that enzymatic degradation and addition reactions can change the basic structure being analyzed without eliminating antioxidant activity. Bioavailability has been demonstrated for caffeic and ferulic acids, two of the more common phenolic acids. Other studies considered blood and tissue antioxidant content as a result of diet change. These studies showed that antioxidants in fruits, vegetables, wine and tea are significantly bioavailable.

It was reported that diets high in fruits and vegetables increased blood serum antioxidant activity by about 10% [27, 44]. This seems a low amount to be important for health. However, a significant part of blood antioxidant activity is from uric acid, which is not associated with disease prevention [49]. When uric acid is discounted, the relative contribution of diet antioxidants is increased. Since fruits and vegetables were eaten together in these studies, it is not possible to separate individual effect. In one study [27], breakfast cereals were part of the test diet regime. Although amounts of breakfast cereal consumed were not reported, it can be speculated that breakfast cereals were a factor in the improved blood antioxidant capacity. Specific studies on grain products have not been reported, but it is reasonable to expect that known antioxidant compounds are equally available from grains, fruits and vegetables.

Bioavailability of unique antioxidants and antioxidants associated with fiber is unknown. Covalently bound antioxidants would only be 'available' after hydrolysis. This could result from acid in the stomach or by activity of microorganisms in the gut. And, it is possible that antioxidant activity associated with undegraded fiber is important to the health of the colon without degradation. The antioxidant activity associated with fiber is remarkably high in some instances. We observed that oat hull fiber, processed with alkali to remove all soluble and pigmented matter, had a high antioxidant activity of 6,000 TE.

Apparently there is a significant amount of bound or insoluble antioxidant material associated with this fiber. Pure Trolox has an activity of about 400,000, and 6,000 is only 1.5% of that value. Fiber with 1.5% antioxidant content is certainly realistic. It can be speculated that some of the efficacy of high fiber foods might relate to the antioxidant activity associated with fiber. It was reported in an Italian study [50] that persons consuming large amounts of refined grain foods (pasta, bread and rice) had a higher incidence of a variety of cancers. This observation suggests that whole grain products provide more protective phytonutrients and the body defenses against cancer are weaker when these materials are reduced in the diet.

It is likely that the average diet in the United States is adequate to maintaining a reasonable level of antioxidants in our bodies. It has been demonstrated that eating increased amounts of fruits and vegetables can increase the level. Bio-availability studies indicate that there is a rapid turnover of antioxidants [42, 46, 48]. This is consistent with the recommended daily intake of fruits, vegetables and grain products. A high level of antioxidants in the body is possible when there is regular, high consumption.

In conclusion, the antioxidant activity determined using DPPH shows that whole grain cereal products, fruits and vegetables all contribute significant amounts of antioxidants to the daily diet. The substantial content of antioxidants in grain products has been essentially overlooked other than in the report by Prior [31]. Natural antioxidants in fruits and vegetables are believed to be important agents in reducing diseases of aging, if consumed in adequate amounts on a regular basis. These results demonstrate that whole grain products, as commonly consumed, are also excellent sources of antioxidants that should complement fiber to reduce cancer and heart disease. Whole grain products, a rich source of common and unique antioxidants, are a very convenient way to increase average daily antioxidant intake. Further study is needed to determine the full significance of grain antioxidants as compared to those in fruits and vegetables.

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