USDA Database for the Oxygen Radical Absorbance Capacity (ORAC) of selected Foods

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Abstract

Oxidative stress may be one of the factors which play a role in the development of chronic and degenerative diseases, such as cancer, heart disease, and neuronal degeneration. Fruits, nuts, and vegetables have long been considered high in antioxidants. Total antioxidant capacity (TAC) levels are affected by a wide array of factors, such as cultivar, growing conditions, harvesting, food processing and preparation, sampling, and analytical procedures. The Nutrient Data Laboratory (NDL), ARS\USDA has developed a database on the Oxygen Radical Absorbance Capacity (ORAC) and total phenolic compounds (TP) of 275 selected foods. Samples for most of the foods in the database were procured through the USDA's National Food and Nutrient Analysis Program (NFNAP) and were analyzed by Wu et al. by ORAC assay. Valid data from 13 other published articles were combined with data analyzed by Wu, et al. (2004) for the database. In addition to the ORAC assay, some other measures of TAC include ferric ion reducing antioxidant power (FRAP) and trolox equivalent antioxidant capacity (TEAC) assays. These assays are based on other mechanisms using different radical or oxidant sources and generate values that cannot be compared directly to ORAC values. Halvorsen et al. (2006) analyzed approximately 70 of the same NFNAP food samples analyzed by Wu et al. using the FRAP assay to provide total concentration of redox-active compounds. Comparison of the ranking order of some selected foods from these 70 foods measured by the two different assays is presented.

Introduction

Some hypotheses propose the benefits of antioxidant-rich diet. Fruits, nuts, and vegetables have long been considered high in antioxidants. Reactive oxygen species can damage biological molecules such as proteins, lipids and DNA. While the human body has developed a number of systems to eliminate free radicals, the process is not 100% efficient (Young and Woodside, 2001). Oxidative stress is implicated in chronic diseases like heart disease (Diaz et al. 1997), cancer (Ames et al. 1995), neuronal degenerative diseases like Alzheimer's (Christen 2000) and Parkinson's (Lang and Lozano, 1998) and also in the process of aging (Ames et al. 1993). A wide array of factors that affect antioxidant capacity of fruits, vegetables and nuts include cultivars, growing conditions, harvesting, food processing/preparation, sampling and analytical procedures. Several assays, oxygen radical absorbance capacity (ORAC), ferric ion reducing antioxidant power (FRAP) and Trolox equivalent antioxidant capacity (TEAC), all based on different underlying mechanisms and using different radical and oxidant sources are available. ORAC assay is considered by some to be a preferable method because of its biological relevance to the in vivo antioxidant efficacy (Awika et al. 2003). The Nutrient Data Laboratory (NDL) of the ARS\USDA has developed a database on the ORAC and total phenolic compounds (TP) of 275 selected foods.

Objectives

- To develop a database for Oxygen Radical Absorbance Capacity (ORAC) of selected foods.
- To present a table of (20) foods rank ordered with highest antioxidant capacities measured by the ORAC assay as µmol of Trolox Equivalents (TE)/100g and as µmol TE based on typical serving size.
- To compare the rank order of foods according to their respective values obtained by the FRAP (Halvorsen et al.) and ORAC (Wu et al.) methods that had been applied to the same samples.
- To compare the rank order of similar foods (different sample sources) analyzed by two laboratories using the same ORAC method (Ou et al and Wu et al).

Methods

- Fifty nine fruits, nuts, and vegetables, and some unique foods consumed by American Indians and Alaskan natives procured through USDA's National Food and Nutrient Analysis (NFNAP)* were analyzed by ORAC assay by Wu et al. (2004).
- Data from 13 other published articles that used ORAC assay as well as selected data provided by Welch Foods Inc. were combined with the Wu et al. data to develop "The USDA Database for Oxygen Radical Absorbance Capacity of Selected Foods."
- Analytical data from literature based on the method that used the fluorescein probe were considered for the database. Methods that used β-phycoerythrin (β-PE) as the fluorescent probe were not used. Thus most of the data used were generated after 2000.
- The quality of all data was evaluated by the system developed by Holden et al. (2002) and assigned Confidence Codes indicating relative quality of the data and the reliability of the given means.
- The rank order of foods based on the values generated by the two methods (FRAP and ORAC) for the same samples were compared.
- The rank order of selected foods analyzed by the same ORAC method in different laboratories (Ou et al. and by Wu et al.) were compared. The samples were obtained from different sources.

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Results

- The USDA Database for Oxygen Radical Absorbance Capacity of 275 foods was released on the NDL web site: www.ars.usda.gov/nutrientdata. The database reports Hydrophilic ORAC (H-ORAC), Lipophilic ORAC (L-ORAC) and Total ORAC values as µmol TE/100g and Total Phenolics (TP) as mg Gallic Acid Equivalents (GAE)/100g of foods.
- **Table 1**: The top 20 foods ranked by µmol TE/100g and per typical serving size depict a totally different picture of antioxidant capacities of foods and illustrate the importance of considering typical serving size when assessing intake. Spices and chocolates dominated the µmol TE/100g list, while fruits, berries and various apple varieties dominated the per typical serving size list. Although spices, cinnamon and cloves, were included in the household measure list, 1 teaspoon of those spices is a generous amount and is not used in one serving.
- The comparison of the rank order of the top 20 foods based on typical serving size of the same analytical samples (NFNAP) analyzed by two different methods for their antioxidant capacities, FRAP and ORAC, included different foods. Only 10 out of top 20 foods were identical in the two lists, although their rankings were different. The ORAC list included different varieties of apples that were not included in the FRAP list, while pineapple, orange and apple juices and some vegetables were included in the FRAP list that were not in the top 20 of the ORAC list (**Table2**)
- **Table 3** Compares the values for similar foods, analyzed by the same ORAC method. The values for raw beets, red onions, spinach, broccoli, snap beans, carrots and cabbage were significantly different. The samples for these analyses were obtained from separate sources.

Discussion

There are several assay methods to measure antioxidant capacities of foods. These methods are based on different underlying mechanisms and use different radical and oxidant sources. Therefore any single method does not measure "total antioxidant activity". This would require an array of assays to get the full profile of antioxidant activity (Ou et al 2002). This point is illustrated by comparing the same samples analyzed by different assays. The FRAP assay measures ferric ion reducing activity while the ORAC assay estimates peroxy radical scavenging activity. Therefore the ranking of foods analyzed by the two methods is different, particularly when presented per typical serving size. When similar foods are analyzed by the same method the variation could be attributed to the application of the method by different laboratories, to the use of different samples, different cultivars, seasons, harvesting time etc.

Table 1. Comparison of values in the USDA ORAC database per µmol TE/100g and µmol TE/typical serving

ORAC Database Foods ranked per 100g basis	µmol TE/100g	ORAC Database Foods ranked per typical serving		µmol TE/100g
Spices, cloves, ground	314446	Baking chocolate, unsweetened	1 square (29)	14479
Spices, cinnamon, ground	267536	Elderberries, raw	1/2 cup (72.5)	10655
Spices, oregano, dried	200129	Apples, Red Delicious, raw. with skin	1 med (182)	7781
Spices, turmeric, ground	159277	Apples, Granny Smith, raw, with skin	1 med (182)	7094
Cocoa, dry powder, unsweetened	80933	Juice, Pomegranate, 100%	1 cup (253)	5923
Spices, cumin seed	76800	Candies, chocolate, dark	1 oz (28.35)	5903
Spices, parsley, dried	74349	Plums, dried (prunes), uncooked	1/2 cup (87)	5700
Spices, basil, dried	67553	Alcoholic beverage, wine, table, red	5 fl oz. (147)	5693
Baking chocolate, unsweetened	49926	Artichokes, boiled	1/2 med (60)	5650
Spices, curry powder	48504	Apples, raw, with skin	1 med (182)	5609
Chocolate, dutched powder	40200	Cranberries, raw	1/2 cup (55)	5271
Sage, fresh	32004	Pears, raw	1 med (178)	5235
Spices, mustard seed, yellow	29257	Prune juice, canned	1 cup (256)	5212
Spices, ginger, ground	28811	Apples, Gala, raw, with skin	1 med (182)	5147
Spices, pepper, black	27618	Candies, semisweet chocolate	1 oz (28.35)	5118
Thyme, fresh	27426	Nuts, pecans	1 oz (28.35)	5086
Marjoram, fresh	27297	Plums, black diamond, with peel, raw	1 fruit (66)	5003
Spices, chili powder	23636	Apples, Golden Delicious, raw, with skin	1 med (182)	4859
Candies, chocolate, dark	20823	Blueberries, raw	1/2 cup (74)	4848
Candies, semisweet chocolate	18053	Apples, Red Delicious, raw, without skin	1 med (161)	4727

Table 2. Comparison of food rankings based on FRAP and ORAC assays per typical serving (same samples)

FRAP(Total Redox)* per Typical Serving		ORAC** per Typical Serving	
Food	**Serving Size**	**Food**	**Serving Size**
Walnuts, English	1 oz (28.35g)	Baking chocolate, unsweetened, squares	1 square (28.35)
Blackberries	1/2 cup (72 g)	Apples, Red Delicious, raw. with skin	1 med (182)
Nuts, pecans	1 oz (28.35g)	Plums, dried (prunes), uncooked	1/2 cup (87)
Artichokes, boiled	1/2 med. (60g)	Apples, Granny Smith, raw, with skin	1 med (182)
Baking chocolate, unsweetened, squares	1 oz (28.35g	Candies, chocolate, dark	1 oz (28.35)
Pineapple juice	1 cup (240g)	Artichokes, boiled	1/2 med (60)
Cranberries, raw	1/2 cup (55g)	Cranberries, raw	1/2 cup (55)
Strawberries	1/2 cup (88g)	Apples, Gala, raw, with skin	1 med (182)
Plums, dried (prunes), uncooked	1/2 cup (87g)	Nuts, pecans	1 oz (28.35)
Orange juice	1 cup (240g)	Plums, black	1 fruit (66)
Apple juice	1 cup (240g)	Apples, Golden Delicious, raw, with skin	1 med (182)
Raspberries	1/2 cup (61.5)	Apples, Red Delicious, raw, without skin	1 med (161)
Blueberries	1/2 cup (74g)	Apples, Fuji, raw, with skin	1 med (182)
Plums, black	1 fruit (66)	Blueberries, raw	1/2 cup (74)
Candies, chocolate, dark	1 oz (28.35g	Plums, raw	1 fruit (66)
Cabbage, red, cooked	1/2 cup (75g)	Blackberries, raw	1/2 cup (72)
Peppers, red, cooked	1/2 cup (70g)	Walnuts, English	1 oz (28.35)
Spinach, frozen uncooked	1/2 cup (78g)	Apples, Golden Delicious, raw, without skin	1 med (161)
Kiwi fruit	1 fruit (76g)	Pears, green cultivar	1 med (178)
Sweet Potato, baked	1 med. (114g)	Figs, raw	2 med (100)

*** Halvorsen et al. (2006)** ****Wu et al. 2004**

Table 3. Comparison of similar foods (different samples) analyzed by ORAC assay in two different laboratories

Food Description	Ou et al. 2002 µmol TE/100g FW	Wu et al. 2004 µmol TE/100g FW
Beet, raw	**1369**	**2774**
Onions, red, raw	**1759**	**1146**
Spinach, raw	**1520**	**2640**
Broccoli, raw	**1159**	**1590**
Peppers, green, raw	**816**	**558**
Cauliflower, raw	**765**	**647**
Peppers, red, raw	**757**	**901**
Bean, snap, raw	**569**	**290**
Carrots, raw	**678**	**1215**
Cabbage, raw	**531**	**1359**
Tomato, raw	**342**	**337**

Conclusions

- The ORAC database provides a table of antioxidant capacities (µmol TE/100g) and Total phenol (mg GAE)/100g) contents of selected 275 foods.
- Antioxidant capacities of foods measured by different methods represent different underlying mechanisms and result in different rankings of the same foods.
- Antioxidant capacities measured by the same method of similar foods demonstrate variabilities in values perhaps accountable by factors such as application of analytical methods by different laboratories or to the cultivar, season etc.

References

Ames, B. N., Gold, L. S. & Willet, W. C. (1995) The causes and prevention of cancer. *Proc. Natl. Acad. Sci. USA. 92: 5258-5265.*

Ames, B. N., Shigenaga, M. K. & Hagen, T. M. (1993) Oxidants, antioxidants, and the degenerative diseases of aging. *Proc. Natl. Acad. Sci. USA. 90: 7915-7922.*

Awika, J. M., Rooney, L. W., Wu, X., Prior, R. L., and Cisneros-Zevallos, L. (2003) Screening methods to measure antioxidant activity of sorghum (Sorghum bicolor) and sorghum products. *J. Agric. Food Chem., 51:6657-6662.*

Christen, Y. (2000) Oxidative stress and Alzheimer disease. *Am. J. Clin. Nutr. 71: 621S-629S.*

Diaz, M. N., Frei, B. & Keaney, J. F. Jr. (1997) Antioxidants and atherosclerotic heart disease. *New Eng. J. Med. 337: 408-416.*

Halvorsen, B. L., Carlsen, M. H., Phillips, K. M., Bøhn, S. K., Holte, K., Jacobs, D. R., and Blomhoff, R. (2006) Content of redox-active compounds (ie, antioxidants) in foods consumed in the United States. *Am. J. Clin. Nutr., 84:95-135.*

Holden, J. M., Bhagwat, S. A., Patterson, K. Y. (2002). Development of a multi-nutrient data quality evaluation system. *J. Food Comp. Anal. 15, 339-348.*

Lang, A. E. & Lozano, A. M. (1998) Parkinson's disease. First of two parts. *N. Eng. J. Med. 339: 111-114.*

Ou, B., Huang, D., Hampsch-Woodill, M., Flanagan, J. A., and Deemer, E. K. (2002) Analysis of antioxidant activities of common vegetables employing oxygen radical absorbance capacity (ORAC) and ferric reducing antioxidant power (FRAP) assays: A comparative study. *J. Agric. Food Chem., 50:3122-3128.*

Wu, X., Beecher, G. R., Holden J. M., Haytowitz, D. B., Gebhardt, S. E., and Prior, R. L. (2004) Lipophilic and hydrophilic antioxidant capacities of common foods in the United States. *J. Agric. Food Chem., 52:4026-4037.*

Young, I. S., and Woodside, J. V. (2001) Antioxidant in health and disease. *J. Clin. Path., 54:176-180.*