Oxalate Content of Food: A Tangled Web

Kyrollis Attalla, Shubha De, and Manoj Monga

OBJECTIVE To account for variations in dietary oxalate content in resources available to hyperoxaluric patients. Our objective is to examine the heterogeneity of the oxalate content reported across various Web-based sources and smartphone applications.

METHODS A search of "oxalate content of food" was performed using the Google search engine. Smartphone applications were identified by their ability to assess oxalate content. Oxalate contents were obtained, and common foods were selected for comparison. Food groups were compared to better understand how patients are guided when using these references to manipulate their diet.

RESULTS Thirteen sources were identified, and 8 sources (6 Web sites and 2 applications) were used to construct figures for comparison of commonly listed foods. Oxalate content was extremely variable between various sources. Fruits with the widest observed range of oxalate included oranges (2.07-10.64 mg/100 g) and bananas (0-9.9 mg/100 g). Among vegetables, the oxalate contents of spinach (364.44-1145 mg/100 g), rhubarb (511-983.61 mg/100 g), and beets (36.9-794.12 mg/100 g) were most variable. Among nuts, the oxalate content of peanuts ranged from 64.57 to 348.58 mg/100 g, and pecans ranged from 4.08 to 404.08 mg/100 g.

CONCLUSION Wide variations exist in the reported oxalate content of foods across several Web-based sources and smartphone applications, several of which are substantial and can have a sizable impact on the construction of a low oxalate diet. As dietary counseling has proven benefits, patients and caregivers should be aware of the heterogeneity that exists in the reported oxalate content of foods. UROLOGY 84: 555—560, 2014. © 2014 Elsevier Inc.

As the most common type of kidney stone, the occurrence of calcium oxalate stones are in part attributable to urinary oxalate content.[1] Because the urine concentration of oxalate is much lower than that of calcium, the crystallization of calcium oxalate is far more sensitive to changes in oxalate concentration than that of calcium.[2] Liver synthesis and the absorption of dietary calcium are primarily responsible for the oxalate found in urine, and because dietary oxalate can account for 10%-45% of oxalate found in urine,[2,3] reduction in oxalate intake is a common preventive strategy for calcium oxalate stone formers.

With an increasing number of patients using Internet-based medical resources, many reference sites are available for people interested in adjusting their oxalate consumption. Stone formers adhering to a low oxalate diet may be confused by the inconsistency in oxalate values for a single food across Web sites. This is also a challenge for health-care professionals as oxalate levels can vary based on analytical techniques, cultivar biological variations, time of harvest, and growing conditions.[4]

Because no gold standard oxalate reference database exists, large variations in the reported oxalate contents could impact the counseling and subsequent compliance of hyperoxaluric patients. Therefore, our objective is to examine the heterogeneity of the oxalate content of foods reported across various Web-based sources and smartphone applications. Food groups were compared to better understand how patients are guided when using these references to manipulate their diet.

METHODS

Recent reports suggest that 77% individuals seeking online health advice start at search engines.[5] Simulating patients searching the Internet for information regarding a low oxalate diet, a Web search of "oxalate content of food" was conducted using the Google search engine, yielding 9 Web sites. Duplications were excluded from further analysis. Similarly, a search of applications for the iPhone or iPad was conducted and applications displaying or calculating the oxalate content of foods were purchased and downloaded.

Oxalate contents were obtained from each source, and foods that were common to most sources were selected for comparison. All foods were converted to milligrams of oxalate per 100 g of food, so that oxalate measurements could be compared across all sources. Some sources reported a range of oxalate values for a food item. When ranges of oxalate content were identified, ensuring the most conservative diet was followed, the highest value of the stated range was used. Descriptive statistics were used to compare the oxalate values of foods across the identified sources.

Financial Disclosure: *The authors declare that they have no relevant financial interests.*
From the Glickman Urologic and Kidney Institute, Cleveland Clinic, Cleveland, OH
Reprint requests: Manoj Monga, M.D., The Glickman Urologic and Kidney Institute, Cleveland Clinic, 9500 Euclid Avenue/Q10, Cleveland, OH 44195. E-mail: endourol@yahoo.com
Submitted: November 7, 2013, accepted (with revisions): March 12, 2014

http://dx.doi.org/10.1016/j.urology.2014.03.053
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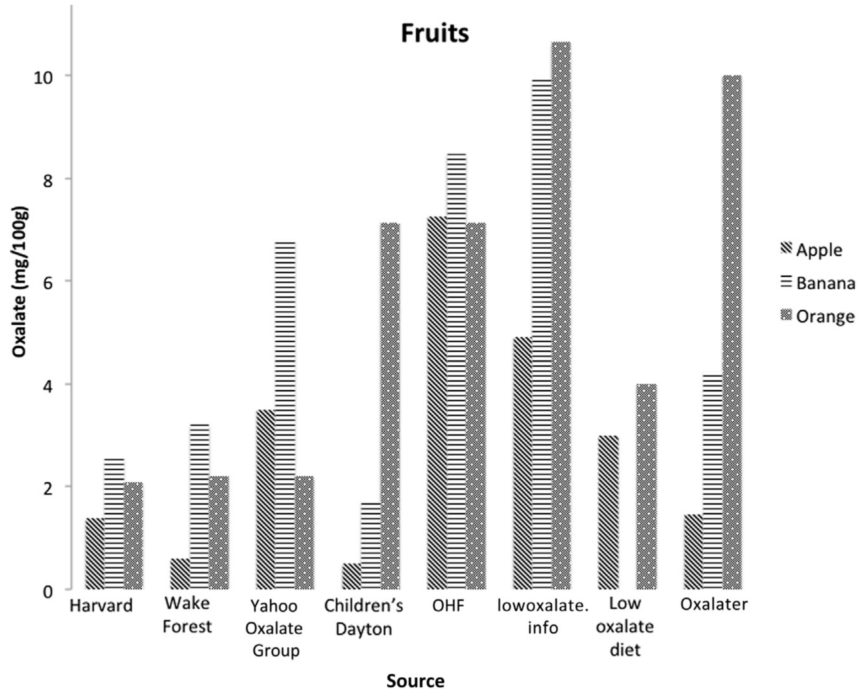

Figure 1. Oxalate content of fruits (mg/100 g).

RESULTS

A total of 13 sources were identified: 10 Web sites and 3 smartphone applications. One site, "Women's Wellness Place," contained a chart identical to the chart found in "Northwoods Urology" and was excluded from the study. The smartphone application search yielded 3 applications; one application, "iOxalate," identified foods as either "high," "medium," or "low" in oxalate content and gave no measured value, and was excluded from the study. A fitness and nutrition group requiring a free subscription, "Trying Low Oxalates," was found and provided subscribers with diet advice and a comprehensive list of foods and oxalate values. Of the remaining 11 sources available for analysis (9 Web sites and 2 applications) listed in Appendix 1, 8 sources (6 Web sites and 2 applications) were used to construct figures for comparison because of the commonalities in foods between them.

Most Web sites used milligrams of oxalate per 100 g of food source as a common unit. The measured oxalate found in Harvard's Web site, the "Trying Low Oxalates" group, and the "Oxalater" application reported values in milligrams per serving of food, and required conversion to mg/100 g, necessitating reference to establish the conversion of milligrams of oxalate content in a "serving" to mg/100 g. "Trying Low Oxalates" provided users with the weight (in grams) of common serving sizes of foods and was used as the reference for conversions.

Four dietary groups (fruits, Fig. 1; vegetables, Fig. 2; nuts, Fig. 3; dairy and grain, Fig. 4) were compared across 8 sources. Oxalate content was found to be heterogeneous across virtually all food items compared between sources. Among fruits with the widest observed range of oxalate, the oxalate content of oranges ranged from 2.07 to 10.64 mg/100 g, and the oxalate content of bananas ranged from 0 to 9.9 mg/100 g. Among vegetables, the oxalate content of spinach ranged from 364.44 to 1145 mg/100 g, that of rhubarb ranged from 511 to 983.61 mg/100 g, and that of beets ranged from 36.9 to 794.12 mg/100 g. Among nuts, the content of peanuts ranged from 64.57 to 348.58 mg/100 g and pecans ranged from 4.08 to 404.08 mg/100 g. The oxalate content of milk and rice were low (<10 mg/100 g); however, values were also found to be inconsistent.

COMMENT

Dietary oxalate reduction is a common practice in the management of hyperoxaluric stone formers. After reviewing several online sources and smartphone applications, the heterogeneity in dietary oxalate content was found to vary widely among certain foods. Some foods such as spinach, rhubarb, and peanuts are consistently identified as having high levels of oxalate and are easily identified by users as the ones to be avoided. However, finding variable oxalate measurements of many other foods and knowing what foods can be included in a low oxalate diet can make proper diet modification challenging.

One of the challenges faced with dietary counseling is that individual foods, preparation techniques, and testing methods can impact oxalate content. Oxalate quantification has been prone to errors in both extraction and measurements. Existing in soluble (potassium oxalate) and insoluble (calcium oxalate and magnesium oxalate) forms can affect both laboratory processing and gut

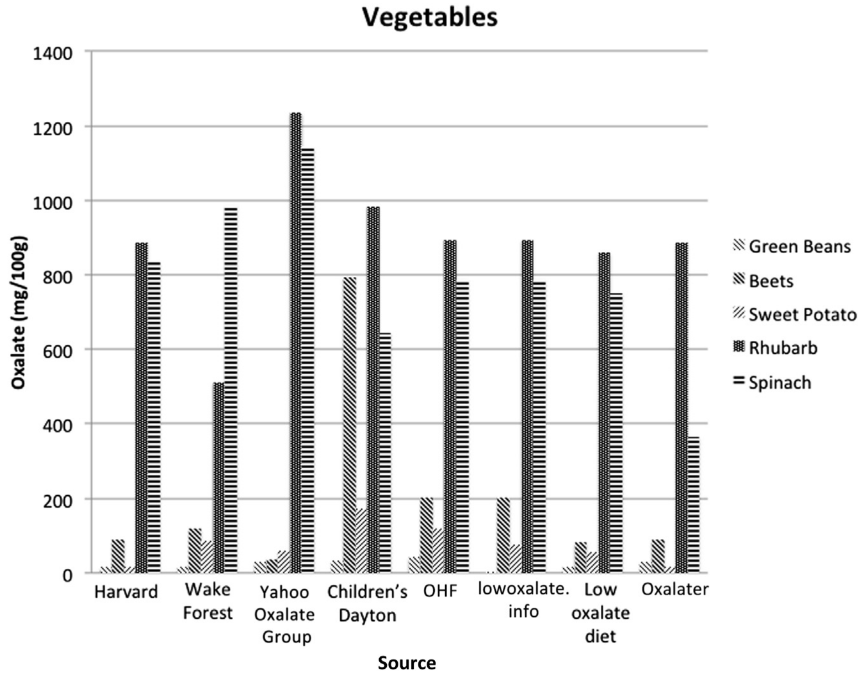

Figure 2. Oxalate content of vegetables (mg/100 g).

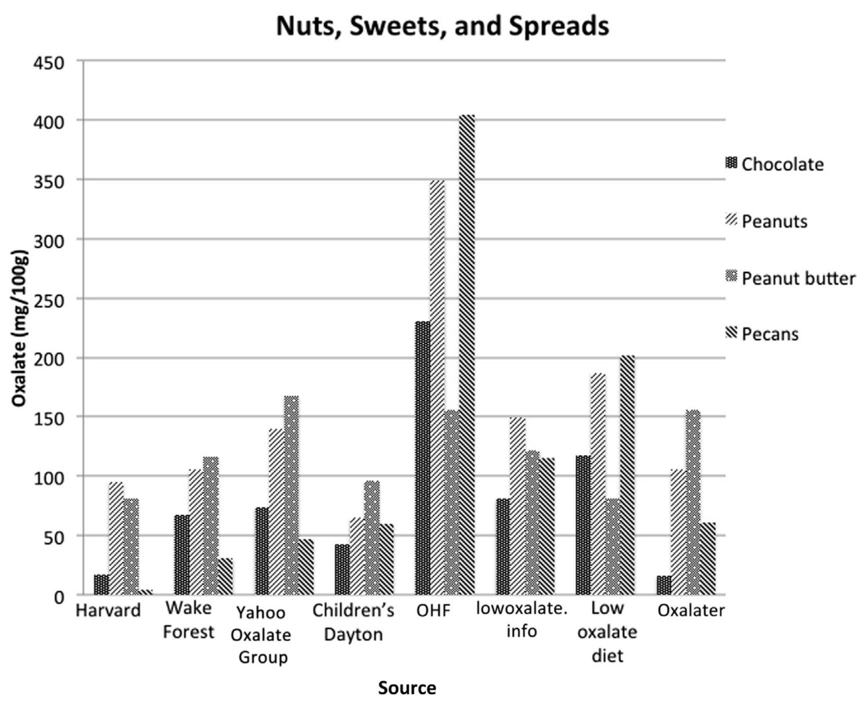

Figure 3. Oxalate content of nuts, sweets, and spreads (mg/100 g).

absorption. Acid extractions (used for colorimetric and gas chromatography) may increase the amount of oxalate measured depending on the acid preparation used.[6] Atomic absorption used for oxalate quantification from precipitated calcium results in unknown losses of oxalate.[4] Contemporary food assays now rely predominantly on ion chromatography and capillary electrophoresis[1,7] and have been determined accurate and reproducible in estimating oxalate content.[8-10] At the time of review, no sources were found to document which analytic methods were used.

Despite the accuracy with which oxalate is measured, features intrinsic to foods contribute to its variability. Several factors related to plant type and growing conditions influence the oxalate content of plant foods. The oxalate content in apples, for instance, varies depending on the length of the growing season, harvesting practices, and the variety of apple. The developmental stage of

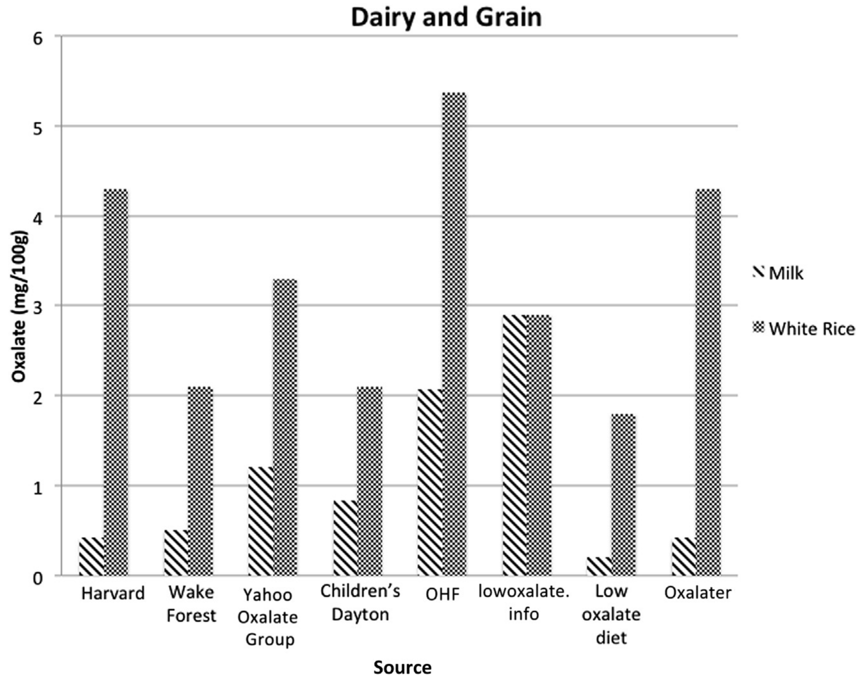

Figure 4. Oxalate content of dairy and grain (mg/100 g).

vegetables (ie, green vs red bell peppers), soil chemistry and moisture, fertilization, and plant part are all considerable factors impacting the oxalate content of many grown foods.[11] The oxalate content of spinach has also been shown to have a distinct seasonal variation, being the lowest in the fall, followed by summer, spring, and highest in the winter and showed a strong positive correlation with days required for harvest.[12] Furthermore, fast-growing cultivars contained lower oxalate compared with slow-growing cultivars. Food processing and preparation also introduces a degree of variability in the measured oxalate content of foods. Oxalate is extracted from plants that are soaked, and boiling vegetables has been found to decrease oxalate content by 30%-87%.[13]

In addition to the amount of oxalate in one's diet, absorption also plays an integral role in how much is finally excreted. Absorbed throughout the gastrointestinal (GI) tract, up to 90% of absorbed oxalate is excreted within 12 hour of consumption.[3] However, how much is absorbed depends on the form, as soluble potassium oxalate is readily absorbed whereas less absorbable calcium and magnesium oxalate may pass through the GI tract with minor effects on serum levels.[13] The amount available for absorption may also be reduced by having healthy levels of *Oxalaobacter*, as noncolonized patients have been identified as having higher levels of oxalate in their urine.[14] Concomitant calcium ingestion at the time of oxalate consumption also reduces soluble oxalate content by binding oxalate, forming nonabsorbable salts which pass through the GI tract instead of into the blood stream.

Because the degree to which these factors exert influence on the oxalate content of foods is largely unknown, comparing several sources may help guide those aiming to maintain a diet low in oxalate. The Academy of Nutrition and Dietetics' Nutrition Care Manual recommends oxalate to be restricted to <40-50 mg/day, which is simplified by avoiding foods highest in oxalate as the first step in dieting.[15] When these foods are eliminated, maintaining a diet with foods that are only low or moderate in oxalate content may help reduce oxalate consumption for stone patients.[15]

A retrospective review of dietary counseling has shown a 55.5% decrease in urinary oxalate in patients counseled during clinic visits.[16] Likewise, recurrent stone formation was significantly decreased in hyperoxaluric patients,[17] and the supersaturation of calcium oxalate, and thus the risk of formation of new stones was found to be decreased in up to 80% of patients after dietary counseling.[18]

As access to information improves, more people are turning to the Web for medical and nutritional advice. Between 1996 and 2003, a 12-fold increase in MEDLINE citations for "Web-based therapies" was observed,[19] and currently, 72% of the US Internet users have used online resources in the past year, specifically for health-related information.[5] Interestingly, a meta-analysis revealed Web-based interventions to be superior to non—Web-based interventions in terms of increased knowledge of nutritional status, increased participation in healthcare, slower health decline, and weight loss maintenance.[19]

In our analysis, although few sources reported oxalate content in milligrams per serving, those that did (Harvard, Oxalate and Hyperoxaluria Foundation, E.S. Nephrology, and the Oxalater application) made identifying the estimated oxalate content of a given food fairly simple. Moreover, as it may seem rather arduous to search several lists for food items in a given meal, and comprehensive lists such as those found on Harvard's site, "Trying Low Oxalates" group, and the "Low-oxalate Diet" application would appear to be favored by dieters. The "Low-oxalate Diet" application appeared to be a user-friendly resource for quickly identifying the oxalate value of a given food and contained measurements that were fairly consistent across the averages of most other sources. As the application is on a handheld device, it may also be a useful tool in knowing which foods to purchase when food shopping. Sources which reported the oxalate content as ranges, most notably "Oxalate and Hyperoxaluria Foundation," would appear to be less favored by dieters; selecting the proper reference point from a wide range can make the difference between exceeding or remaining below the recommended daily intake.

Although search trends for stone disease have been demonstrated to positively correlate with known epidemiologic variations in stone disease,[20] no data exist regarding the efficacy of Web-based resources aiding stone formers adhere to appropriate diet. Although our study only considered dedicated online resources, patients may also consider blogs, discussion groups, and message boards to have equal validity. In general, it is prudent to educate patient to use reputable sites and to double-check their understanding and strategies with health-care providers. If patients are having trouble with compliance and/or outcomes, it is important to ask about self-education, review their references, and if necessary, offer more appropriate alternatives.

CONCLUSION

Wide variations exist in the amount of dietary oxalate and the way it is reported across Internet-based sources and smartphone applications. Each will have varying appeal, with exhaustive lists empowering some patients, whereas overwhelming others. The simplest strategy eliminates only high or very high oxalate containing foods, compared with assessing each meal and documenting daily intake in milligrams. When using daily totals, we recommend using the most conservative estimates, avoiding sources listing values in ranges while paying attention to the method of food preparation.

Dietary counseling has proven benefits, and although limited data exist regarding the efficacy of Web-based resources in stone disease, increasing numbers of patients turning to the Internet for medical knowledge should prompt caregivers and patients alike to be cognizant of the heterogeneity that exists in the measured oxalate content of foods.

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EDITORIAL COMMENT

Ever seen a patient with a long list of foods allegedly containing high oxalate? Some are thankful: "I never liked 'rabbit food' anyway." Others are mad: "You doctors should get your stories straight; my ophthalmologist told me to eat spinach because it's good for my eyes." The World Wide Web is not always a good source of information about dietary oxalate and its relationship to kidney stones.

In this issue, the authors of "Oxalate Content of Food: A Tangled Web" confirm, after reviewing more than a dozen Web sites and smartphone applications, extreme heterogeneity between sources for nearly all food items. Moreover, they note these sources' lack of distinction between the oxalate content of foods and its bioavailability.

This comment is written fresh from an appointment with a man aged >80 years, of ideal body weight, and with no major comorbidities. He recently underwent shock wave lithotripsy for a renal stone, his first. The stone was 100% calcium oxalate monohydrate. No other tests were done. On the basis of this, and after being told to "watch" his oxalate intake, the patient collected pages and pages from the Web of the oxalate content of foods. He assembled these into a binder and documented the minimum and maximum values for each item, as reported by each source, noting the frequent vast difference in values. He explained that he was trying to stay below 50 mg of oxalate per day and asked if I could help him. He asked if something in his diet had caused the stone. I suggested, to his disbelief, that perhaps the reason he had not been bothered with stones earlier was because of his healthy lifestyle, including diet. "But now I have made all these changes," he said. So I asked, "What changes?" He said—and this is all true—he had thrown his wheat grinder in the garbage (he and his wife have, for some 40 years, ground their own whole grains), exchanged brown rice for white, resisted eating many of the vegetables he formerly liked, and stopped shopping at the co-operative store (as an aside, intended as evidence of the multitude of things going wrong recently, he related that for the first time in his life he recently required a laxative). Anyway, I mentally calculated the magnitude of his reduced magnesium, phytate, fiber, antioxidant, and prebiotic intakes as he leafed through the binder. I wondered how his 24-hour urine profile must look now compared with prestone event. I explained that high urine oxalate might not be the cause of his recent stone and that he might not need to restrict so many foods. Long story short, he agreed to a 24-hour urine collection on his usual (ie, prestone) diet and a follow-up consult.

Low oxalate diets are gaining popularity, promoted by some for pancreatitis or exocrine pancreatic insufficiency,[1] autism, and vulvar pain.[2] The oxalate content of foods does not necessarily predict urinary excretion because of multiple diet-related and physiologic factors.[2,3] But as this concept goes largely unappreciated on the Web, a source of medical information for many, detangling patients' perceptions remains on our clinical agenda.

Kristina L. Penniston, Ph.D., Department of Urology, University of Wisconsin School of Medicine and Public Health, Madison, WI

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http://dx.doi.org/10.1016/j.urology.2014.03.054
UROLOGY 84: 559−560, 2014.

Appendix 1. Reference values by food item for each resource

Food Item	Harvard	Wake Forest	Yahoo	CD	OHF	Lowox	LO Diet	Oxalater
Apple	1.38	0.4-0.6	1-3.5	0.5	3.62-7.25	3-4.9	3	1.45
Banana	2.54	3.2	6.8	0-1.69	4.24-8.47	5-9.9	0	4.24
Beans (green)	15	15.7	30.1	33	1.67-41.67	0.1-2.9	15	30.83
Beets	89.41	61.4-118	36.9	794.12	>116.47	≥15	81.1	89.41
Broccoli (cooked)	1.28	1.8-5.4	1.4	1.8	6.41-12.82	10-14.9	3.6	1.28
Carrot	12.82	7.7	17.8	5.7	12.9-32.05	≥15	7.7	19.23
Celery	8.33	11.7	19.6	61.2	16.7-41.7	≥15	20	5
Chocolate	17.44	50-66.8	73.7	42.5	60.5-230.2	≥15	117	16.28
Milk	0.42	0.5	1.2	0-0.83	<2.08	0.1-2.9	0.2	0.42
Orange	2.07	2.2	2.2	17.14	3.57-7.14	10-14.9	4	10
Peanuts	95.07	44.7-105.1	140	64.57	91.6-348.6	≥15	187	105.63
Peanut butter	81.25	53.2-116	160-168	95.8	62.5-156.25	≥15	81.1	156.25
Pecans	4.08	20.2-30.4	46.9	59.2	106.1-404.1	≥15	202	61.22
Pepper (black)	0	92	623	95.2-476.2	476.2-1190.5	10-14.9	92	428.57
Potato	39.92	5.7-28.5	24.3	27.1	4.12-10.3	≥15	17.9	39.92
Potato (sweet)	17.01	0.2-86.9	58.1	171.32	31.6-120.3	≥15	56	17.01
Rhubarb	886.88	379-511	1235	983.61	>162.3	≥15	860	886.88
Rice (white)	4.3	1.3-2.1	3.3	2.1	<5.38	0.1-2.9	1.8	4.3
Spinach	838.89	537-987	1145	645	>110	≥15	750	364.44
Tomato	5.69	2.5-13.2	11.8	1.63-8.13	8.13-20.33	5-9.9	2	16.26

CD, Children's Dayton; LO Diet, low-oxalate diet iPhone app; Lowox, www.lowoxalate.info; OHF, Oxalate and Hyperoxaluria Foundation; Oxalater, oxalater iPhone app; Yahoo, Yahoo oxalate group.