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The oxalate content of fruit and vegetable juices, nectars and drinks

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ABSTRACT

Fruit and vegetable juices are recommended for the treatment of hypocitraturia in calcium oxalate stone disease as alternatives to drugs containing alkaline citrate. Since dietary oxalate can contribute considerably to urinary oxalate excretion, the oxalate content of vegetable and fruit juices, nectars and drinks was analyzed using a validated HPLC-enzyme-reactor method. The highest oxalate concentrations were found in rhubarb nectar (198.3 mg/100 ml) and beetroot juices (60.1–70.0 mg/100 ml). The oxalate levels of all other beverages were below 10 mg/100 ml. Interestingly, except for carrot juice, the oxalate content of juices containing vegetables from organic farming was higher than from conventional farming. The consumption of even 500 ml/d of certain vegetable juices can contribute to a considerable extent to the daily oxalate intake. Calcium oxalate stone formers should therefore pay attention not only to the oxalate content but also to the ingested amount of these beverages.

1. Introduction

Approximately 75% of all urinary stones mainly consist of calcium oxalate (Hesse and Siener, 1997). Hypocitraturia is a common metabolic abnormality, diagnosed in up to 60% of calcium oxalate stone formers (Siener et al., 2005). Fruit and vegetable juices are recommended for the treatment of hypocitraturia as alternatives to pharmacologic therapy in the form of alkaline citrate. Particularly citrus juices, such as orange, grapefruit and lemon, but also tomato juice are considered rich sources of citrate (Penniston et al., 2008; Yilmaz et al., 2008, 2010). Ingested citrate is absorbed in the intestine and nearly completely metabolized to bicarbonate, providing an alkali load, which in turn enhances urinary citrate excretion (Simpson, 1983).

Moreover, fruit and vegetable juices are considered a good source of bioactive compounds which have been associated with a number of beneficial effects on human health. The positive physiological effects of juice consumption may particularly be due to their content of different classes of phytochemicals including flavonoids, found e.g. in grapefruit, orange and apple, and carotenoids, e.g. in carrot and tomato juices, which exhibit, among others, anti-oxidative, anti-inflammatory and anti-carcinogenic properties (Watzl, 2008). A study conducted by Holoch and Tracy (2011) indicated a likely role of antioxidants in preventing stone formation.

However, plants and plant products are main sources of dietary oxalate (Noonan and Savage, 1999; Hönow and Hesse, 2002; Siener et al., 2006a,b; Nguyen and Savage, 2013). Secondary hyperoxaluria, resulting from high dietary intake or intestinal hyperabsorption of oxalate, is considered a primary risk factor in the pathogenesis of calcium oxalate stone disease. It has been suggested that dietary contribution to urinary oxalate excretion is up to 50% (Holmes et al., 2001). A high dietary intake of oxalate can significantly increase urinary oxalate excretion even in healthy individuals without disturbances in oxalate metabolism (Siener et al., 2013). Intestinal hyperabsorption of oxalate can considerably contribute to urinary oxalate excretion (Voss et al., 2006).

Furthermore, dietary oxalate reduces the absorption of calcium and magnesium and is expected to impair the bioavailability of a number of trace elements due to the formation of insoluble complexes (Kelsay and Prather, 1983; Heaney et al., 1988; Bohn et al., 2004).

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Detailed knowledge of food oxalate content is therefore of essential importance for dietary treatment of recurrent calcium oxalate urolithiasis. Most fruits and vegetables in a typical Western diet, which have been analyzed so far, contained low to moderate concentrations of oxalate (Hönow and Hesse, 2002; Nguyen and Savage, 2013). Because comprehensive and reliable data on the oxalate content of fruit and vegetable juices are lacking, the purpose of the present study was to determine the soluble and total oxalate content of various types of fruit and vegetable juices, nectars and drinks.

2. Materials and methods

All fruit and vegetable juices, nectars and drinks were commercially produced and purchased from local establishments in Bonn, Germany. Samples were obtained shortly before analysis. The products are listed in Tables 1 and 2. All beverages were shaken prior to analysis.

2.1. Sample preparation

The measurement of total and soluble oxalates was performed following the method outlined by Hönow and Hesse (2002). For the extraction of the soluble oxalate content, each beverage sample was filtrated. The filtrates were acidified with 50 μl 2 N hydrochloric acid (p.a.; Merck, Darmstadt, Germany) to stabilize potentially contained ascorbic acid. Total oxalate content was determined in beverages, which left residues after filtration. For the analysis of the total oxalate content, 2 ml of the unfiltered sample of each beverage were suspended with 2 ml distilled water and 2 ml 2 N hydrochloric acid, homogenized, and filtrated. The filtrates were immediately analyzed by HPLC-enzyme-reactor method after dilution. For the determination of soluble and total oxalate contents, 10 μl of the filtrated solution were injected twice. The detection limit was 0.68 μM (0.06 mg) (Hönow and Hesse, 2002). All samples, including both oxalate extraction methodologies, were analyzed in duplicate. The oxalate content is presented as mg/100 ml fresh weight as this is how these products are consumed. The number of different products (*n*) is indicated in the tables.

2.2. HPLC-enzyme-reactor method

Analysis of filtrates was performed by a selective and sensitive HPLC-enzyme-reactor method (Hönow et al., 1997). This method combines enzymatic conversion of oxalate to hydrogen peroxide and its amperometric detection with the selectivity of a chromatographic separation. HPLC-system (Gynkotek Modell 300, Gina 50, Germering, Germany) consisted of an anion exchange column (AS4A-DIONEX, ThermoFisher Scientific, Waltham, Massachusetts), a mobile phase of an aqueous EDTA solution (2.0 g/l, adjusted to pH 5.0 with 0.3 mol/l NaOH; flow rate: 0.6 ml/min) (p.a.; Merck, Darmstadt, Germany), an enzyme reactor containing 5 units of immobilized oxalate oxidase (oxalate oxidase: E.C. 1.2.3.4.; Sigma Diagnostics, St. Louis, USA; carrier: VA Epoxy Biosynth, Riedel-de-Häen, Seelze, Germany), which oxidized oxalate to hydrogen peroxide and carbon dioxide. Resulting hydrogen peroxide was analyzed by an amperometric platinum detector (potential: +0.5 V; silver-silver chloride electrode; Gynkotek PED 300, Germering, Germany). Peaks were quantified via peak area and external calibration curves (Hönow et al., 1997). Typical chromatograms for oxalate standard and samples (apple juice) are included as Supplementary Figs. 1 and 2.

3. Results

The soluble and total oxalate contents of various types of fruit and vegetable juices, nectars and drinks are listed in Tables 1 and

Table 1
Oxalate content of vegetable juices, nectars and drinks (mg/100 ml).

	Kind of sample	Manufacturer	Soluble oxalate			Total oxalate		
			n	Mean	SD	*n*	Mean	SD
Vegetable juices								
Beetroot juice *Beta vulgaris*	100% juice	Grünfink	1	54.33	–	1	60.09	–
Beetroot juice *Beta vulgaris*	100% juice, organic[a]	Naturkind; Füllhorn; Schneekoppe	3	65.15	6.52	3	70.01	8.04
Carrot juice *Daucus carota*	100% juice	A. Dohrn & A. Timm; Grünfink	2	3.25	4.60	2	5.81	6.20
Carrot juice *Daucus carota*	100% juice, organic[a]	Hipp; Füllhorn	2	1.76	0.24	2	5.07	0.69
Sauerkraut juice *Brassica oleracea*	100% juice, organic[a]	Füllhorn; Naturkind	2	0.38	0.30		–	
Tomato juice *Lycopersicum esculentum*	100% juice	A&P; Drink	2	0.80	1.13	2	4.34	1.34
Tomato juice *Lycopersicum esculentum*	100% juice, organic[a]	Naturkind; Vita Verde	2	2.12	0.62	2	8.12	3.49
Multi-vegetable juice	100% juice (main constituents: tomato, carrot, celery, lemon)	A&P; Drink	2	0.76	1.06	2	3.64	2.62
Multi-vegetable juice	100% juice (main constituents: tomato, carrot, beetroot, celery), organic[a]	Naturkind; Vita Verde	2	3.45	0.78	2	8.45	3.92
Vegetable nectars								
Rhubarb nectar *Rheum rhabarbarum*	60% juice	Bauer	1	197.14		1	198.31	
Celeriac nectar *Apium graveolens*	50% juice	Grünfink	1	1.11			–	
Vegetable drinks								
Soybean drink *Glycine max*	62% soymilk	Drinho	1	1.34		1	4.40	
Soybean drink *Glycine max*	6.4% soybeans, organic[a]	Alpro soya	1	0.78		1	1.26	

[a] Organic: plants from organic farming.

Table 2
Oxalate content of fruit juices, nectars and drinks (mg/100 ml).

	Kind of sample	Manufacturer		Soluble oxalate			Total oxalate	
			n	Mean	SD	*n*	Mean	SD
Fruit juices								
Apple juice *Malus sylvestris*	100% juice	Niehoffs Vaihinger; Becker's Bester; Van Nahmen; Voelkel; Amecke	5	0.18	0.05	3	0.87	0.03
Cranberry juice *Vaccinium vitis idaea*	100% juice (wild fruits), organic[a]	Voelkel	1	2.05			–	
Elderberry juice *Sambucus nigra*	100% juice (wild fruits)	Voelkel	1	1.77			–	
Grape juice *Vitis vinifera*	100% grape juice, red	Drink	1	2.55		1	3.93	
Grape juice *Vitis vinifera*	100% grape juice, white	Niehoffs Vaihinger; Hipp	2	1.40	0.14	1	1.50	
Grape and guava juice *Vitis vinifera*, *Psidium guajava*	80% grape juice (white) from concentrate, 20% guava puree	Ceres	1	1.05		1	1.97	
Grape and litchi juice *Vitis vinifera*, *Litchi chinensis*	90% grape juice (white) from concentrate, 10% litchi puree	Ceres	1	0.62			–	
Grape and passion fruit *Vitis vinifera*, *Passiflora edulis*	91% grape juice (white), 9% passion fruit juice from concentrate	Ceres	1	0.56			–	
Grapefruit juice *Citrus paradisi*	100% juice from concentrate	Albi	1	0.27			–	
Orange juice *Citrus sinensis*	100% juice from concentrate, without pulp	hohes C	2	LOD[b]			–	
Pear juice *Pyrus communis*	100% juice and pulp	Frispa; Lindavia	2	0.40	0.04	2	0.54	0.02
Pineapple juice *Ananas comosus*	100% juice from concentrate	Drink	1	0.83			–	
Multi-fruit juice	100% fruit content (apple, orange, guava puree, passion fruit, banana puree, pineapple, mango puree, papaya puree)	Frispa	1	1.16		1	1.25	
Fruit nectars								
Multi-fruit nectar	50% fruit content (orange, apple, passion fruit juice from concentrates, mango and banana pulp)	Merziger	1	0.31			–	
Passion fruit nectar *Passiflora edulis*	25% juice from concentrate	Niehoffs Vaihinger	1	0.78			–	
Banana nectar *Musa paradisiaca*	25% banana pulp	Niehoffs Vaihinger	1	1.84			–	
Fruit drinks								
Mango drink *Magnifera indica*	23% mango pulp	Rubicon	1	0.39			–	
Guava drink *Psidium guajava*	20% guava pulp	Rubicon	1	1.38			–	
Raspberry-cassis drink	8% juice (3% raspberry, 3% black currant, 2% lemon)	Voelkel	1	0.52			–	

[a] Organic: plants from organic farming.
[b] LOD: Limit of detection.

2. The highest total and soluble oxalate concentrations were found in rhubarb nectar with a juice content of 60% (198.3 and 197.1 mg/100 ml, respectively) and in beetroot juices (60.1–70.0 mg/100 ml and 54.3–65.2 mg/100 ml, respectively). The oxalate content of all other fruit and vegetable juices, nectars and drinks was below 10 mg/100 ml. However, the oxalate values of almost all vegetable juices were higher compared to fruit juices. Among fruit juices, the soluble and total oxalate concentration was highest in red grape juice (2.55 and 3.93 mg/100 ml, respectively). Interestingly and surprisingly, except for carrot juice, the soluble and total oxalate content of juices containing vegetables from organic farming was higher than from conventional farming.

4. Discussion

Fruit and vegetable juices are promoted as healthy beverages as they are considered as good sources of vitamins, minerals and secondary plant substances. Due to the high citrate content, especially tomato and citrus juices have been recommended for the treatment of hypocitraturia in calcium oxalate urolithiasis (Penniston et al., 2008; Yilmaz et al., 2008, 2010). Because adherence to citrate medication is limited due to adverse events (Qaseem et al., 2014), juices seem to be favorable alternatives to pharmacologic therapy in the form of alkaline citrate. However, plant and plant products are main sources of the stone-forming anti-nutrient oxalate (Noonan and Savage, 1999; Hönow and Hesse, 2002; Siener et al., 2006a,b; Nguyen and Savage, 2013).

According to a previous study, the oxalate content of foods mainly depends on the plant families and the plant organ (Siener et al., 2006a). The oxalate concentrations of rhubarb nectar and beetroot juices, species of the Polygonaceae and Chenopodiaceae families, respectively, were highest among the beverages. The values for soluble oxalate obtained for beetroot juices (54.33 and 65.15 mg/100 ml) were similar to the values previously reported for beetroot (59.3 mg/100 g). The soluble oxalate concentration determined in rhubarb nectar with a juice content of 60% (197.14 mg/100 ml) was close to the values reported for raw rhubarb stems, i.e. 228 mg oxalate per 60 g (Siener et al., 2006a). Due to the high oxalate content, the intake of beetroot and rhubarb juice and nectar should be avoided in calcium oxalate stone formation.

Data from the study indicated that the growing conditions of the vegetables used for the juices seem to exert an effect on the oxalate content. Interestingly, except for carrot juice, the soluble and total oxalate contents of juices containing vegetables from organic farming, i.e. beetroot, tomato and multi-vegetable juices, was higher than from conventional farming. Typical organic farming practices include very strict limits on chemical synthetic pesticide and synthetic fertiliser use, and choosing plant species that are resistant to disease and adapted to local conditions. The higher oxalate values in juices containing vegetables from organic farming could be associated with the possible role of oxalate in plant tissues. Although not precisely defined, a suggested role of oxalate in plants is in disease and pest resistance (Noonan and Savage, 1999; Bauer et al., 2011). Thus, in some plants, oxalate formation appears to be an inducible defense response to herbivory or tissue wounding (Nakata, 2003; He et al., 2014). The findings of the present study supported this hypothesis.

Except for beetroot juices and rhubarb nectar, the oxalate content of all other vegetable juices, nectars and drinks was below 10 mg/100 ml. Assuming a daily ingestion of 500 ml, multi-vegetable juices from organic farming, containing 8.45 mg oxalate/100 ml, would lead to an oxalate intake of 42 mg or 0.469 mmol per day. Taking into account an intestinal oxalate absorption exceeding 10% of the intake in calcium oxalate stone formers, the consumption of this beverage would add 0.047 mmol oxalate per day to urinary oxalate excretion. The intake of beverages containing more than 5 mg oxalate per 100 ml, i.e. all vegetable juices and nectars, except for tomato and multi-vegetable juices from conventional farming, sauerkraut juice and celeriac nectar, should therefore be restricted in calcium oxalate stone formers.

The values for total oxalate contents of tomato juices from conventional farming were about 2–4 times higher than the 1.11–2.04 mg/100 ml reported in the previous literature (Yilmaz et al., 2008, 2010). The difference may be due to the different methods used for oxalate extraction and analysis. Variations among tomato cultivars may also partly contribute to the different oxalate levels. The oxalate concentrations reported by Hönow and Hesse (2002) for tomato juice (4.1 mg total and 3.6 mg soluble oxalate/100 ml, respectively) were similar to the values presently reported for tomato juice from conventional farming (Table 1).

The analyzed fruit juices, nectars and drinks contained relatively low levels of total oxalate, ranging from below the detection limit for orange juice to 2.05 mg/100 ml for cranberry and 3.93 mg/100 ml for red grape juice. The presently reported values for cranberry juice were higher than the value of 0.4 and 1.5 mg oxalate per 100 ml previously reported for cranberry juices (Hönow and Hesse, 2002; Kessler et al., 2002). The difference may be explained by the different cultivation methods, e.g. organic and conventional farming. The literature regarding the effect of cranberry juice on urinary oxalate has yielded conflicting results. Urinary oxalate has been shown to increase (Kessler et al., 2002; Gettman et al., 2005), or decrease during cranberry juice consumption (McHarg et al., 2003). These conflicting data probably reflect variability in the amount, source and components of cranberry juice tested, in basal diets used and in the study population among prior studies. It is unlikely that the low amount of oxalate of cranberry juice used in these studies is responsible for the increased urinary oxalate excretion.

Due to their high citrate content, particularly citrus juices, as orange, grapefruit and lemon juice are recommended for the treatment of hypocitraturic calcium oxalate stone formers (Penniston et al., 2008). The analyzed orange and grapefruit juices revealed total and soluble oxalate concentrations between below the detection limit and 0.27 mg/100 ml, respectively, which is considered to be very low. The oxalate values reported by Hönow and Hesse (2002) for orange (0.1 and 0.2 mg/100 ml) and grapefruit juices (0.12 mg/100 ml) were similar to the values presently reported. The literature regarding the effect of orange and grapefruit juices on urinary oxalate are likewise conflicting. A study conducted by Wabner and Pak (1993) in normal subjects and hypocitraturic stone patients found a significant increase in urinary oxalate excretion during consumption of 1.2 l of orange juice, while a study by Goldfarb and Asplin (2001) revealed an increased oxalate excretion during consumption of 240 ml of grapefruit juice. However, in a study under controlled conditions Hönow et al. (2003) failed to detect significant changes in urinary oxalate excretion during consumption of 0.5 and 1.0 l, respectively, of orange and grapefruit juice, respectively. Moreover, Hönow et al. (2003) observed a significant increase in citrate excretion during orange and grapefruit juice ingestion compared to mineral water. Due to their low oxalate content and ability to increase citrate excretion, citrus juices can be recommended for the treatment of hypocitraturic calcium oxalate stone formers.

5. Conclusions

The determination of the oxalate content of vegetable and fruit juices, nectars and drinks is required as important precondition for the accurate assessment of dietary oxalate intake and the recommendation of suitable beverages in calcium oxalate stone disease. The oxalate concentrations of rhubarb nectar and beetroot juices, species of the Polygonaceae and Chenopodiaceae families, respectively, were highest among the beverages. The oxalate content of all other analyzed beverages was below 10 mg/100 ml. Except for carrot juice, the soluble and total oxalate content of juices containing vegetables from organic farming was higher than from conventional farming. The results indicated that the consumption of even 0.5 l/d of certain vegetable juices can contribute to a considerable extent to the daily oxalate intake. Calcium oxalate stone formers should therefore pay attention not only to the oxalate content but also to the ingested amount of these beverages.

Conflict of interest

The authors declare no competing financial interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jfca.2015.10.004.

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