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Original Article

Oxalate content of purslane leaves and the effect of combining them with yoghurt or coconut products

A.-G. Moreau [a], G.P. Savage [b,*]

[a] L'Institut Polytechnique LaSalle, Beauvais, France
[b] Food Group, Agriculture and Life Sciences, Lincoln University, Canterbury, New Zealand

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ABSTRACT

The total oxalate of purslane (*Portulaca oleracea* L.) leaves grown in a green house was 1072.7 ± 23.2 mg/100 g dry matter (DM) while the level was 1234.1 ± 37.5 for leaves grown in shaded light in the same greenhouse. Lightly cooking the leaves grown in full and shaded light had no effect on soluble or insoluble content of the leaf tissue. Overall, leaves grown in shaded light contained higher levels of insoluble oxalates leading to an increased amount of total calcium within the leaves being bound to oxalate compared to the levels in the leaves grown in full light in the greenhouse. Addition of yoghurt, coconut milk or coconut cream to the raw leaves had the effect of reducing the overall oxalate content of the mixture by simple dilution. However, the addition of yoghurt to raw purslane leaves significantly reduced the soluble oxalate content of the mixture. The soluble oxalate content of the raw leaves was 53.0% which reduced to 10.7% when yoghurt was added to the leaves. Addition of coconut milk or coconut cream to fresh purslane leaves, while they both gave the mixture an acceptable taste, had no effect on reducing the percentage soluble oxalate content of the mixture.

1. Introduction

Common purslane (*Portulaca oleracea* L.), an annual succulent plant, is native to India and the Middle East and also grows in the United States, Europe, Australia and China. It has been ranked as the eighth most common food plant in the world (Coquillat, 1951). This leafy vegetable is eaten throughout Europe and Asia either raw in a salad or cooked. It is appreciated for its tangy or acid taste. Its texture and appearance is similar to spinach when cooked. Purslane forms part of a Mediterranean diet, especially in Greece and Turkey and thus it has been the topic of many investigations which have revealed various health benefits. Purslane is an excellent source of minerals (Bianco et al., 1998), vitamin C, vitamin E and carotenoids (Guil et al., 1997; Liu et al., 2000; Simopoulos, 2004) and a rich source of α-linolenic acid, a major omega-3 fatty acid (Simopoulos et al., 1992; Palaniswamy et al., 2004). Oxalate is found in many plant families (Libert and Franceschi, 1987) and the oxalate content of a wide range of vegetables, fruits, nuts, and wild edible plants has been determined in a number of comprehensive studies (Santamaria et al., 1999; Savage et al., 2000; Judpresong et al., 2006).

Several authors have promoted the positive attributes of purslane (Simopoulos et al., 1992; Palaniswamy et al., 2004; Gonnella et al., 2005) but they have given little mention to any negative features. A few authors have measured high levels of oxalates in either the whole plants or the leaves of purslane ranging from 255 to 1294 mg total oxalate/100 g fresh weight (FW) (Gontzea and Sutzescu, 1968; Awadalla et al., 1985; Guil et al., 1997; Bianco et al., 1998). More recently, Poeydomenge and Savage (2007) reported that leaves, stems and buds contained 235, 56 and 91 mg total oxalates/100 g FW, respectively. In a more detailed analysis of the fresh leaves they showed that the total oxalate content ranged from 158 mg total oxalate/100 mg FW for the larger mature leaves to 113 mg total oxalate/100 g FW in young leaves. This range of oxalate values in the edible portions of purslane are comparable or in some cases, somewhat lower than the highest values reported for Thai vegetables, such as bamboo shoots with 163 m g/100 g FW (Judpresong et al., 2006), spinach grown in Italy with 543 mg/100 g FW (Santamaria et al., 1999), taro leaves grown in New Zealand with 589 mg/100 g FW (Oscarsson and Savage, 2007) and oca tubers grown in New Zealand with 162 mg/100 g FW (Savage et al., 2008).

* Corresponding author. Tel.: +64 3 3253 803; fax: +64 33253 851.
E-mail address: savage@lincoln.ac.nz (G.P. Savage).

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Oxalate can be found as soluble and insoluble forms in plants. Soluble salts are formed when oxalate binds with potassium, sodium or magnesium (magnesium oxalate is less soluble than the potassium and sodium salts) while insoluble salts are produced when the oxalate binds with calcium or iron. Finally, oxalate can also be found as free oxalic acid (Noonan and Savage, 1999). Cooking can reduce the soluble oxalate (but not the insoluble) content of many common vegetables if the cooking water containing the leached soluble oxalate is discarded (Judpresong et al., 2006; Savage et al., 2000). As oxalate has no metabolic use in the body, once it has been absorbed it will be transported to the kidneys to be excreted in the urine as a waste product. The amount of oxalate excreted in the urine is an important risk factor in the development of calcium oxalate crystals, the most common component of kidney stones.

Because of its characteristic tangy taste purslane is commonly eaten raw in Mediterranean countries as a garnish or mixed into a salad. While purslane is often eaten raw with yoghurt and is sometimes lightly cooked in a similar way to spinach, these processes are likely to result in reduction of soluble oxalates either by binding with calcium in the yoghurt or through losses into the cooking water. The positive nutritional characteristics of purslane are underexploited and underutilised in Western diets but its relatively high oxalate content may suggest a limit to its wider use particularly for people who have a tendency to form kidney stones. Even Gonnella et al. (2005) who promoted its positive features suggested that the daily consumption of purslane is inadvisable. This paradoxical situation motivated this present study. Moreover, information about the proportions of soluble and insoluble oxalate actually absorbed when purslane is eaten with yoghurt or other garnishes such as coconut cream or coconut milk is unknown. Therefore, this study aimed to investigate the effect of cooking and the addition of these garnishes.

2. Materials and methods

2.1. Sample materials

Golden purslane (*Portulaca oleracea* L.) seeds (Koanga Gardens, Maungaturoto, NZ) were grown in a standard growing potting mix (80% bark, 20% pumice) in a greenhouse maintained between 15 and 25 °C at the Horticulture Research Area, Lincoln University, Canterbury, New Zealand (43°38′S 172°27′E) 19 m above sea level. The seeds were sown in potting mixture in a greenhouse on 16 March 2007. The seedlings were planted out into 50 mm plastic pots on 23 April 2007. The plants were either grown in full natural sunlight in a greenhouse or in reduced light under black shade cloth (Harco Black 70% shade cloth SC-3525, Harkness & Young Ltd., Auckland, NZ) in the same greenhouse. The plants were irrigated on demand throughout the growing season. Leaves were harvested on 6 July 2007 when the plants had reached a height of 150 mm.

2.2. Cooking and processing treatments

In the first experiment the freshly picked leaves were boiled (50 g fresh material was added to 500 ml boiling tap water) for 5 min and allowed to drain for 2 min. The drained samples were then freeze-dried and ground to a powder. In the second experiment 50 g yoghurt (Yoplait Greek style, Yoplait NZ Ltd., Palmerston North, NZ), 50 g coconut milk (Sincere, Sun Tan Holdings Ltd., Christchurch), or 50 g coconut cream (Samoa Tropical Products Ltd., Apia, Samoa) were added to separate 50 g samples of fresh purslane leaves grown in full light and mixed with a spoon. The mixed samples were then freeze-dried and ground to a powder using a Sunbeam Multigrinder (model no. EMO400 Sunbeam Corporation Ltd., New South Wales, Australia). Each treatment was repeated four times for the processing experiment.

2.3. Chemical analysis

Dry matter (DM) contents of the purslane leaves were determined, in duplicate, by drying in an oven at 105 °C for 24 h (AOAC, 2002). Total calcium contents were determined on the freeze-dried material. A freeze-dried sample (0.5) was digested in 7 ml of concentrated nitric acid and 1 ml of 30% hydrogen peroxide at 200 °C for 30 min in a Milestone Ethos Microwave System (Milestone SRL, Sorisole, Italy). The samples were then filtered through Whatman 52 paper into a 50 ml volumetric flask with Nanopure water (Barnstead, Nanopure II). Calcium determination was performed on a GBC 909 AAS (GBC Scientific Equipment, Dandenong, Victoria, Australia) in emission mode using a nitrous oxide/acetylene flame. The instrument was calibrated with calcium standards (2–10 μg/ml containing a final concentration of 600 μg Sr/ml and 2000 μg Cs/ml). The samples were diluted 1:9 sample to diluent with a solution containing 675μg Sr/ml and 2250 μg Cs/ml prior to analysis.

Soluble and total oxalate contents of each sample of purslane were extracted and measured as described in detail by Savage et al. (2000). Four separate 0.5 g samples of ground purslane leaves were placed in a 100 ml flask, 40 ml Nanopure water added and incubated in a water bath at 80 °C for 15 min to extract soluble oxalates. Total oxalates were extracted using 40 ml 0.2 M HCL at 80 °C for 15 min. The extracts were allowed to cool and then transferred quantitatively into 100 ml volumetric flasks and made up to volume. The extracts were centrifuged at 2889 rcf for 15 min. The supernatant was filtered through a 0.45 mm cellulose nitrate filter. The chromatographic separation was carried out using a 300 × 7.8 mm Rezex ROA ion exclusion organic acid column (Phenomenex, Torrance, CA, USA) attached to a cation H+ guard column (BioRad, Richmond, California, USA). The analytical column was held at 25 °C. The equipment consisted of an auto sampler (Hitachi AS-2000, Hitachi Ltd., Kyoto, Japan), a ternary Spectra-Physics, SP 8800 HPLC pump (Spectra-Physics, San Jose, California, USA), a Waters, U6K injector (Waters Inc., Marlborough, Massachusetts, USA), a UV/VIS detector Spectra-Physics SP8450 (Spectra-Physics, San Jose, California, USA) set on 210 nm. Data capture and processing were carried out using a peak simple chromatography data system (SSI Scientific Systems Inc, State College, PA, USA). The mobile phase used was an aqueous solution of 25 mM sulphuric acid. Samples (20 ml) were injected onto the column and eluted at a flow rate of 0.6 ml/min. Insoluble oxalate content (calcium oxalate) was calculated by difference (Holloway et al., 1989). Each sample was analysed in quadruplicate and all data are presented as mg oxalate/100 g dry matter (DM).

2.4. Statistical analysis

The data were analysed using Genstat Tenth Edition software (Laws Agricultural Trust, UK).

3. Results

The total soluble and insoluble content of the raw leaves grown in full sunlight or under shade cloth in the greenhouse are shown in Table 1, compared with leaves harvested from the same plants after boiling in tap water for 5 min. The raw and cooked leaves grown in shaded light contained significantly ($P < 0.001$) more total oxalates than the leaves grown in full light. The raw and cooked leaves grown in shaded light also contained significantly ($P < 0.001$) more insoluble oxalate compared to the plants grown in full light, while the soluble oxalate contents were similar.

Table 1
Mean oxalate content, total calcium and calculated calcium bound to oxalate (mg/100 g DM ± SE) and percentage of the total calcium bound in oxalate of raw or cooked purslane leaves grown in full or shaded light.

	Grown in full light		Grown in shaded light		Source of variation		
	Raw	Cooked	Raw	Cooked	Effect of light	Effect of cooking	Interaction
Dry matter (%)	5.38 ± 0.19	5.42 ± 0.54	4.14 ± 0.53	3.84 ± 0.42	*	NS	NS
Total oxalate	1072.7 ± 23.2	1125.2 ± 22.8	1234.1 ± 37.5	1249.4 ± 12.2	***	NS	NS
Soluble oxalate	569.0 ± 25.9	459.6 ± 9.8	475.3 ± 41.6	503.0 ± 21.4	NS	NS	NS
Insoluble oxalate[a]	503.8 ± 40.8	665.5 ± 21.9	758.7 ± 56.0	746.5 ± 29.8	***	NS	NS
Calculated calcium bound to oxalate[b]	223.9 ± 18.1	295.8 ± 9.7	337.2 ± 24.9	331.8 ± 13.2	***	NS	*
Total calcium	1828.8 ± 6.6	1292.5 ± 31.2	1128.0 ± 20.5	1235.0 ± 27.3	***	***	***
Calcium bound in oxalate/total calcium (%)	12.2 ± 1.0	22.9 ± 1.1	30.0 ± 2.7	26.9 ± 1.3	***	*	***

Probability: NS = not significant; $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.
[a] Insoluble oxalate = total oxalate − soluble oxalate (Holloway et al., 1989).
[b] Assuming all insoluble oxalate is calcium oxalate.

Overall, the short cooking time had no effect on the total, soluble or insoluble oxalate contents of the leaves.

The total amount of calcium bound to oxalate was calculated assuming that all the insoluble oxalate in the leaves was calcium oxalate; overall, the leaves grown in shaded light contained a significantly ($P < 0.001$) higher proportion of bound calcium compared to the leaves grown in full light.

In the second part of the experiment the oxalate content of the fresh leaves grown in full sunlight in a greenhouse were combined with yoghurt, coconut milk or coconut cream. The mixture was then freeze-dried and analysed for oxalate content (Table 2). The addition of yoghurt, coconut milk or coconut cream to the leaves had the effect of reducing the overall oxalate content of the mixture by simple dilution. The addition of yoghurt significantly reduced the soluble oxalate content of the mixture. The soluble oxalate content of the raw leaves was 53.0% of the total oxalate content while the soluble oxalate content of the leaves and yoghurt mixture was reduced to 10.7% as calcium in the yoghurt combined with the soluble oxalate in the leaves converting it insoluble oxalate. Yoghurt contains 251 mg Ca/100 g DM thus the overall effect was to reduce the available calcium content of the combined mixture.

Addition of coconut milk or coconut cream, while they both gave the mixture an acceptable taste they did not reduce the percentage soluble oxalate content of the mixture. Fresh purslane leaves contain relatively high levels of total calcium (1829 mg/100 g DM) with only 12.2% of the calcium bound in the insoluble oxalate fraction. Coconut milk and coconut cream contain respectively, 14, 15 mg Ca/100 g DM which had little overall effect of reducing the soluble oxalate content of the mixture.

4. Discussion

Oxalate occurs in many plants and oxalate formation is linked to the glycolate cycle and also to photosynthesis (Noonan and Savage, 1999). Therefore, the accumulation of oxalates in leaves of purslane can be explained by photosynthetic activity. In the present study more total and more insoluble oxalate appeared to accumulate in the plants grown under shaded conditions leading to a higher proportion of calcium and possibly zinc and iron being bound as oxalates in the leaf tissue. It should be noted, however, that the plants grown under shaded conditions did not grow as tall or produce as many leaves compared to the plants grown under full light conditions. Overall, the levels of oxalates in the leaves of the plants grown in a greenhouse environment are much lower than when the plants are grown in full sun conditions (Poeydomenge and Savage, 2007).

In this experiment, boiling the leaves for a relatively short time (5 min) had very little effect on the soluble oxalate content of the leaves. This is in contrast to the earlier study by Poeydomenge and Savage (2007) who observed a 33.5% loss of soluble oxalates when the purslane leaves were cooked for 5 min in boiling water and allowed to drain for 2 min. Studies on other vegetables have shown that boiling an oxalate-rich plant allows it to lose soluble oxalate into the cooking water (Savage et al., 2000). A recent study reported losses of soluble oxalate between 38 and 87% from various vegetables such as spinach, Swiss chard and Brussels sprouts (Chai and Liebman, 2005). Chai and Liebman (2005) boiled their foods for 12 min while purslane in this study was only boiled for 5 min. Tabekhia et al. (1978) boiled purslane for 25 min and this resulted in a significant decrease of both soluble and insoluble oxalate levels ($P < 0.001$), however, this treatment also resulted in an undesirable loss of total solids and valuable nutrients. It seems unlikely that boiling purslane for such a long time will allow it to retain its health benefits.

Earlier studies have reported the reduction of soluble oxalates in spinach (Brogren and Savage, 2003) and in taro (Oscarsson and Savage, 2007) from 49 to 73% when cooked with a milk-based product. Consuming purslane with a calcium rich food such as yoghurt would allow a reduction in the absorption of soluble oxalate since calcium binds with soluble oxalate forming insoluble oxalates which are less efficiently absorbed in the gastrointestinal

Table 2
Mean oxalate content, total calcium and calculated calcium bound to oxalate (mg/100 g DM ± SE) and percentage of the total calcium bound in oxalate of raw purslane leaves grown in full light with and without the addition of yoghurt, coconut milk or coconut cream.

	Dry matter (%)	Total oxalate (mg/100 g DM)	Soluble oxalate (mg/100 g DM) (% of the total oxalate)	Insoluble oxalate[a] (mg/100 g DM)	Calculated calcium bound to oxalate[b] (mg/100 g DM)	Total calcium (mg/100g DM)	Calcium bound in oxalate/ total calcium (%)
Raw leaves	5.38 ± 0.19	1072.7 ± 23.2	569.0 ± 25.9 (53.0%)	503.8 ± 40.8	223.9 ± 18.1	1828.8 ± 6.6	12.2 ± 1.0
Leaves with yoghurt	24.16 ± 0.02	230.5 ± 13.2	24.6 ± 1.3 (10.7%)	205.8 ± 12.1	91.5 ± 5.4	1094.8 ± 39.4	8.4 ± 0.7
Leaves with coconut milk	20.71 ± 0.02	215.3 ± 1.8	149.4 ± 4.0 (69.4%)	65.9 ± 5.0	29.3 ± 2.2	305.0 ± 6.5	9.6 ± 0.8
Leaves with coconut cream	24.94 ± 0.02	191.6 ± 7.5	128.6 ± 9.7 (67.1%)	63.0 ± 4.4	28.0 ± 2.0	252.5 ± 8.5	11.2 ± 1.1

[a] Insoluble oxalate = total oxalate − soluble oxalate (Holloway et al., 1989).
[b] Assuming all insoluble oxalate is calcium oxalate.

tract. Therefore, the oxalate bioavailability from purslane would be reduced if it is cooked with a milk-based product.

Gonnella et al. (2005) reported that the buds of purslane grown hydroponically contained lower oxalic acid concentrations. The reduction in the oxalate content of purslane could be a response to a change in the NO_3^-/NH_4^+ ratio in the nutrient solutions as Palaniswamy et al. (2004) reported that the oxalate concentration in purslane leaves could be lowered from 623 mg/100 g FW to 380 mg/100 g FW when grown with a NO_3^-/NH_4^+ ratio of 25:75. It is also possible that the oxalate content of purslane leaves is considerably reduced when the plants are grown under glass in a greenhouse. It is possible that the production of oxalate in the leaf tissue is increased when the leaves are exposed to UV light. However, in this experiment the total oxalate content of plants grown in shaded conditions was higher than when grown in full light.

In Turkey, purslane leaves and sometimes stems, either raw or cooked, are mostly consumed with yoghurt (Özlem Tuncay, Personal Communication). In the case of "Yogurtlu Semizotu" (raw purslane mixed with garlic yoghurt; 2:1 w/w) using the data obtained in this study a 100 g serving of this dish would contain 30.6 mg soluble oxalate but as yoghurt is also added to Yogurtlu Semizotu the soluble oxalate consumed would be reduced to 3.7 mg soluble oxalate for the whole dish. The consumption of this amount of soluble oxalate even on a daily basis would pose no health risks from the soluble oxalate content. However, the addition of coconut cream or coconut milk would be additional alternatives to yoghurt in the Pacific region. In this study the combination of raw purslane with coconut milk or coconut cream gave the mixture an interesting and pleasant taste but would not be as effective at reducing the soluble oxalate content as the addition of yoghurt to purslane leaves.

5. Conclusions

Overall, the results of this experiment confirm that growing purslane in a greenhouse appears to lead to a reduction in the total oxalate content of the leaves when compared to the levels of oxalates in plants grown in full sunlight. This experiment also confirms that the consumption of raw purslane with yoghurt significantly reduces the soluble oxalate content of the mixture. The additions of coconut cream or coconut milk are not so effective at reducing the soluble oxalate content of the final mixture.

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References

AOAC, 2002.In: Official Methods of Analysis of AOAC International. 17th ed. AOAC International, Gathersberg, MD.
Awadalla, M.Z., Bassily, N.S., Saba, N.H., 1985. Oxalate content of some common Egyptian food stuffs. The Journal of the Egyptian Public Health Association 150 (3–4), 41–51.
Brogren, M., Savage, G.P., 2003. Bioavailability of soluble oxalate from spinach eaten with and without milk products. Asia Pacific Journal of Clinical Nutrition 12, 219–224.
Bianco, V.V., Santamaria, P., Elia, A., 1998. Nutritional value and nitrate content in edible wild species used in southern Italy. In: Rubatzky, V.E., Chen Hang, J.Y., Péron, (Eds.), Proceedings of the 3rd IS on Diversification of Vegetable Crops, Acta Horticulturae 467, 71–87.
Chai, W., Liebman, M., 2005. Effect of different cooking methods on vegetable oxalate content. Journal of Agricultural and Food Chemistry 53, 3027–3030.
Coquillat, M., 1951. Bulletin Mensuel de la Société Linnéenne de Lyon. Lyon 21, 165.
Gonnella, M., Charfeddine, M., Conversa, G., Santamaria, P., 2005. Portulaca: from weed to function as a foodstuff? Colture-Protette 34, 49–55.
Gontzea, I., Sutzescu, P., 1968. Natural Antinutritive Substances in Foodstuffs and Forages. S. Karger, Basel, Switzerland.
Guil, J.L., Rodríguez-García, I., Torija, E., 1997. Nutritional and toxic factors in selected wild edible plants. Plant Foods for Human Nutrition 51, 99–107.
Holloway, W., Argall, M., Jealous, W., Lee, J., Bradbury, J., 1989. Organic acids and calcium oxalate in tropical root crops. Journal of Agricultural and Food Chemistry 37, 337–340.
Judpresong, K., Chaoenkiatkul, S., Sungpuag, P., Vasanachitt, K., Nakjamanong, Y., 2006. Total and soluble oxalate contents in Thai vegetables, cereal grains and legume seeds and their changes after cooking. Journal of Food Composition and Analysis 19, 340–347.
Liu, L., Howe, P., Zhou, Y., Xu, Z., Hocart, C., Zhang, R., 2000. Fatty acids and β-carotene in Australian purslane (*Portulaca oleracea*) varieties. Journal of Chromatography A 893, 207–213.
Libert, B., Franceschi, V.R., 1987. Oxalate in crop plants. Journal of Agricultural and Food Chemistry 35, 926–938.
Noonan, S.C., Savage, G.P., 1999. Oxalate content of foods and its effect on humans. Asia Pacific Journal of Clinical Nutrition 8, 64–74.
Oscarsson, K.V., Savage, G.P., 2007. Composition and availability of soluble and insoluble oxalates in raw and cooked taro (*Colocasia esculenta* var. Schott) leaves. Food Chemistry 101, 559–562.
Palaniswamy, U.R., Bible, B.B., McAvoy, R.J., 2004. Oxalic acid concentrations in purslane (*Portulaca oleracea*e L.) is altered by the stage of harvest and the nitrate to ammonium ratios in hydroponics. Scientia Horticulturae 102, 267–275.
Poeydomenge, G.Y., Savage, G.P., 2007. Oxalate content of raw and cooked purslane. Journal of Food, Agriculture and Environment 5, 124–128.
Santamaria, P., Elia, A., Serio, F., Todaro, E., 1999. A survey of nitrate and oxalate content in fresh vegetables. Journal of Science of Food and Agriculture 79, 1882–1888.
Savage, G.P., Vanhanen, L., Mason, S.M., Ross, A.B., 2000. Effect of cooking on the soluble and insoluble oxalate content of some New Zealand foods. Journal of Food Composition and Analysis 13, 201–206.
Savage, G.P., Mason, S.L., Vanhanen, L., 2008. The effect of storage on the oxalate content of New Zealand grown oca. International Journal of Food Science and Technology 43, 2130–2133.
Simopoulos, A.P., Norman, H.A., Gillapsy, J.E., Duke, J.A., 1992. Common purslane: a source of omega-3 fatty acids and antioxidants. Journal of the American College of Nutrition 11, 374–382.
Simopoulos, A.P., 2004. Omega-3 fatty acids and antioxidants in edible wild plants. Biological Research 37, 263–277.
Tabekhia, M.M., Toma, R.B., El-Mahdy, A.R., 1978. Effects of Egyptian cooking methods on total, free oxalates and mineral content of two leafy, green vegetables (Jew's mellow and purslane. Nutritional Reports International 18, 611–617.