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ARTICLE

Traditional green leafy vegetables as underutilised sources of micronutrients in a rural farming community in south-west Nigeria I: estimation of vitamin C, carotenoids and mineral contents

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Objective: To determine the micronutrient composition of fresh and boiled traditional green leafy vegetables (TGLVs).
Design: Sixteen TGLVs categorised into cultivated and uncultivated vegetables were analysed for vitamin C (ascorbic acid [AA] and dehydroascorbate [DHAA]), β-carotene, lutein and minerals.
Results: *Basella alba* had the highest AA (72 mg/100 g) content; *Vernonia amygdalina* (unwashed), had the highest β-carotene and lutein concentrations (14.1 and 29.0 mg/100 g, respectively); *Amaranthus hybridus* had the highest AA (43 mg/100 g) and β-carotene (9.3 mg/100 g) content, for cultivated *sp. Celosia argentea* had the highest Fe content; Zn content of all the vegetables was low, 0.4–2.6 mg/100 g. Cooking resulted in significant losses in AA content in all the samples, 19% in *B. alba* to 100% in *Crassocephalum crepidioides*. Carotenoid losses were observed in 10 samples and six samples had increased values of β-carotene (12% to 183%) and lutein (64% to double).
Conclusion: Traditional green leafy vegetables studied were found to be rich in the micronutrients of interest, especially in carotenoids. Boiling of leafy vegetables, as traditionally done, led to considerable losses of the micronutrients. The micronutrient content of uncultivated leafy vegetables compared well with commonly cultivated species.

Keywords: Ascorbic acid, indigenous vegetables, iron, lutein, provitamin A

Introduction

There is renewed research attention to promote traditional green leafy vegetables (TGLVs), especially uncultivated species, used in traditional food system in many countries. This is because they have been part of the food system and culture for a very long time.[1] Moreover, many of them compare well in terms of their micronutrient contents with the more commonly consumed cultivated TGLVs.[2,3] They are often readily available and cheap, and contribute to improving the micronutrient quality and diversity of local diets, and could lessen the burden of 'hidden hunger', thus enhancing health.[4,5] Despite these assertions, these TGLVs tend to disappear from the diets of many people as they migrate from villages to towns, where many of the uncultivated TGLV species may not be available in urban markets.[6] Furthermore, poor knowledge of the nutritional benefits of TGLVs and the growing disinterest of the younger generation for these foods contribute to their being underutilised.[7]

TGLVs play an important nutritional role in the dietary structure of Nigerians in rural areas: apart from being rich sources of β-carotene, iron and vitamin C,[2] they are also a major source of dietary lutein.[8] While vitamin C enhances non-heme iron absorption,[9] lutein and zeaxanthin (xanthophyll carotenoids) may protect against age-related macular diseases (AMD).[10] Most TGLVs are boiled before their consumption and, for some, specific preparation to reduce bitterness (e.g. extensive washing), to allow their incorporation into traditional sauces and improve palatability is necessary. Many resource-poor and rural households rely on their consumption for the supply of micronutrients. However, seasonal availability and poor attention of agricultural food systems, research and development to traditional foods such as uncultivated TGLVs also lead to the decrease in their utilisation.[11] These include insufficient and sometimes poor-quality data on the nutritive value of many TGLVs, particularly uncultivated species.[12] Hence large knowledge gaps still exist in the composition and contribution of these foods to dietary intakes;[13] for example, there is insufficient data on the lutein content of TGLVs in Nigeria. The nutrient composition of foods is an important factor in their utilisation. In this context, our primary aims were to determine micronutrient content: vitamin C (ascorbic acid [AA] and dehydroascorbic acid [DHAA]), carotenoids (the pro-vitamin A β-carotene and lutein) and minerals for 16 fresh and boiled TGLVs (representing the available and consumed species identified in a rural farming community in south-west Nigeria[14]).

Materials and methods

Leafy vegetable collection

The chosen 13 uncultivated and three commonly cultivated (16 samples) TGLVs were obtained from field locations in the study community or purchased from the local market of the community, early in the morning to ensure freshness when not available in the field. A minimum of 5 individual plants pooled and mixed to form a composite (per sample) was sampled and edible portions (leaves and stalk) were sorted, packed into paper wraps, and stored at 4°C immediately before their transportation in a cold chain (cooled box with ice packs by plane) to *Sécurité et Qualité des Produits d'Origine Végétale* (SQPOV), *Institut National*

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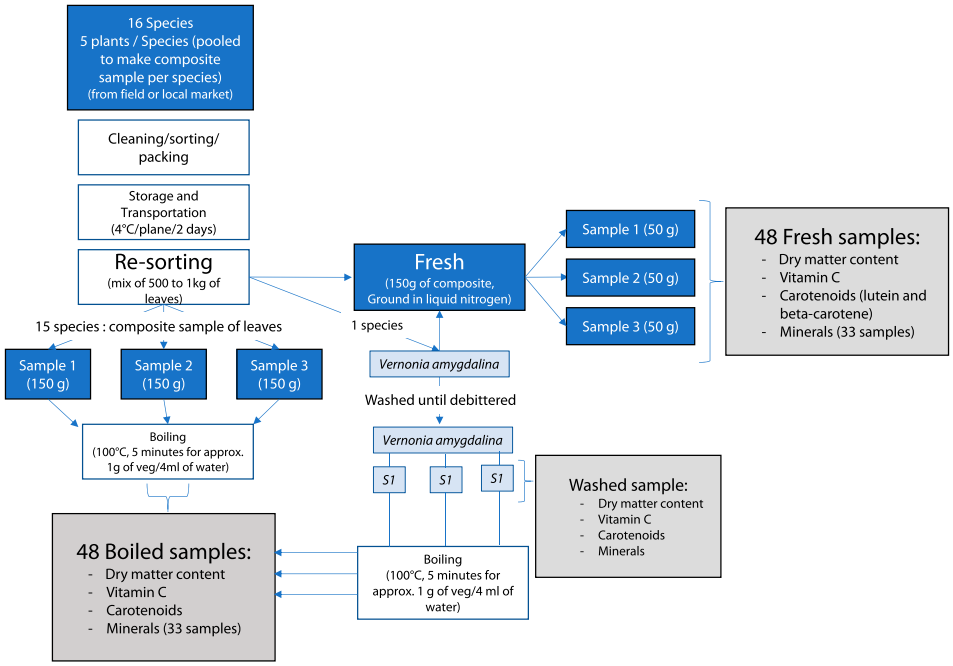

Figure 1. Diagram of sampling and processing of the 16 collected species.

de la Recherche Agronomique (INRA), Avignon, France, where analyses were carried out. The overall weight of each sample was between 0.5 and −1 kg. On arrival, samples were re-sorted, to remove damaged leaves, re-weighed and divided into two representative portions.

Sample handling and preparation for analysis

Of the two representative portions, the first portion was ground fresh in liquid nitrogen with an A11 analytical mill (IKA, Staufen, Germany), divided into 3 aliquots (50 g each) and kept as fresh aliquots at −80°C. The second portion was divided into 3 aliquots (150 g each) and boiled separately by adding the vegetables directly into boiling demineralised water and cooked for 5 minutes (see Figure 1). The vegetable/liquid ratio was approximately 1 g/4 ml. The cooked vegetables were drained, rapidly frozen at −30°C, ground in liquid nitrogen and stored at −80°C. The bitter leaf sample (*Vernonia amygdalina*) was debittered by squeeze-washing the leaves with tap water and draining intermittently until the bitterness could not be tasted in the leaves. The debittered leaves were split into the same aliquots as done for the other boiled leaves.

Chemical analyses

Analyses were conducted on the pooled sample entity, as described in the first section of the Materials and methods section.

Dry matter was analysed on each aliquot after 72 hours' oven drying at 70°C.

Ascorbic acid (AA) was quantified in triplicate on nitrogen-ground powders as described by Stevens *et al.*[15] Absorbance was measured at 525 nm on a spectrophotometer (Safas Xenius, Monaco).

For each sample, two analytical repetitions were carried out and quantification was determined by an external calibration against AA. A solution of pure AA (> 99%) (master solution) at 1 ± 0.2 mg/ml was prepared daily from an exact quantity of powder and kept at 4°C or on ice, for not more than 4 hours. LOD and LOQ were in accordance with Stevens *et al.*[15] Ascorbic acid and dehydroascorbic acid (DHAA) were quantified and results were expressed in total vitamin C, i.e. the sum of AA and DHAA in mg/100 g fresh weight.

Carotenoids were extracted on the nitrogen-ground powders, using the micro method described by Bureau *et al.*[16] They were quantified by HPLC-DAD (SPD-M20A Shimadzu Inc., Kyoto, Japan) using a C30 column (250 × 4.6 mm, particle size 3 µm; YMC Co, Kyoto, Japan) eluted at 30°C, flow rate 1.4 ml min^{-1}, with a methanol–methyl tert-butyl ether (MTBE) gradients. Lutein and β-carotene were quantified at 450 nm and lycopene (used as internal standard) at 503 nm. Quantification was performed relative to the peak area of the internal standard (lycopene). Response factors were calculated for lycopene and β-carotene from standard solutions. Master (reference) solutions were made from pure standard. Their exact concentrations were controlled for each calibration and for each batch of experimentation (internal standard) by checking the exact UV-vis absorbance using the molar extinction coefficient ($E^{1\%}$–1 cm) of 3450 for lycopene and 2592 for the β-carotene. Limit of detection (LOD) was measured at 5×10^{-4} µg/ml. Linearity of the DAD response was measured for concentration of β-carotene between 1.25×10^{-2} and 0.4 µg/ml. All the HPLC injections were within those limits. Slope of the linear models was 1.53 ± 0.04 and $R^2 = 0.988 \pm 0.003$ (by means of three calibrations covering the experimentation period).

Minerals were analysed by inductively coupled plasma atomic emission spectroscopy (ICP-AES) after mineralisation and redissolution in HNO_3 according to European standard EN 15510 by Inovalys (Nantes, France). Analysis was performed as a one-shot measure on a bulked powder of the three repetitions of fresh and boiled samples (as described in sample preparation for analysis). The maximal relative technical errors were measured by Inovalys as being 10% for all minerals except for copper, which was 20%.

Table 1: Dry matter (DM) and ascorbic acid and carotenoid (100 g of edible portion [EP], fresh weight) content of green leafy vegetables

Scientific name	Condition	DM (g)	Vitamin C (mg)	β-carotene (mg)	RAE[e] (mg)	Lutein(mg)
Cultivated:						
Amaranthus hybridus	Raw	15.7 ± 0.1	43.0 ± 1.6	9.0 ± 0.2	0.8 ± 0.02	14.7 ± 0.8
	Boiled	8.7 ± 0.2	7.9 ± 0.8	2.9 ± 0.1	0.2 ± 0.01	6.0 ± 0.3
Celosia argentia	Raw	12.3 ± 0.1	7.8 ± 1.5	6.5 ± 0.1	0.6 ± 0.004	13.6 ± 0.8
	Boiled	7.0 ± 0.2	0.9 ± 0.2	5.3 ± 0.01	0.4 ± 0.001	12.5 ± 0.2
Corchorus olitorius	Raw	17.4 ± 0.4	34.0 ± 3.8	5.7 ± 0.01	0.5 ± 0.001	10.0 ± 0.2
	Boiled	4.9 ± 0.2	9.3 ± 1.7	1.1 ± 0.02	0.1 ± 0.001	2.0 ± 0.1
Uncultivated:						
Abelmoscus esculentu[a]	Raw	23.0 ± 0.9	33.9 ± 1.0	6.1 ± 0.4	0.5 ± 0.03	11.9 ± 1.4
Adansonia digitata	Powder[b]	100.0 ± 0.0	73.0 ± 1.0	18.0 ± 0.5	1.5 ± 0.04	50.5 ± 1.5
	Boiled	9.9 ± 0.1	6.0 ± 1.6	1.5 ± 0.01	0.1 ± 0.001	3.0 ± 0.1
Amaranthus dubius	Raw	20.4 ± 0.1	50.0 ± 2.4	4.6 ± 0.2	0.4 ± 0.02	7.0 ± 0.9
	Boiled	9.7 ± 0.8	3.0 ± 1.4	3.6 ± 0.3	0.3 ± 0.03	6.6 ± 0.6
Amaranthus viridis	Raw	17.2 ± 0.6	29.7 ± 2.9	5.7 ± 0.1	0.5 ± 0.01	8.8 ± 0.4
	Boiled	9.1 ± 0.1	0.6 ± 0.2	8.0 ± 0.1	0.7 ± 0.01	14.5 ± 0.5
Basella alba	Raw	6.9 ± 0.1	72.0 ± 1.8	3.9 ± 0.01	0.3 ± 0.01	9.5 ± 0.3
	Boiled[d]	6.0 ± 1.3	58.9 ± 4.1	2.5 ± 0.2	0.2 ± 0.01	5.7 ± 0.6
Basella rubra	Raw	6.7 ± 0.1	52.8 ± 2.0	4.0 ± 0.1	0.3 ± 0.01	9.1 ± 0.3
	Boiled	5.0 ± 1.3	33.0 ± 7.5	2.6 ± 0.2	0.2 ± 0.01	5.7 ± 0.3
Crassocephalum crepidioides	Raw	10.9 ± 0.3	5.0 ± 0.1	5.8 ± 0.01	0.5 ± 0.001	11.2 ± 0.6
	Boiled	5.9 ± 0.1	*nd*	9.0 ± 0.1	0.8 ± 0.004	19.0 ± 0.2
Launaea taraxacifolia	Raw	11.9 ± 0.4	19.0 ± 1.4	5.4 ± 0.1	0.5 ± 0.01	9.0 ± 0.6
	Boiled	7.8 ± 0.2	1.7 ± 0.5	8.6 ± 0.6	0.7 ± 0.04	15.0 ± 1.7
Senecio biafrae	Raw	7.8 ± 0.7	7.0 ± 0.7	2.5 ± 0.2	0.2 ± 0.02	7.2 ± 0.5
	Boiled	5.0 ± 0.1	2.6 ± 1.2	4.0 ± 0.1	0.3 ± 0.01	12.0 ± 0.2
Solanum americanum	Raw	15.1 ± 0.1	70.0 ± 6.6	10.7 ± 0.5	0.9 ± 0.04	17.8 ± 1.0
	Boiled	9.4 ± 0.3	6.8 ± 0.7	12.0 ± 0.3	1.0 ± 0.03	31.0 ± 1.3
Solanum macrocarpon	Raw	15.2 ± 2.2	11.5 ± 3.3	7.5 ± 0.3	0.6 ± 0.002	17.5 ± 1.6
	Boiled	10.5 ± 0.9	4.0 ± 0.7	7.0 ± 0.6	0.7 ± 0.04	16.0 ± 2.0
Talinum triangulare	Raw	7.0 ± 0.0	8.8 ± 1.9	1.8 ± 0.02	0.1 ± 0.001	3.9 ± 0.1
	Boiled	5.2 ± 0.4	6.0 ± 2.1	5.0 ± 0.1	0.4 ± 0.004	7.7 ± 0.1
Vernonia amygdalina	Raw	16.9 ± 0.2	5.0 ± 1.4	14.1 ± 0.4	1.1 ± 0.03	29.0 ± 4.3
	Washed[c]	12.0 ± 1.3	0.1 ± 0.3	4.2 ± 0.2	0.4 ± 0.02	9.4 ± 1.1
	Boiled	9.1 ± 0.3	*nd*	2.8 ± 0.1	0.2 ± 0.004	7.0 ± 0.4

[a]Cultivated mostly for the fruit, i.e. okra, but the leaves are consumed.
[b]Leaves processed into dry powder: analysed in dry from.
[c]Debittered.
[d]Boiled without water; nd: not detected.
[e]Retinol activity equivalent (RAE): conversion of 12 µg β-carotene to 1 µg RAE was used (FAO/INFOODS, 2012).

Data analysis

Two analytical repetitions of each aliquot of vegetable sample (as technical triplicate) were carried out. Results are reported as means with SD of fresh weight per 100 g of sample. Independent sample *t*-test was performed on two of the TGLV species with more than one variety, to ascertain if there were significant differences in their micronutrient content. Statistically significance was given as $p < 0.005$.

Results

Vitamin C, β-carotene, retinol activity equivalent (RAE) and lutein, and minerals (Fe, Zn, Ca, Mg, K, Na, P and Cu) contents of the raw and boiled cultivated and uncultivated TGLVs are presented in Tables 1 and 2, respectively.

Vitamin C

Vitamin C concentration in the raw leafy vegetables ranged from 50 to 72 mg/100 g in uncultivated TGLVs compared with commonly cultivated species like *Celosia argentea*, *Corchorus olitorius* and *Amaranthus hybridus*, which ranged from 7.8 mg to 43 mg/100 g. Dry powdered leaves of *Adansonia digitata* had 73 mg/100 g vitamin C (note that this is in 100 g dry matter, hence in fresh matter vitamin C would be lower per 100 g). Between *Amaranthus species,* there was no significant difference between the *A. hybridus* (cultivated and commonly consumed) and *A. dubius* (uncultivated) species, ($p > 0.05$), but the vitamin C concentration of *A. viridis* (uncultivated) was significantly different ($p < 0.05$). For *Solanum* species, vitamin C concentration varied widely and the difference between *S. americanum* and *S. macrocarpon* was statistically significant at $p < 0.005$.

Vitamin C content of the boiled TGLVs ranged from 0.6 ± 0.2 mg in *A. viridis* to 58.9 ± 4.1 mg in *Basella alba* (green stem). Vitamin C was not detected in boiled *Crassocephalum crepidioides* (see Table 1).

Table 2: Mineral contents of green leafy vegetables (mg/100 g edible portion)

Scientific name	Condition	Fe	Zn	Ca	Mg	K	Na	*P*	Cu	Mn
Cultivated:										
Amaranthus hybridus	Raw	8.87	0.99	344	166	818	*Tr*	61	*Tr*	3.66
	Boiled	7.46	0.69	297	84	328	*Tr*	26	*Tr*	3.03
Celosia argentia	Raw	27.51	0.66	478	275	1425	6.22	82	0.32	4.51
	Boiled	5.66	0.39	140	59	216	*Tr*	23	*Tr*	1.25
Cochorus olitorius	Raw	20.09	0.74	223	86	812	*Tr*	85	0.29	3.14
	Boiled	6.42	0.22	64	24	145	*Tr*	23	*Tr*	0.92
Uncultivated:										
Abelmoscus esculentus	Raw	6.12	2.08	579	159	529	3.17	86	0.35	14.27
Adansonia digitata	Raw	33.62	2.02	2283	490	1050	15.61	165	0.95	4.41
Amaranthus viridis	Raw	19.08	2.63	469	175	705	4.57	108	*Tr*	5.95
	Boiled	12.09	1.33	383	82	176	*Tr*	45	*Tr*	3.50
Crassocephalum crepidioides	Raw	5.95	0.62	111	23	671	*Tr*	39	*Tr*	1.69
	Boiled	2.91	0.29	72	10	120	5.25*	16	*Tr*	0.90
Launaea taraxacifolia	Raw	2.97	0.58	154	34	709	6.04	36	*Tr*	1.10
	Boiled	2.60	0.40	126	21	225	*Tr*	25	*Tr*	0.75
Solanum macrocarpon	Raw	4.39	1.01	248	75	709	*Tr*	64	0.43	1.36
	Boiled	2.47	0.68	182	51	304	*Tr*	38	*Tr*	0.94
Talinum triangulare	Raw	7.06	0.47	68	86	635	*Tr*	20	*Tr*	2.28
	Boiled	3.64	0.37	64	66	421	*Tr*	14	*Tr*	1.73
Veronia amygdalina	Raw	3.72	1.23	188	44	832	*Tr*	65	0.29	1.39
	Washed	1.39	0.54	247	34	233	*Tr*	35	*Tr*	0.98
	Boiled	1.18	0.35	183	25	89	*Tr*	18	*Tr*	0.72

Note: Values are one-shot measure on a bulked powder of the three repetitions. Maximal relative error was 10% for all minerals except for Cu, which was 20%. *Tr* = Trace.

Carotenoids

β-carotene content of the raw leafy vegetables ranged from 1.8 mg/100 g in *Talinum triangulare* to 14.1 mg/100 g in raw *Vernonia amygdalina*. *Adansonia digitata* (dried powered leaves, as sold in the local market) had 18 mg/100 g (see Table 1). Among the *Amaranthus* species, *A. hybridus* had the highest β-carotene content ($p < 0.01$). *Solanum americanum* had significantly higher β-carotene content than *S. macrocarpon*. β-carotene content of debittered *Vernonia amygdalina* leaves (4.2 mg/100 g) was substantially lower than in the unwashed leaves (14.2 mg/100 g).

Lutein levels were found to be generally high in the TGLVs (see-Table 1). Values were between 10 mg/100 g in *C. olitorious* and 15 mg/100 g in *A. hybridus* for cultivated TGLVs and between 7 mg/100 g in *S. biafrae* and 29 mg/100 g in *V. amygdalina* (unwashed), for uncultivated TGLVs.

β-carotene in boiled TGLVs ranged from 1.1 ± 0.02 mg in *C. olitorious* to 12.0 ± 0.3 mg in *Solanum americanum*. Lutein content of boiled TGLVs were between 2.0 ± 0.1 mg in *C. olitorious* and 31.0 ± 1.3 mg in *Solanum americanum* (see Table 1).

Mineral content

Nine minerals were quantified in 11 fresh samples (see Table 2). Three of the uncultivated leafy vegetables, namely *Abelmoscus esculentus* leaves, *Amaranthus viridis* and *Vernonia amygdalina*, had zinc levels > 1 mg/100 g of raw vegetable. *Celosia argentea* (27 mg/100 g) and *A. viridis* (19 mg/100 g) had the highest Fe content for both the cultivated and uncultivated TGLVs, respectively. The TGLVs also had considerable calcium concentrations: from as high as 579 mg/100 g in *Abelmoscus esculentus* leaves to 68 mg/100 g in *Talinum triangulare*. Dried powered leaves of *Adansonia digitata* had a calcium content of 2283 mg/100 g. The concentration of potassium was in the range of 812–1425 mg/100 g in fresh leaves of the cultivated TGLVs and from 529 to 832 mg/100 g in the uncultivated TGLVs. *Adansonia digitata* had a concentration of 1050 mg/100 g of dried sample. Sodium content of most of the leafy vegetables was very low.

For the boiled TGLVs iron content ranged from as high as 12 mg/100 g in *Amarathus viridis* to as low as 1.18 mg/100 g in boiled debittered *Vernonia amygdalina* leaves; potassium content was 145–328 mg/100 g in the cultivated TGLVs and 89–421 mg/g in the uncultivated TGLVs (see Table 2).

Discussion

The aims of this study were to determine the micronutrient content of fresh and boiled TGLVs, and potential contribution of TGLVs to micronutrient requirement.

Vitamin C

Five uncultivated vegetables (*Basella alba*, *Basella rubra* (green and red stem, respectively), and *Solanum americanum*, *Adansonia digitata and Amaranthus dubius*) and two of the cultivated vegetables compared well with the vitamin C content of raw spinach obtained by Delchier *et al.*[17], who used similar analytical methods. However, the results indicate that TGLVs vary widely in vitamin C concentrations that have been reported by some previous studies.[18,19] The wide variation could be due to factors such as analytical method, handling of the samples prior to analysis, or pre- and post-harvest factors such as climatic conditions, maturation, harvesting methods and storage, which are known to cause variation in vitamin C content of horticultural crops.[20]

Carotenoids

To the best of our knowledge, this study is the first report of lutein content of 16 TGLVs found in south-west Nigeria. There is a dearth of reports on the lutein content of TGLVs in Nigeria. TGLVs were found to be rich in lutein and with generally higher values than in literature reports for similar vegetables.[21,22] *V. amygdalina* stood out as having the highest lutein content. Lutein has been reported as the main carotenoid in the green vegetables.[16] Given the high lutein content of most of the TGLVs, promoting their consumption could enhance lutein intake of consumers. This may be important where eye disease concerns exist,[23] such as age-related macular diseases (AMDs) that have been related to lutein consumption,[24] evidence of which is beyond the scope of the present study.

Mineral content

The iron content of TGLVs generally fell within values that have been reported in the literature.[18,25] Green leafy vegetables are generally poor sources of zinc and this is coupled with low bioavailability.[4,18,26] For proper absorption of zinc from foods with low bioavailability of the nutrient, animal source protein should be consumed.[27] The high potassium and low sodium content of the TGLVs is an important finding, given the role of potassium in human nutrition, which includes electrolyte balance, heart health and muscular function, among others.

Effect of boiling on vitamin C, carotenoid and mineral content of TGLVs

Boiling in water resulted in huge losses of vitamin C from 18.6% in *Basella alba* (Green stem) to 100% in *Crassocephalum crepidioides*. Blanching and cooking in water, similar to the domestic method, result in huge losses of vitamin C,[16,28] in agreement with our observations, given that vitamin C is a water-soluble vitamin that is easily affected by heat processing.[16] However, losses may be minimised if vegetables are boiled in smaller quantities of water[29] or steamed.[16,19] This is an important point because, in Nigeria, green leafy vegetables undergo preprocessing, which includes boiling in large quantities of water that are thereafter discarded; this is usually done to increase palatability or remove a bitter taste. Thereafter the vegetables are added to a sauce, usually a combination of tomatoes, pepper, onions and vegetable oil or palm oil, with or without melon seed paste.

For carotenoids, increased analytical values were obtained for some of the TGLVs: from 12% in *S. americanum* to 183% in *T. triangulare* (β-carotene) and 64–100% in *A. viridis* and *T. triangulare*, for lutein content, respectively. Carotenoid losses observed in some of the boiled leafy vegetables ranged from 1.3% in *S. macrocarpon* to 82% in *C. olitorious* (β-carotene) and 8% in *Celosia argentea* to 77% in *C. olitorious* (lutein). β-carotene and lutein losses were high at 92% and 93%, respectively, in dried *Adansonia digitata* after boiling. Surprisingly, *V. amygdalina,* which underwent squeeze washing (debittering) and boiling, lost 33% and 23% of β-carotene and lutein content, respectively. Domestic cooking methods like blanching, pressure cooking, steaming and microwaving have been reported to increase the extractability of carotenoid content up to 130% in green leafy vegetables.[16,22] Six TGLVs were observed to have increased carotenoid values after boiling. Loss of moisture and soluble solids, which leads to more carotenoids per unit weight of food, could also be attributed.[16] Carotenoids losses between 9% and 53% have equally been reported.[16,21]

Boiling considerably reduced the concentration of potassium in the vegetables to less than half of the concentration in the raw vegetables. Percentage loss ranged from 35% in *A. hybridus* to 72% in *C. olitorius* compared with uncultivated leafy vegetables' mean (%) loss, which ranged from 27% in *Talinum triangulare* to 55% in *Crassocephalum crepidioides*. Cultivated TGLVs were more prone to loss of minerals than the uncultivated leafy vegetables after boiling. This could imply that the minerals in the uncultivated leafy vegetables were more stable or resilient during boiling than in the cultivated species.

Conclusion

The study indicates that TGLVs vary widely in vitamin and mineral content of their fresh and boiled leaves. The TGLVs studied are rich in lutein content. The study also highlights the nutritional relevance of uncultivated TGLVs when compared with cultivated TGLVs; uncultivated and less utilised TGLVs are as nutrient-dense as the conventional and commonly consumed leafy vegetable species, especially in β-carotene and lutein. Boiling of the leafy vegetables in excess water, as is traditionally done, led to considerable losses of the micronutrients. Cooking of green leafy vegetables is one of the factors that could either enhance or reduce the amount of micronutrients present. Processing methods that optimise the retention of nutritional properties of TGLVs should be promoted.

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References

1. Smith FI, Eyzaguirre P. African leafy vegetables: their role in the World Health Organization's global fruit and vegetables initiative. 2007 [cited 2016 Jul 13]. Available from: https://tspace.library.utoronto.ca/handle/1807/55368.
2. Schönfeldt HC, Pretorius B. The nutrient content of five traditional South African dark green leafy vegetables—A preliminary study. J Food Comp Anal. 2011;24(8):1141–6.
3. Gupta S, Jyothi Lakshmi A, Manjunath MN, et al. Analysis of nutrient and antinutrient content of underutilized green leafy vegetables. LWT Food Sci Technol. 2005 Jun;38(4):339–45.
4. Icard-Vernière C, Olive F, Picq C, et al. Contribution of leafy vegetable sauces to dietary iron, zinc, vitamin a and energy requirements in

children and their mothers in Burkina Faso. Plant Foods Hum Nutr. 2015;70(1):63–70.
5. Uusiku NP, Oelofse A, Duodu KG, et al. Nutritional value of leafy vegetables of sub-Saharan Africa and their potential contribution to human health: a review. J Food Comp Anal. 2010;23(6):499–509.
6. Mbhenyane X. Indigenous foods and their contribution to nutrient requirements. S Afr J Clin Nutr. 2017;30(4):5–7.
7. Voster IH, van Rensburg Willem J, Van Zijl JJB, et al. The importance of traditional leafy vegetables in South Africa. 2007 [cited 2016 May 4]. Available from: https://tspace.library.utoronto.ca/handle/1807/55383.
8. Perry A, Rasmussen H, Johnson EJ. Xanthophyll (lutein, zeaxanthin) content in fruits, vegetables and corn and egg products. J Food Comp Anal. 2009;22(1):9–15.
9. Lane DJ, Richardson DR. The active role of vitamin C in mammalian iron metabolism: much more than just enhanced iron absorption!. Free Radic Biol Med. 2014;75:69–83.
10. Moeller SM, Parekh N, Tinker L, et al. Associations between intermediate age-related macular degeneration and lutein and zeaxanthin in the carotenoids in age-related eye disease study (careds): ancillary study of the women's health initiative. Arch Ophthalmol. 2006;124 (8):1151–62.
11. Padulosi S, Thompson J, Rudebjer P. Fighting poverty, hunger and malnutrition with neglected and underutilized species (NUS): needs, challenges and the way forward. Rome: Bioversity International; 2013; [cited 2016 May 4]. Available from: https://cgspace.cgiar.org/bitstream/handle/10568/68927/.
12. Grivetti LE, Ogle BM. Value of traditional foods in meeting macro- and micronutrient needs: the wild plant connection. Nutr Res Rev. 2000;13(1):31–46.
13. Burlingame B, Charrondiere R, Mouille B. Food composition is fundamental to the cross-cutting initiative on biodiversity for food and nutrition. J Food Comp Anal. 2009;22(5):361–5.
14. Ejoh SI, Samuel FO. Identification of traditional green leafy vegetables, benefits to consumers and level of utilisation in a rural farming community in southwest Nigeria: qualitative findings. West Afr J Food Nutr. 2016;13(1):10–23.
15. Stevens R, Buret M, Garchery C, et al. Technique for rapid, small-scale analysis of vitamin C levels in fruit and application to a tomato mutant collection. J Agr Food Chem. 2006;54(17):6159–65.
16. Bureau S, Mouhoubi S, Touloumet L, et al. Are folates, carotenoids and vitamin C affected by cooking? Four domestic procedures are compared on a large diversity of frozen vegetables. LWT-Food Sci Technol. 2015;64(2):735–41.
17. Delchier N, Reich M, Renard CMGC. Impact of cooking methods on folates, ascorbic acid and lutein in green beans (Phaseolus vulgaris) and spinach (Spinacea oleracea). LWT-Food Sci Technol. 2012;49 (2):197–201.
18. van Jaarsveld P, Faber M, van Heerden I, et al. Nutrient content of eight African leafy vegetables and their potential contribution to dietary reference intakes. J Food Comp Anal. 2014;33 (1):77–84.
19. Amusan EA, Ejoh SI, Akinyele IO. Effect of boiling and steaming methods on the ascorbic acid content of wild and cultivated indigenous green leafy vegetables found in Ibadan, Oyo State. Nigerian J Nutr Sci. 2015;36(2):59–63.
20. Lee SK, Kader AA. Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biol Technol. 2000;20(3):207–20.
21. Djuikwo VND, Ejoh RA, Gouado I, et al. Determination of major carotenoids in processed tropical leafy vegetables indigenous to Africa. Food Nutr Sci. 2011;2(08):793.
22. Okpalamma F, Ojimelukwe P, Mazi EA. Post-harvest storage and processing changes in carotenoids and micronutrients in Fluted Pumpkin (Telferia occidentalis Hook F.). IOSR-J Agric Vet Sci. 2013;6 (4):34–9.
23. Ojofeitimi EO, Adelekan DA, Adeoye A, et al. Dietary and lifestyle patterns in the aetiology of cataracts in Nigerian patients. Nutr Health. 1999;13(2):61–8.
24. Roberts RL, Green J, Lewis B. Lutein and zeaxanthin in eye and skin health. Clin Dermatol. 2009;27(2):195–201.
25. Stadlmayr B, Charrondiere UR, Enujiugha VN, et al. West African food composition table. Rome: Food and Agriculture Organization of the United Nations; 2012.
26. Hait M, Patel A, Bai S. Micronutrient levels in selected leafy vegetables obtained from local market of Bilaspur, C.G., India. J Sci Letters. 2016;11:102–8. 23.
27. World Health Organisation. Vitamin and mineral requirements in human nutrition: report of a joint FAO/WHO expert consultation, Bangkok, Thailand, 21–30 September 1998. World Health Organization; 2004. [cited 2017 Jan 24]. http://apps.who.int/iris/handle/10665/42716.
28. Han S, Xu B. Bioactive components of leafy vegetable edible Amaranth (*Amaranthus mangostanus* L.) as affected by home cooking manners. Am J Food Sci Technol. 2014;2(4):122–7.
29. Sreeramulu N, Ndossi GD, Mtotomwema K. Effect of cooking on the nutritive value of common food plants of Tanzania: part 1—Vitamin C in some of the wild green leafy vegetables. Food Chem. 1983;10 (3):205–10.

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