Journal of Horticulture
ISSN: 2376-0354
OPEN ACCESS Freely available online
Research Article

Comparative Evaluation of Domestic Processing and Storage Losses of Micronutrients and the Health Benefits of Five Underutilized Green Leafy Vegetables (Glvs)

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ABSTRACT

Talinum triangulare, *Amaranthus hybridus*, *Gnetum africanum*, *Pterocarpus mildbraedii* and *Telfairia occidentalis* are underutilized Green Leafy Vegetables (GLVs). Storage and cooking losses undermine their nutritional and health benefits. *T. triangulare* has strong anti-oxidant properties; *A. hybridus* is good for managing blood pressure; *T. occidentalis* possess hypolipidaemic and anti-hyperglycaemic effects; *G. africanum* possess anti-inflammatory and anti-microbial properties; *P. mildbraedii* is an anti-microbial agent and is useful for the management of respiratory disorders. This review presents a comparative evaluation of the effects of moist heat treatment (boiling for 5 min at 98°C) and storage (at 29 ± 2°C), on the nutrients found in these vegetables which have health benefits for humans. Moist heat treatment reduces the vitamin content of the GLVs while the mineral content is more stable to cooking and storage conditions. Cooking reduces minerals in *T. occidentalis* (for zinc, iron, magnesium, and calcium) and iron for *T. triangulare*. Cooking losses were high for niacin in *P. mildbraedii*; loss of riboflavin was highest in *A. hybridus* while the loss of vitamin C was highest in *T. triangulare*. Nutrient loses through other improved processing methods such as sautéing, microwave heating, freezing, irradiation should be established. Processing methods that will reduce the loss of water-soluble vitamins and iron should be investigated. Additional health benefits of each vegetable should be scientifically established.

Keywords: Underutilized green leafy vegetables; *Talinum triangulare*; *Amaranthus hybridus*; *Gnetum africanum*; *Pterocarpus mildbraedii*; *Telfairia occidentalis*; Storage and cooking losses; Health benefits; Micronutrients

INTRODUCTION

Over 7000 plant species are used for food worldwide and they play very important roles in nutrition, food security, income generation and food culture. Dark green leafy vegetables are considered an integral part of the underutilized food crops even though their intake will contribute significantly to sustainable food security [1-6]. Green leafy vegetables are valued for their vitamin, mineral and dietary fibre contents. They are generally low in calories, fat, proteins, and carbohydrates (although there are few exceptions). They are also rich in carotenoids (non-enzymic antioxidants) essential amino acids, and phenolic compounds. *Gnetum africanum* (Eru) is mainly collected from the wild [7] and could be propagated using the seeds [8,9]. The leaves are difficult to chew and slightly bitter [10]. It may be mixed with *T. occidentalis* and *T. triangulare* leaves to make delicious and health boosting soup in the Nigerian cuisine [11,12]. *Pterocarpus mildbraedii* leaves may be collected from the wild and are sometimes domesticated. *Telfairia occidentalis* is mainly cultivated. *Talinum traingluare* [13] and *Amaranthus hybridus* may be cultivated or found in the wild.

In addition to giving sensory appeal to foods, green leafy vegetables are "colours of good health" contributing micronutrients for metabolic reactions of the body and phytonutrients that possess additional heal benefits [14] yet many GLVs are underutilized [15-17]. This review presents scientifically validated research information on five underutilized GLVs and summarizes the effects of the most common processing and storage methods on their nutrient content as shown in Figure 1.

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Received: 19-Jun-2023, Manuscript No. HORTICULTURE-23-25210; **Editor assigned:** 22-Jun-2023, PreQC No. HORTICULTURE-23-25210 (PQ); **Reviewed:** 07-Jul-2023, QC No. HORTICULTURE-23-25210; **Revised:** 14-Jul-2023, Manuscript No. HORTICULTURE-23-25210 (R); **Published:** 21-Jul-2023, DOI: 10.35248/2376-354.23.10.330

Citation: Ojimelukwe PC, Okpalanma F (2023) Comparative Evaluation of Domestic Processing and Storage Losses of Micronutrients and the Health Benefits of Five Underutilized Green Leafy Vegetables (Glvs). J Hortic. 10:330.

Figure 1: The underutilized green leafy vegetables under review.

MATERIALS AND METHODS

Nutrients and health benefits of green leafy vegetables

Concise summary of the major nutrients and health benefits of *Amaranthus hybridus*, *Talinum triangulare*, *Telfairia occidentalis*, *Gnetum africanum* and *Pterocarpus mildbraedii* as shown in Table 1.

Amaranthus hybridus in a rich source of β-carotene, iron, calcium, vitamin C and folic acid [18]. *Talinum triangulare* is a rich source of Vitamin C, Vitamin E, Omega-3 fatty acids, calcium, magnesium, soluble fibres (pectin), potassium, β-carotene, proteins, and dietary fibre [19]. *Telfairia occidentalis* contains significant amounts of folic acid, calcium, zinc, potassium, cobalt, copper, iron, vitamins A, C, and K [13]. It also contains significant amounts of protein and fat [20]. *Gnetum africanum* is a good source of riboflavin, niacin, and tocopherol [21]. *Pterocarpus mildbraedii* is a good source of zinc, calcium, iron, potassium, vitamins A, B, and C [22]. *Amaranthus hybridus* helps reduce weight and ward off heart disease as it lowers blood cholesterol. *Talinum triangulare* aids digestion of food preventing gastrointestinal disorders. *Telfairia occidentalis* possess anti-diabetic activities, regulating the glucose level of diabetic patients due to the ethyl acetate content of the leaf. *Gnetum africanum* is a good source of protein that contains both essential and non-essential amino acids. It is used to treat enlarged spleen, control excess urination and constipation. *Pterocarpus mildbraedii* leaves possess antioxidant, antibacterial, antispasmodic, and diuretic properties.

Table 1: The major nutrients and health benefits five green leafy vegetables under review

Green Leafy Vegetable	Common names	Major components	Health benefits	References
Amaranthus hybridus Family: Amaranthaceae	African Spinach, Amaranth; bushgreen	phytonutrients; soluble and insoluble dietary fibre; protein (12-17%); carotenoids, chlorophylls, anthocyanins, betalains, betacyanins, flavonoids, phenolic acids, proteins (rich in the essential amino acids methionine and lysine), and minerals	Good for managing weight and high blood pressure; strengthens the immune system; treats anaemia	[23,24]
Talinum triangulare Family: Portulaceae	Water leaf; spinach	Rich in carotenoids (lutein and zeaxanthin); low in calories and high in fibre;	Boosts the immune cells of the eyes, macular degeneration of the eye and cataract; controls blood pressure; weight; cancer; cholesterol levels; diverticulosis, heart diseases, improves memory, perception, and cognitive abilities; sensitizes the neurons in the cerebrum; has anti-fungal; anti-bacterial; antioxidant and anti-inflammatory properties	[5,25,26]
Telfairia occidentalis Tribe: Jolifficeae; Subfamily: Curcubitae			Possess antioxidant; anti-hyperglycaemic and hepato-protective properties; used to manage anaemia, diabetes, gastrointestinal disorders; sustain flow of breast milk during lactation; an antioxidant	[15, 27-29]
Gnetum africanum Family: Gnetaceae	Eru/Okazi/Ukazi/ Afang/Okok	Rich in protein (20.12%), fibre, iron, flavone-glycosides, and stilbenes,	Helps to keep the heart healthy, controls excess urination treats boils, wart and enlarged spleen; improves digestion.	[5,7,10,21]
Pterocarpus mildbraedii Family Papilionaceae	White camp wood	Rich in ascorbic acid and carotenoids	Used in traditional folklore for the treatment of fever, headaches, convulsion, pains, and respiratory disorders and as an antimicrobial.	[3,30]

The proximate composition of the underutilized green leafy vegetables as shown in Table 2. Values for *Amaranthus hybridus* (34.8%) and *Telfairia occidentalis* (35.4%) were for protein concentrates while values for *Talinum triangulare*, *Gnetum africanum* and *Pterocarpus mildbraedii* were for the whole leaves. Idris [31] had observed 24% protein in *T.occidentalis* leaves, while Akubugwo, et al. [18] obtained 17.92% protein for *A. hybridus* leaves. In terms of protein content, *Talinum triangulare*, *Pterocarpus mildbraedii*, and *Telfairia occidentalis* have the highest values. Efforts of researchers to investigate the protein concentrate have been documented. Total ash content of *P. mildbraedii* is quite high (20.63 %) and is indicative of high amounts of mineral elements.

The vitamin content of selected underutilized green leafy vegetables as shown in Table 3. *Amaranthus hybridus* contained significantly high amounts of ascorbic acid and vitamin K. *Telfairia occidentalis* was found to be rich in riboflavin, thiamine, and niacin.

The mineral content of the five underutilized green leafy vegetables under study as shown in Table 4. *P. mildbraedii* is a very rich source of potassium, calcium, magnesium, sodium and iron (a reflection of its high total ash content). Composition also depends on variety and environmental factors [34,36].

The essential amino acid composition of the underutilized green leafy vegetables in comparison with FAO (Food and Agriculture Organization) standards as shown in Table 5. Lysine contents of all the underutilized GLVs were lower than the FAO standard values. Phenylalanine and arginine contents of all the GLVs were higher than the FAO standard vales. *A. hybridus* had higher amounts of histidine, and leucine than the FAO standard. The leucine content of *P. mildbraedii* isoleucine and threonine contents of *G. africanum* and valine content of *T. triangulare* was higher than the FAO standard values. *T. triangulare* had higher amounts of valine than the FAO standard value while *G. africanum* had higher amounts of threonine than the FAO standard. *A. hybridus* had the highest essential amino acid composition while *T. occidentalis* had the least when compared with the FAO standard. *Amaranthus hybridus*, *Talinum triangulare*, *Gnetum africanum* and *Pterocarpus mildbraedii* are good sources of essential amino acids.

Table 2: Proximate composition of the underutilized green leafy vegetables [13,32,33]

Proximate composition (g/100 g) Parameter	*Amaranthus hybridus* (Leaf protein concentrate)	*Telfairia occidentalis* (Leaf protein concentrate)	*Talinum triangulare*	*Gnetum africanum*	*Pterocarpus mildbraedii*
Moisture	7.6 ± 0.6	6.6 ± 0.6	10.1	29.11 ± 0.57	13.3 ± 0.01
Protein	34.8 ± 1.1	35.4 ± 1.2	28.22	16.47 ± 0.02	26.5 ± 0.45
Crude fat	9.6 ± 0.02	10.7 ± 0.6	7.45	6.28 ± 0.03	8.66 ± 0.01
Total ash	17.2 ± 0.01	12.3 ± 0.01	26	8.25 ± 0.16	20.63 ± 0.03
Crude fibre	1.7 ± 0.15	1.6 ± 0.08	11.45	28.05 ± 0.81	12.33 ± 0.02
Carbohydrate	29.0 ± 0.4	33.4 ± 2.4	16.78	41.04 ± 0.56	18.61 ± 0.44

Table 3: Selected vitamins of underutilized green leafy vegetables (content per 100g edible portion (fresh weight basis)) [5,6,34,35]

Vitamin	*Amaranthus hybridus*	*Telfairia occidentalis*	*Talinum triangulare*	*Gnetum africanum*	*Pterocarpus mildbraedii*
Ascorbic acid (mg)	154.30 ± 0.14	10.33%	48.95 ± 0.30	50.87	20.06 ± 0.01
Riboflavin (mg)	1.84 ± 0.02	13.25%	0.17 ± 0.01	4.24	0.46 ± 0.01
Thiamin(mg)	0.14 ± 0.01	9.78%	0.03 ± 0.00	2.75	0.25 ± 0.01
Niacin (mg)	3.69 ± 0.01	3.46%	0.45 ± 0.02	1.54	1.55 ± 0.01
Vitamin K (µg)	122.21	1.46%	-	-	18.71 ± 0.01

Table 4: Mineral composition of the underutilized green leafy vegetables (mg/100 g) (mg/kg) [5,6,31,32,35]

Mineral element	*Amaranthus hybridus*	*Telfairia occidentalis*	*Talinum triangulare*	*Gnetum africanum*	*Pterocarpus mildbraedii*
Na	32.3	3120.00%	3.72	0.16 ± 0.0	603.00 ± 3.01
K	11.6	2040.00%	2.6	1.90 ± 0.05	1048.55 ± 4.17
Mg	11.6	1430.00%	2.24	0.28 ± 0.03	778.00 ± 2.21
Ca	50.2	51.3	0.83	0.88 ± 0.05	1283.00 ± 5.15
P	-	-	0.9	0.18 ± 0.00	1002.10 ± 3.34
Zn	7.5	11.6	0.08	-	25.10 ± 1.02
Fe	10.4	6.4	0.4	0.59 ± 0.004	146.45 ± 2.22
Cu	-	-	0.02	-	9.55 ± 1.76
Mn	0.08	0.1	0.01	-	4.00 ± 0.12

Table 5: Essential amino acid composition of underutilized green leafy vegetables.

Essential amino acids composition (mg/g)	*Amaranthus hybridus* [33]	*Telfairia occidentalis* [33]	*Talinum triangulare* [44]	*Gnetum africanum* [10]	*Pterocarpus mildbraedii* [45]	FAO standard, 2013
Lys	39.2	26.5	16.56	40.07 ± 3.94	32.4	57
His	33.2	11.2	12.56	16.33 ± 0.24	19.2	20
Arg	59.5	58.3	37.25	25.86 ± 1.76	42.2	24
Thr	27.6	17.2	25.62	55.61 ± 0.06	28	31
Val	39	24.8	88.75	32.78 ± 3.21	42.2	43
Met	34.1	10	13.75	2.4	8.3	
Ile	47.1	22.1	34.43	42.50 ± 4.06	35.5	32
Leu	75.4	53.9	5.6.37	45.71 ± 3.15	81	66
Phe	38.4	32.2	38.81	28.84 ± 3.52	40.3	27.92 ± 4.01

RESULTS

Cooking losses for vitamins and minerals in Green Leafy Vegetables (GLVs)

The vitamin losses for the five green leafy vegetables during domestic processing cooked for 5min in boiling water (1:5 ratio: vegetable: water) as shown in Figure 2a.

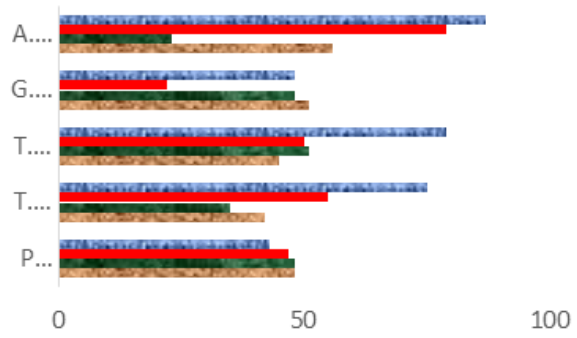

Figure 2a: Percentage cooking losses in vitamins of underutilized green leafy vegetables. **Note:** (■) *A. hybridus*; (■) *G. africanum*; (■) *T. triangulare*; (■) *P. mildbraedii*

The cooking losses for vitamins in the five GLVs. For niacin (Vitamin B3) the cooking loss was highest for *P. mildbraedii* and lowest for *A. hybridus*. Thiamin loss was remarkably high for *G. africanum* and relatively low for *A. hybridus*. The cooking loss was highest for vitamin B2 in *A. hybridus* and lowest for *G. africanum* and *P. mildbraedii*. Loss of vitamin C was highest in *Talinum triangulare* and lowest in *A. hybridus*. Boiling in water may result to up to 100% loss of vitamin C [35] in some vegetables.

The cooking loss for minerals cooked for 5 min in boiling water (1:5 ratio: vegetable: water) in the five GLVs as shown in Figure 2b. Loss of zinc during cooking was highest for *T. occidentalis* and lowest for *A. hybridus*, *T. triangulare* and *G. africanum*. Loss of iron was highest for *T. occidentalis* and *T. triangulare* and lowest for *G. africanum* and *A. hybridus*. The cooking loss for magnesium was highest for *T. occidentalis* and lowest for *P. mildbraedii*. Loss of calcium was highest for *T. occidentalis* and lowest for *P. mildbraedii*. The loss of potassium was highest for *T. occidentalis* and lowest for *G. africanum*. Both boiling and microwave cooking have been observed to cause drastic micronutrient losses in green leafy vegetables [37].

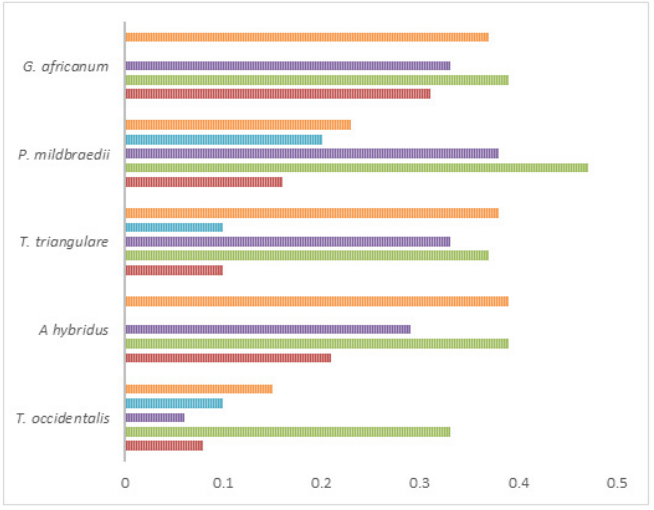

Figure 2b: Loss of minerals in green leafy vegetables during domestic processing. **Note:** (■) *G. africanum*; (■) *P. mildbraedii*; (■) *T. triangulare*; (■) *A. hybridus*; (■) *T. occidentalis*

Storage losses for vitamins and minerals in green leafy vegetables

The storage loss of vitamins in the GLVs (wrapped in paper and stored in the dark for 5 days at room temperature (28 ± 2°C) as shown in Figure 2c. The loss of vitamin K during storage was highest for *G. africanum* and lowest for *P. mildbraedii*. The loss of niacin (vitamin B3) was highest *G. africanum* and lowest in T. traingulare. The loss of thiamine (vitamin B1) was highest in *G. africanum* and lowest in *T. occidentalis*. Storage loss of riboflavin (vitamin B2) was most marked in *T. triangulare* and least in *T. occidentalis* and *A. hybridus*. Loss of vitamin C during storage was highest in *P. mildbraedii* and lowest in *A. hybridus*.

The mineral loses during the storage of the green leafy vegetables. The loss of minerals in the GLVs due to storage (wrapped in a newspaper and stored in the dark for 5 days at room temperature (28 ± 2°C) as shown in Figure 2d. Loss of zinc during storage was highest for *G. africanum* and *A. hybridus* and was lowest in *T. triangulare*. Loss of iron during storage was highest for *P. mildbraedii*

and *T. occidentalis*. There was no loss of iron in *A. hybridus* because of storage and loss of iron in *T. triangulare* was relatively low. There was no loss of magnesium in *P. mildbraedii* and *A. hybridus* because of storage. Loss of magnesium in *G. africanum* was relatively low. Loss of calcium was highest in *T. occidentalis* and lowest in *T. triangulare*. Loss of potassium was highest in *P. mildbraedii*, *T. triangulare* and *T. occidentalis* but lowest in *G. africanum*.

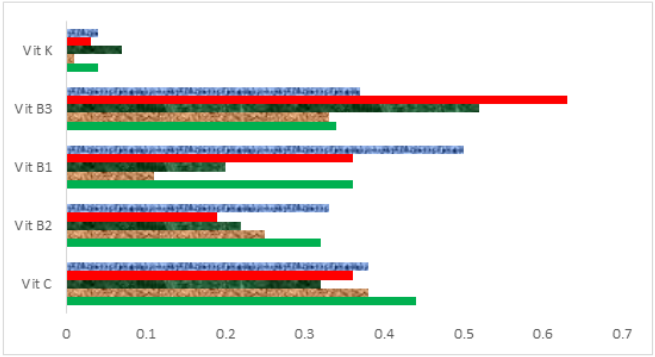

Figure 2c: Storage losses of vitamins in green leafy vegetables. **Note:** (■) Vit k; (■) Vit B3; (■) Vit B1; (■) Vit B2; (■) Vit C

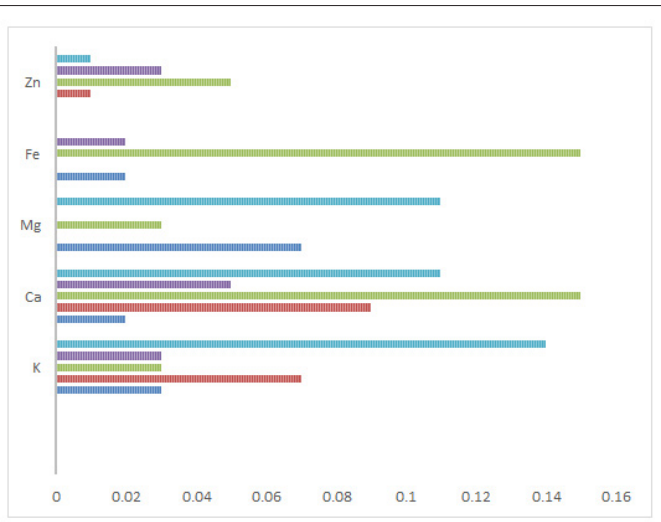

Figure 2d: Storage losses of minerals in green leafy vegetables. **Note:** (■) *G. africanum*; (■) *P. mildbraedii*; (■) *T. triangulare*; (■) *A. hybridus*; (■) *T. occidentalis*

DISCUSSION

The total carotene contents of the green leafy vegetables. Except for *Amaranthus hybridus* (where the raw leaves contained more carotene than the stored leaf), cooking and storage led to an increase in the carotene content of vegetables as shown in Figure 3. The increase due to cooking was higher than the increase due to storage. In addition to vision, vitamin A is involved in normal growth and development, immunity, maintenance of the epithelial cells and reproduction. Vitamin A deficiency is a public health problem in some developing countries where available fruits and vegetables can effectively be used to meet the vitamin A needs. Carotenoids are effective for the management of obesity and diabetes [38]. Carotenoids are accessory pigments to chlorophyll and are antioxidants [1].

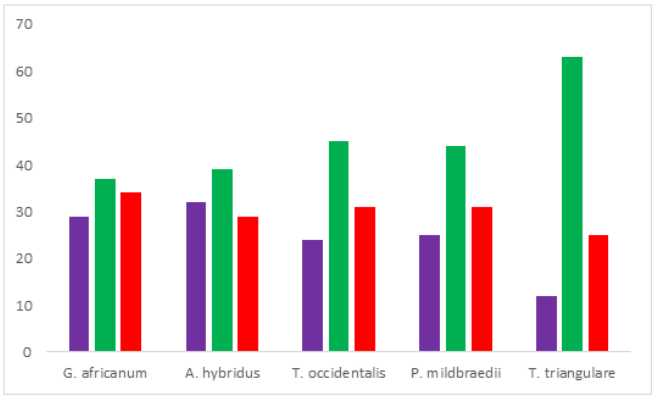

Figure 3: Total carotene content of green leafy vegetables. **Note:** (■) Raw; (■) Cooked; (■) Stored

The American dietary guidelines recommend five servings of vegetables per day for an intake of 2000 calories [39-42] one of which should be green leafy vegetables diversified for optimal nutritional benefits [43].

CONCLUSION

The major nutrients from five underutilized green leafy vegetables are reported; nutrient losses during moist heat treatment and storage were compared and the best sources of nutrients identified. *Gnetum africanum*, *Telfairia occidentalis* and *Amaranthus hybridus* are protein rich nutritious leafy vegetables. *Amaranthus hybridus*, *Pterocarpus mildbraedii* and *Telfairia occidentalis* contain relatively high amounts of vitamins and minerals and are blood and immune system boosters. Mineral elements in *Amaranthus hybridus* are retained well comparatively during storage. Storage by wrapping the green leafy vegetables in paper and storing in the dark at 30 ± 2°C minimizes the loss of nutrients (especially the mineral elements). Short term storage does not result in the loss of Fe and magnesium in *A. hybridus*.

AUTHOR CONTRIBUTION STATEMENT

Philippa C Ojimelukwe: Writing-original draft and the final paper; data curation. Felix N Okpalanma: Literature search and initial collation.

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CONFLICT OF INTEREST STATEMENT

The Authors declare that there is no conflict of interest.

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