

Comparative evaluation of domestic processing and storage losses of micronutrients, and the health benefits of five underutilized Green leafy vegetables

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Systematic Review

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Abstract

Talinum triangulare, *Amaranthus hybridus*, *Gnetum africanum*, *Pterocarpus mildbraedii* and *Telferia 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 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 (Okpalandma et al., 2013; 2016; Okpalandma and Ojimelukwe, 2017; 2018a; 2018b). 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 high in *A. hybridus* while the loss of vitamin C was high in *T. triangulare*. Nutrient losses 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 established.

Introduction

Over 7 000 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 (Okpalandma et al., 2013). 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 anti-oxidants) essential amino acids, and phenolic compounds. *Gnetum africanum* (Eru) is mainly collected from the wild (Shiembo, 1997). The leaves are difficult to chew and slightly bitter (Ali et al., 2011). It may be mixed with *T.occidentalis* and *T. triangulare* leaves to make delicious and health boosting soup in the Nigerian cuisine. *Pterocarpus mildbraedii* leaves may be collected from the wild and are sometimes domesticated. *Telferia occidentalis* is mainly cultivated. *Talinum triangulare* and *Amaranthus hybridus* may be cultivated or found in the wild.

Figure 1 shows the five green leafy vegetables under review. 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 health benefits yet many GLVs are underutilized (Bailderman et al., 2016). 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.

Nutrients And Health Benefits Of Green Leafy Vegetables

Table 1 is a concise summary of the major nutrients and health benefits of *Amaranthus hybridus*, *Talinum triangulare*, *Telferia occidentalis*, *Gnetum africanum* and *Pterocarpus mildbraedii*.

Amaranthus hybridus is a rich source of β-carotene, iron, calcium, vitamin C and folic acid (Akubugwo et al., 2007). *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 (Ajah et al., 2010). *Telferia occidentalis* contains significant amounts of folic acid, calcium, zinc, potassium, cobalt, copper, iron, vitamins A, C, and K (Ajibade et al., 2006). It also contains significant amounts of protein and fat (Okonwu et al., 2018). *Gnetum africanum* is a good source of riboflavin, niacin and tocopherol (Eleazu and Eleazu, 2013). *Pterocarpus mildbraedii* is a good source of zinc, calcium, iron, potassium, vitamins A, B, and C (Koko and Yako, 2018). *Amaranthus hybridus* helps reduce weight and ward off heart disease as it lowers blood cholesterol. *Talinum triangulare* aids digestion of food preventing gastrointestinal disorders. *Telferia 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.

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) is shown in Fig 2a

Fig. 2a. Percentage cooking losses in vitamins of Underutilized Green leafy vegetables

Fig 2a shows 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 (Ejoh *et al.*, 2019) in some vegetables.

The loss in minerals during domestic processing of the green leafy vegetables is shown in Figure 2b

Fig. 2b. Loss of minerals in green leafy vegetables during domestic processing

Fig 2b shows the cooking loss for minerals (cooked for 5min in boiling water (1:5 ratio: vegetable: water) in the five GLVs. 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 (Wireko-Manu *et al.*, 2020).

Storage Losses For Vitamins And Minerals In Green Leafy Vegetables

Figure 2c shows the losses in vitamins during storage of five green leafy vegetables

Fig. 2c. Storage losses of vitamins in green leafy vegetables

Fig 2c shows the storage loss of vitamins in the GLVs (wrapped in a newspaper and stored in the dark for 5 days at room temperature (28 ± 2°C). 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. triangulare*. 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*.

Figure 2d shows the mineral losses during the storage of the green leafy vegetables.

Fig. 2d. Storage losses of minerals in green leafy vegetables.

Fig 2d shows 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 ($28 \pm 2^{\circ}\text{C}$)). 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* as a result of storage and loss of iron in *T. triangulare* was relatively low. There was no loss of magnesium in *P. mildbraedii* and *A. hybridus* as a result 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*.

Fig. 3. Total carotene content of Green Leafy vegetables

Fig 3 shows 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. 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 (WHO, 2009). Carotenoids are effective for the management of obesity and diabetes (Lee *et al.*, 2019). Carotenoids are accessory pigments to chlorophyll and are antioxidants (Omayma, *et al.*, 2013).

The American dietary guidelines recommends five servings of vegetables per day for an intake of 2000 calories (FAO, 2009; HHS/USDA, 2015; Moll and Davis, 2017); one of which should be green leafy vegetables diversified for optimal nutritional benefits (National Research Council, 1989).

Conclusion

The major nutrients from five underutilized green leafy vegetables; nutrient losses during moist heat treatment and storage were compared and the best sources of nutrients identified. *Gnetum africanum* and *Amaranthus hybridus* are protein rich nutritious leafy vegetables. *Amaranthus hybridus* 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. This review scientifically validates this ethnobotanical practice. Storage by wrapping the green leafy vegetables in paper and storing in the dark at $30 \pm 2^{\circ}\text{C}$, 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*.

Declarations

Author contribution statement

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

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Tables

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

Green Leafy Vegetable	Common names	Major components	Health benefits	References
<i>Amaranthus hybridus</i> . family <i>Amaranthaceae</i>	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	Girija et al., 2011; Jimenez et al., 2017.
<i>Talinum triangulare</i> Family Portulacaceae.	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	Shakuntala and Shadaksharaswamy, 1985; Okpalanma and Ojimekwe, 2018a; Afolabi and Oloyede, 2014.
<i>Telfairia occidentalis</i> Tribe: Jolifficeae; subfamily: Curcubitae			Possess antioxidant; anti-hyperglycaemic and hepatoprotective properties; used to manage anaemia, diabetes, gastrointestinal disorders; sustain flow of breast-milk during lactation; an antioxidant	Adaramonye et al., 2007; Alada, 2000; Kayode et al., 2009; Oboh et al., 2006
<i>Gnetum africanum</i> Family <i>Gnetaceae</i>	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.	Okpalanma and Ojimekwe, 2018a; Ali et al., 2011); Shiemo, 1997; Ogbonnaya and Chinedum, 2013.
<i>Pterocarpus mildbreadii</i> ;	White camp wood	Rich in ascorbic acid and carotenoids	Used in traditional	Okpalanma et al., 2016; Bosch, 2004.

Proximate composition of the underutilized green leafy vegetables

Proximate composition (g/100 g) Parameter	<i>Amaranthus hybridus</i> (Leaf protein concentrate)	<i>Telfairia occidentalis</i> (Leaf protein concentrate)	<i>Talinum triangulare</i>	<i>Gnetum africanum</i>	<i>Pterocarpus mildbraedii</i> (Dike, 2010)
Moisture	7.6 ± 0.6	6.6 ± 0.6	10.1	29.11 ± 0.57 ^a	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 ^b	8.66±0.01
Total ash	17.2 ± 0.01	12.3 ± 0.01	26	8.25 ± 0.16 ^a	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

Selected vitamins of underutilized green leafy vegetables (content per 100g edible portion (fresh weight basis)

Vitamin	<i>Amaranthus hybridus</i>	<i>Telfairia occidentalis</i>	<i>Talinum triangulare</i>	<i>Gnetum africanum</i>	<i>Pterocarpus mildbraedii</i>
Ascorbic acid (mg)	154.30 _b ±0.14	10.33%),	48.95 ± 0.30	50.87	20.06±0.01
Riboflavin (mg)	1.84 _b ±0.02	13.25%),	0.17 ± 0.01	4.24	0.46 0.01
Thiamin(mg)	0.14 _b ±0.01	9.78%),	0.03 ± 0.00	2.75	0.25 0.01
Niacin (mg)	3.69 _b ±0.01	3.46%),	0.45 ± 0.02	1.54	1.55 0.01
Vitamin K (µg)	122 _a .21	1.46%),			18.71 0.01

Mineral composition of the underutilized green leafy vegetables (mg/100 g) (mg/kg)

Mineral element	<i>Amaranthus hybridus</i>	<i>Telfairia occidentalis</i>	<i>Talinum triangulare</i>	<i>Gnetum africanum</i>	<i>Pterocarpus mildbraedii</i>
Na	32.3	31.2	3.72	0.16 ± 0.0 ^a	603.00 ± 3.01
K	11.6	20.4	2.60	1.90 ± 0.05	1048.55 ± 4.17
Mg	11.6	14.3	2.24	0.28 ± 0.03	778.00 ± 2.21
Ca	50.2	51.3	0.83	0.88 ± 0.05 ^a	1283.00 ± 5.15
P			0.90	0.18 ± 0.00	1002.10 ± 3.34
Na					
Zn	7.5	11.6	0.08		25.10 ± 1.02
Fe	10.4	6.4	0.40	0.59±0.004 ^a	146.45 ± 2.22
Cu			0.02		9.55 ± 1.76
Mn	0.08	0.1	0.01		4.00 ± 0.12

Composition also depends on variety and environmental factors (Eyo et al., Isong et al., Udosen and Ukpanah)

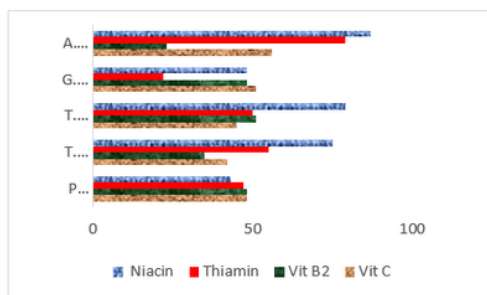
Essential amino acids composition (mg/g)	<i>A. hybridus</i>	<i>T. occidentalis</i>	<i>Talinum triangulare</i> (Ogunbenle et al., 2018)	<i>Gnetum africanum</i>	<i>Pterocarpus mildbraedii</i>	FAO standard, 2013
Lys	39.2	26.5	16.56	40.07±3.94	32.40	57
His	33.2	11.2	12.56	16.33±0.24	19.20	20
Arg	59.5	58.3	37.25	25.86±1.76	42.20	24
Thr	27.6	17.2	25.62	55.61±0.06	28.00	31
Val	39.0	24.8	88.75	32.78±3.21	42.20	43
Met	34.1	10.0	13.75	2.4	8.30	
Ile	47.1	22.1	34.43	42.50±4.06	35.50	32
Leu	75.4	53.9	5.6.37	45.71±3.15a	81.00	66
Phe	38.4	32.2	38.81	28.84±3.52	40.30	27.92±4.01a

Figures

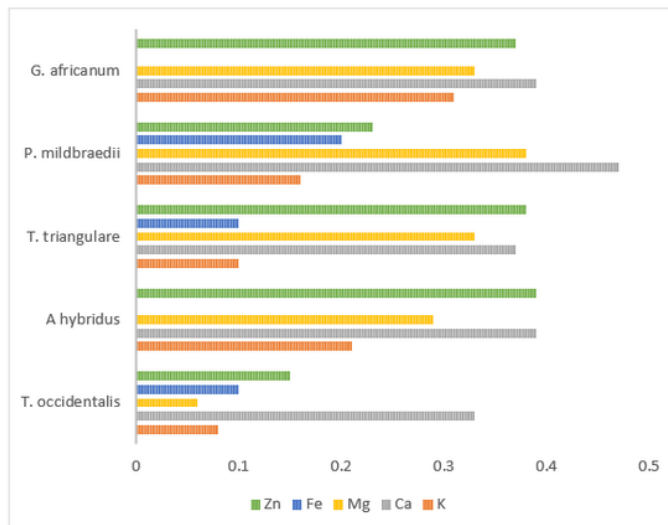


Figure 1

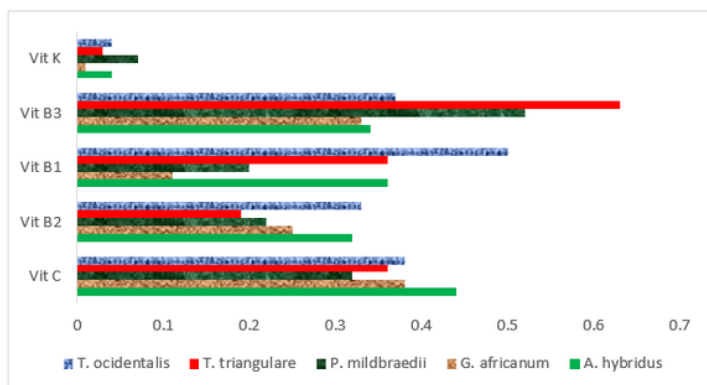
The underutilized green leafy vegetables under review



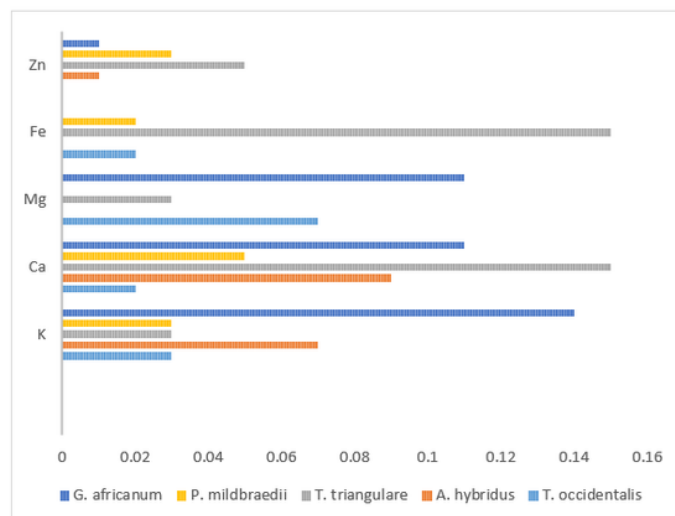
A



B



C



D

Figure 2

a. Percentage cooking losses in vitamins of Underutilized Green leafy vegetables

b. Loss of minerals in green leafy vegetables during domestic processing

c. Storage losses of vitamins in green leafy vegetables

d. Storage losses of minerals in green leafy vegetables

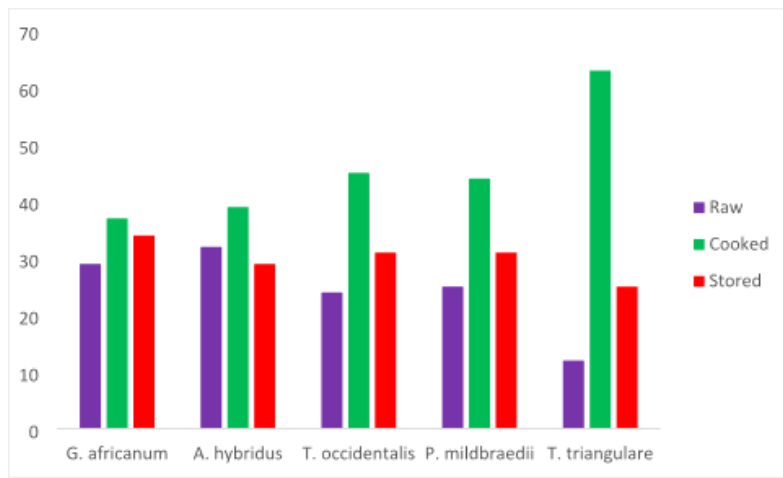


Figure 3

Total carotene content of Green Leafy vegetables