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Vitamins and phytochemical contents in four leafy vegetables subjected to different processing methods

Chinyere, G. C.* and Obasi, N. A.

Department of Biochemistry, Abia State University, Uturu, Nigeria.

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Vitamin and phytochemical contents of the leaves of *Vernonia amygdalina*, *Gnetum africanum*, *Gongronema latifolium* and *Ocimum gratissimum* subjected to different processing methods were investigated. Processing treatments employed include fresh milling, sun drying, oven drying, steaming and a combination of these. The vitamins evaluated include vitamins A, B_1, B_2, B_3, B_6 and E while the phytochemicals were alkaloids, saponins, tannins, phenols, hydrocyanic acid and phytic acid. The results indicated high levels of vitamins and phytochemicals in the leaves. The different processing methods produced diverse effects on the vitamin and phytochemical contents of the leaves. In all the vegetables tested, fresh milling followed by sun drying were the most effective methods of retaining vitamins and phytochemicals, while steaming in combination with oven drying reduced most of the vitamins and phytochemicals. Other treatments caused varying degrees of significant losses of vitamins and phytochemicals at P = 0.05 in all the vegetables tested. To ensure safety and wholesomeness in the use of these leaves, processing methods leading to the retention of maximum nutrients and loss of maximum anti-nutrients should be encouraged to achieve the desired objective.

Key words: *Vernonia amygdalina*, *Gnetum africanum*, *Gongronema latifolium*, *Ocimun gratissimum*, processing, vitamins, phytochemicals.

INTRODUCTION

The role of plants and vegetables in the maintenance of health and disease prevention cannot be overemphasized (Thompson, 1994; Morrison and Hark, 1999; Matasyol et al., 2007). This explains the recent increase in the dietetic and medicinal uses of plants and vege-tables in rural and urban areas. Plants and vegetables are sources of essential nutrients and non-nutritive chemicals (phytochemicals) that have been linked to their numerous roles. This evidence was provided by Okwu (2001; 2004) and Ojiako and Nwanjo (2006) amongst other authors that have evaluated and reported the compositional qualities and functional properties of various plants and vegetables.

Vegetables are dietary sources of vitamins and phyto-chemicals which are essential for growth and metabolism as well as disease prevention (Okafor, 1983; Shills and Young, 1992). In Nigeria and other tropical parts of Africa, *Vernonia amygdalina*, *Gnetum africanum* *Gongronema latifolium* and *Ocimum gratissimum* are among the commonly used vegetables. Their uses range from dietetics such as in soups, porridges, salads, etc to medicinal applications such as concoctions and production of useful drugs (Davidson et al., 1975; FAO, 1986).

*Corresponding author. E-mail: gcchinyere@yahoo.com.

Vegetables undergo post harvest treatments such as processing in order to extend their shelf life, preserve them as well as to ensure safety and wholesomeness. However, such treatments have been reported (Ramberg and McAnalley, 2002; Morris et al., 2004) to cause changes in their nutritive and non-nutritive chemical constituents leading to losses. To minimize or completely avoid these losses therefore demands knowledge in the application of processing methods that will achieve the desired effects. Thus, this study is aimed at investigating the levels of vitamins and phytochemicals in four selected leafy vegetables: subjected to different processing methods in order to recommend the best processing option.

MATERIALS AND METHODS

Sample collection

The leaves of the four vegetable plants analyzed; *V. amygdalina*, *G. Africanum*, *G. latifolium*, and *O. gratissimum* were harvested from cultivated farmlands near river banks located at Afikpo, Afikpo North L.G.A., Ebonyi State, South Eastern Nigeria. About 5 kg materials collected from each of the plants were thoroughly mixed, had their stalks removed, rinsed with de-ionized water and the residual moisture evaporated at room temperature before subjecting them to the different processing methods.

Processing methods

About 600 g each of the *V. amygadalina*, *G. Africanum*, *G. latifolium* and *O. gratissimun* leaves harvested were subjected to the following processing techniques:

(i) Fresh milling (FRM) of the leaves using a chopping knife to cut the fresh leaves and then a Thomas-Willey milling machine to blend the leaves into fine pieces,
(ii) Sun-drying (SND) for 2 - 3 days with constant turning over (to avert fungal growth) on clear papers,
(iii) Oven-drying (OVD) on aluminum trays at 80 - 100°C for 24 h,
(iv) Steaming (STM) of the leaf samples over wire gauze placed on top of a boiling water for 30 min,
(v) Fresh milling and Sun-drying (FRM+SND) in which the Thomas-Willey blended samples were further sun-dried for 2 - 3 days with adequate turning over to avert fungal growth,
(vi) Fresh milling and Oven-drying (FRM+OVD) in which the Thomas-Willey blended samples were oven-dried on aluminum trays at 80 - 100°C for 24 h,
(vii) Steaming and Oven-drying (STM+OVD) in which the steamed leaf samples were further oven-dried on aluminum trays at 80 - 100°C for 24 h.

All the processed samples were packed into tightly sealed nylon bags and analyses commenced immediately with minimum delay to forestall a further change in quality of the samples. Where the analysis could not be completed on the same day, samples were kept frozen at temperature of -4°C.

Methods of assay

The Vitamin A content of the leaf samples was determined by weighing out separately 2.0 g of each of the processed samples into a conical flask, mixing with 10.0 ml of hot distilled water and 10 ml of acetone before homogenizing. The homogenate was then centrifuged at 600 rpm for 30 min and the resultant supernatant used for measuring retinol as described by Davies (1976).

The thiamin (Vitamin B1), riboflavin (Vitamin B2), niacin (Vitamin B3), Pyridoxine (Vitamin B6) and tocopherol (Vitamin E) present in the processed samples were extracted with their various solvents and determined spectrophotometrically by methods of AOAC (1999).

Alkaloids Saponins and phenols present in the processed samples were measured by the method of Harborne (1973), modified by Obadoni and Ochuko (2001). Tannin determination was done as described by Van-Burden and Robinson (1981) while hydrocyanic acid content was measured using the method of Bradbury et al. (1991).

The extraction and precipitation of phytin in each of the processed samples were done by the method of Wheeler and Ferrel (1971) while iron in the precipitate was determined as described by Makower (1970) using a 4:6 Fe/p ratio to calculate phytin phosphorus Young and Greaves (1940). Where necessary decolorizing of samples was achieved using activated charcoal.

RESULTS AND DISCUSSION

Tables 1, 2, 3 and 4 give the vitamin content of the selected leafy vegetables subjected to different processing methods. The vitamin contents of raw (fresh milled) vegetables in mg/100 g dry weight ranged from: A (0.36 in *O. gratissimum* to 2.42 in *V. amygdalina*), B1 (0.25 in *G. latifolium* to 3.54 in *V. amygdalina*), B2 (0.41 in *G. latifolium* to 0.98 in *G. africana*), B3 (0.15 in *O. gratissimum* to 2.30 in *V. amygdalina*), B6 (0.41 in *O. gratissimum* to 2.31 in *V. amygdalina*) and E (0.18 in *O. gratissimum* to 2.86 in *V. amygdalina*). Comparatively similar values have been reported in lettuce, cabbage, *Aspilia africana*, *Bryophyllum pinnatum*, *Ipomea batatas* and *Solanum nigrum* L. var virginicum by Ifon and Bassir (1979), Kopas-Land and Warthesen (1995), Alabi et al. (2005), Anita et al. (2006), Okwu and Josiah (2006) and Akubugwo et al. (2007), respectively.

The various treatments (sun drying, oven drying, steaming and a combination of these) caused significant losses of the vitamin contents of all the tested vegetables at P = 0.05. Among the treatments, steaming combined with oven drying (STEm+OVD) had the most adverse effects, accounting for the highest losses in all the vitamins, while sun drying was second to fresh milling as the most effective method of retaining all the vitamins in the samples tested. Bassir and Umoh (1976) and Ajayi et al. (1979) reported similar significant losses in the vitamin contents of vegetables during cooking. Also Mepba et al. (2007) reported similar significant losses in the nutrient contents of blanched, sun-dried and cooked vegetables.

The results also indicated that vitamin losses varied with individual vitamins and vegetable cultivars. This can be attributed to the chemical nature of the individual vitamins and the genetic make-up of each tested vegetable. Soft tissue vegetables loose their vitamin contents easily.

The phytochemical contents of the test vegetables

Table 1. Vitamin composition in differently processed *V. amygdalina* leaves.

Processing method	Vitamin Composition (mg/100 g)					
	B-carotene Pro-Vitamin A	Thiamine (Vitamin B_1)	Riboflavin (Vitamin B_2)	Niacin (Vitamin B_3)	Pyridoxine (Vitamin B_6)	α-Tocopherol (Vitamin E)
FRM	$2.42^a \pm 0.02$	$3.54^a \pm 0.02$	$0.81^a \pm 0.01$	$2.30^a \pm 0.00$	$2.31^a \pm 0.01$	$2.86^a \pm 0.02$
SND	$1.89^b \pm 0.01$	$2.90^b \pm 0.00$	$0.62^b \pm 0.02$	$1.77^b \pm 0.01$	$2.14^b \pm 0.02$	$2.58^d \pm 0.02$
OVD	$1.72^c \pm 0.02$	$2.38^f \pm 0.02$	$0.54^e \pm 0.01$	$1.70^c \pm 0.00$	$2.08^e \pm 0.02$	$2.51^e \pm 0.03$
STM	$1.81^c \pm 0.03$	$2.45^c \pm 0.01$	$0.57^c \pm 0.03$	$1.72^d \pm 0.01$	$2.10^d \pm 0.00$	$2.55^c \pm 0.01$
FRM+SND	$1.81^c \pm 0.00$	$2.43^d \pm 0.01$	$0.56^d \pm 0.02$	$1.70^c \pm 0.01$	$2.11^c \pm 0.03$	$2.53^d \pm 0.02$
FRM+0VD	$1.68^f \pm 0.02$	$2.34^g \pm 0.02$	$0.50^f \pm 0.01$	$1.62^c \pm 0.02$	$2.02^f \pm 0.01$	$2.46^f \pm 0.01$
STM+SND	$1.77^d \pm 0.02$	$2.40^e \pm 0.01$	$0.54^e \pm 0.01$	$1.71^d \pm 0.03$	$2.08^e \pm 0.02$	$2.50^e \pm 0.01$
STM+OVD	$1.56^g \pm 0.02$	$2.36^h \pm 0.01$	$0.47^g \pm 0.03$	$1.60^f \pm 0.00$	$2.01^f \pm 0.01$	$2.44^g \pm 0.00$

*Each data is a mean of three replicates. *Figures followed by the same alphabets along the column are not significantly different at P = 0.05 using Duncan multiple Range Test (DMRT). * FRM = Fresh milling; SND = sun-drying; OVD = oven-drying; STM = steaming.

Table 2. Vitamin composition in differently processed *G. africana* leaves.

Processing Method	Vitamin Composition (mg/100 g)					
	B-carotene Pro-Vitamin A	Thiamine (Vitamin B_1)	Riboflavin (Vitamin B_2)	Niacin (Vitamin B_3)	Pyridoxine (Vitamin B_6)	α-Tocopherol (Vitamin E)
FRM	$2.26^a \pm 0.02$	$0.93^a \pm 0.01$	$0.98^a \pm 0.01$	$0.36^a \pm 0.02$	$0.61^a \pm 0.03$	$0.27^a \pm 0.03$
SND	$2.00^b \pm 0.00$	$0.88^b \pm 0.02$	$0.92^b \pm 0.01$	$0.33^b \pm 0.01$	$0.56^b \pm 0.02$	$0.24^b \pm 0.02$
OVD	$1.80^e \pm 0.01$	$0.78^d \pm 0.02$	$0.81^e \pm 0.03$	$0.26^d \pm 0.02$	$0.48^d \pm 0.00$	$0.15^d \pm 0.04$
STM	$1.94^c \pm 0.02$	$0.81^c \pm 0.01$	$0.85^c \pm 0.01$	$0.29^c \pm 0.03$	$0.50^c \pm 0.01$	$0.19^c \pm 0.01$
FRM+SND	$1.92^d \pm 0.01$	$0.82^c \pm 0.02$	$0.86^d \pm 0.02$	$0.28^c \pm 0.02$	$0.49^c \pm 0.01$	$0.18^c \pm 0.01$
FRM+0VD	$1.75^f \pm 0.01$	$0.76^e \pm 0.02$	$0.78^e \pm 0.01$	$0.23^e \pm 0.01$	$0.45^e \pm 0.01$	$0.11^e \pm 0.01$
STM+SND	$1.91^d \pm 0.03$	$0.79^d \pm 0.03$	$0.80^d \pm 0.00$	$0.25^d \pm 0.04$	$0.47^d \pm 0.02$	$0.16^d \pm 0.02$
STM+OVD	$1.71^g \pm 0.01$	$0.74^f \pm 0.02$	$0.77^e \pm 0.01$	$0.21^f \pm 0.01$	$0.42^f \pm 0.02$	$0.10^e \pm 0.01$

* Each data is a mean of three replicates. * Figures followed by the same alphabets along the column are not significantly different at P = 0.05 using Duncan multiple Range Test (DMRT). * FRM = Fresh milling; SND = sun-drying; OVD = oven-drying; STM = steaming.

Table 3. Vitamin composition in differently processed *G. Latifoluim* leaves.

Processing Method	Vitamin Composition (mg/100 g)					
	B-carotene Pro-VitaminA	Thiamine (VitaminB_1)	Riboflavin (VitaminB_2)	Niacin (Vitamin B_3)	Pyridoxine (Vitamin B_6)	α-Tocopherol (Vitamin E)
FRM	$1.93^a \pm 0.01$	$0.25^a \pm 0.04$	$0.41^a \pm 0.01$	$0.06^a \pm 0.02$	$0.72^a \pm 0.01$	$0.51^a \pm 0.01$
SND	$1.76^b \pm 0.02$	$0.22^b \pm 0.01$	$0.36^b \pm 0.02$	$0.99^b \pm 0.01$	$0.65^b \pm 0.01$	$0.46^b \pm 0.02$
OVD	$1.54^e \pm 0.01$	$0.09^d \pm 0.01$	$0.26^e \pm 0.02$	$0.85^e \pm 0.04$	$0.50^e \pm 0.00$	$0.18^f \pm 0.01$
STM	$1.61^c \pm 0.01$	$0.13^c \pm 0.01$	$0.31^c \pm 0.01$	$0.91^c \pm 0.01$	$0.59^c \pm 0.01$	$0.28^c \pm 0.01$
FRM+SND	$1.57^d \pm 0.03$	$0.09^d \pm 0.01$	$0.28^d \pm 0.02$	$0.88^d \pm 0.02$	$0.53^d \pm 0.03$	$0.22^g \pm 0.02$
FRM+0VD	$1.44^g \pm 0.02$	$0.04^f \pm 0.02$	$0.19^g \pm 0.01$	$0.78^g \pm 0.01$	$0.45^f \pm 0.01$	$0.12^g \pm 0.02$
STM+SND	$1.52^f \pm 0.01$	$0.06^e \pm 0.01$	$0.24^f \pm 0.01$	$0.81^f \pm 0.01$	$0.42^g \pm 0.02$	$0.20^e \pm 0.02$
STM+OVD	$1.38^h \pm 0.01$	$0.03^f \pm 0.01$	$0.18^g \pm 0.02$	$0.76^h \pm 0.01$	$0.41^g \pm 0.01$	$0.09^h \pm 0.01$

* Each data is a mean of three replicates. * Figures followed by the same alphabets along the column are not significantly different at P = 0.05 using Duncan multiple Range Test (DMRT). * FRM = Fresh milling; SND = sun-drying; OVD = oven-drying; STM = steaming.

subjected to different processing methods are given in Tables 5, 6, 7 and 8. Akaloid, saponin and hydrocyanic acid were the predominant phytochemicals quantified; while the tannin, phenol and phytic acid contents were low in all the tested vegetables. Values obtained in this study indicated levels comparatively similar to those

Table 4. Vitamin composition in differently processed *O. gratissimum* leaves.

Processing method	Vitamin Composition (mg/100 g)					
	B-carotene Pro-Vitamin A	Thiamine (Vitamin B_1)	Riboflavin (Vitamin B_2)	Niacin (Vitamin B_3)	Pyridoxine (Vitamin B_6)	α-Tocopherol (Vitamin E)
FRM	$1.36^a \pm 0.02$	$0.31^a \pm 0.01$	$0.43^a \pm 0.01$	$0.15^a \pm 0.04$	$0.41^a \pm 0.03$	$0.18^a \pm 0.01$
SND	$1.32^b \pm 0.02$	$0.28^b \pm 0.02$	$0.40^b \pm 0.00$	$0.11^b \pm 0.01$	$0.37^b \pm 0.01$	$0.16^b \pm 0.01$
OVD	$1.25^c \pm 0.01$	$0.20^c \pm 0.00$	$0.29^d \pm 0.01$	$0.04^d \pm 0.04$	$0.28^d \pm 0.02$	$0.07^d \pm 0.01$
STM	$1.26^c \pm 0.02$	$0.20^c \pm 0.02$	$0.35^b \pm 0.04$	$0.06^c \pm 0.01$	$0.29^c \pm 0.01$	$0.08^c \pm 0.01$
FRM+SND	$1.24^d \pm 0.01$	$0.18^d \pm 0.01$	$0.32^c \pm 0.02$	$0.04^d \pm 0.02$	$0.28^c \pm 0.01$	$0.05^d \pm 0.01$
FRM+0VD	$1.20^e \pm 0.00$	$0.17^d \pm 0.01$	$0.23^e \pm 0.01$	$0.03^d \pm 0.01$	$0.25^d \pm 0.04$	$0.04^d \pm 0.01$
STM+SND	$1.17^f \pm 0.03$	$0.15^e \pm 0.01$	$0.20^f \pm 0.01$	$0.03^d \pm 0.01$	$0.21^e \pm 0.01$	$0.03^e \pm 0.01$
STM+OVD	$1.14^g \pm 0.01$	$0.1^f \pm 0.01$	$0.16^g \pm 0.00$	$0.02^e \pm 0.01$	$0.419^f \pm 0.01$	$0.01^f \pm 0.02$

* Each data is a mean of three replicates. * Figures followed by the same alphabets along the column are not significantly different at P = 0.05 using Duncan multiple Range Test (DMRT). * FRM = Fresh milling; SND = sun-drying; OVD = oven-drying; STM = steaming.

Table 5. Phytochemical composition in differently processed *V. amygdalina* leaves.

Processing method	Phytochemical composition (mg/100 g)					
	Alkanoid	Saponin	Tannin	Phenols	Hydrocyanic acid	Phytic Acid
FRM	$1.59^a \pm 0.01$	$4.12^a \pm 0.02$	$1.03^a \pm 0.01$	$1.80^a \pm 0.00$	$1.36^a \pm 0.02$	$1.51^a \pm 0.01$
SND	$1.26^b \pm 0.02$	$3.50^b \pm 0.01$	$0.93^b \pm 0.03$	$1.66^b \pm 0.02$	$1.06^b \pm 0.02$	$1.23^b \pm 0.01$
OVD	$1.00^e \pm 0.00$	$3.38^c \pm 0.02$	$0.80^e \pm 0.00$	$1.55^c \pm 0.01$	$0.98^c \pm 0.01$	$1.07^c \pm 0.01$
STM	$1.08^d \pm 0.02$	$3.31^e \pm 0.03$	$0.84^c \pm 0.02$	$1.54^c \pm 0.02$	$0.87^c \pm 0.03$	$1.12^d \pm 0.02$
FRM+SND	$1.16^c \pm 0.02$	$3.38^c \pm 0.02$	$0.82^d \pm 0.01$	$1.55^c \pm 0.03$	$0.88^c \pm 0.01$	$1.17^c \pm 0.01$
FRM+0VD	$1.93^f \pm 0.01$	$3.35^d \pm 0.01$	$0.78^f \pm 0.01$	$1.55^d \pm 0.03$	$0.70^e \pm 0.00$	$1.01^f \pm 0.01$
STM+SND	$1.90^f \pm 0.01$	$3.27^f \pm 0.01$	$0.80^e \pm 0.02$	$1.50^d \pm 0.01$	$0.76^c \pm 0.02$	$1.08^e \pm 0.02$
STM+OVD	$1.78^g \pm 0.02$	$3.30^f \pm 0.00$	$0.78^f \pm 0.01$	$1.49^d \pm 0.01$	$0.65^f \pm 0.01$	$1.00^f \pm 0.00$

* Each data is a mean of three replicates. * Figures followed by the same alphabets along the column are not significantly different at P = 0.05 using Duncan multiple Range Test (DMRT). * FRM = Fresh milling; SND = sun-drying; OVD = oven-drying; STM = steaming.

Table 6. Phytochemical composition in differently processed *G. Africana* leaves.

Processing method	Phytochemical composition (mg/100 g)					
	Alkanoid	Saponin	Tannin	Phenols	Hydrocyanic acid	Phytic Acid
FRM	$1.62^a \pm 0.02$	$2.05^a \pm 0.01$	$0.68^a \pm 0.02$	$0.19^a \pm 0.03$	$12.08^a \pm 0.02$	$1.65^a \pm 0.03$
SND	$1.25^b \pm 0.01$	$1.77^b \pm 0.03$	$0.62^b \pm 0.02$	$0.16^b \pm 0.02$	$10.07^b \pm 0.01$	$1.32^b \pm 0.02$
OVD	$0.98^d \pm 0.02$	$1.63^f \pm 0.01$	$0.48^f \pm 0.02$	$0.07^d \pm 0.01$	$9.76^f \pm 0.01$	$1.16^f \pm 0.02$
STM	$1.19^c \pm 0.01$	$1.68^d \pm 0.02$	$0.58^c \pm 0.01$	$0.10^c \pm 0.00$	$9.84^d \pm 0.02$	$1.22^d \pm 0.01$
FRM+SND	$1.16^c \pm 0.01$	$1.70^c \pm 0.01$	$0.55^d \pm 0.03$	$0.08^d \pm 0.01$	$9.92^c \pm 0.02$	$1.25^c \pm 0.01$
FRM+0VD	$0.86^e \pm 0.01$	$1.57^g \pm 0.01$	$0.45^g \pm 0.01$	$0.06^e \pm 0.02$	$9.62^g \pm 0.01$	$1.13^g \pm 0.01$
STM+SND	$1.02^e \pm 0.02$	$1.65^e \pm 0.03$	$0.50^e \pm 0.00$	$0.06^e \pm 0.01$	$9.80^e \pm 0.00$	$1.20^e \pm 0.02$
STM+OVD	$0.78^f \pm 0.02$	$1.54^h \pm 0.02$	$0.42^h \pm 0.02$	$0.04^f \pm 0.01$	$9.58^h \pm 0.02$	$1.06^h \pm 0.01$

* Each data is a mean of three replicates. * Figures followed by the same alphabets along the column are not significantly different at P = 0.05 using Duncan multiple Range Test (DMRT). * FRM = Fresh milling; SND = sun-drying; OVD = oven-drying; STM = steaming.

reported for many medicinal plants such as *A. africana*, *B. pinnatum*, *H. suaveolens*, *I. batatas* and *S. nigrum* L. var virginicum among others (Edeogu et al., 2005, 2006; Antia et al., 2006; Okwu and Josiah, 2006; Akubugwo et al., 2007). This strongly supports the use of these vegetables for medicinal purposes such as in the treatment of ulcers, cancer, hypertension, and high blood pressure (Kupchan, 1971; Ojiako and Nwanjo, 2006; Matasyoh et al., 2007).

The concentration of phytochemicals varies

Table 7. Phytochemical composition in differently processed *G. latifolium* Leaves.

Processing method	Phytochemical composition (mg/100 g)					
	Alkanoid	Saponin	Tannin	Phenols	Hydrocyanic acid	Phytic Acid
FRM	1.01^{a} ± 0.03	2.44^{a} ± 0.02	3.62^{a} ± 0.02	0.90^{a} ± 0.00	2.81^{a} ± 0.01	0.78^{a} ± 0.02
SND	6.38^{b} ± 0.02	2.15^{b} ± 0.01	3.26^{b} ± 0.02	0.81^{b} ± 0.03	2.25^{b} ± 0.03	0.63^{b} ± 0.01
OVD	5.14^{e} ± 0.02	1.86^{f} ± 0.01	3.04^{f} ± 0.02	0.65^{e} ± 0.04	1.88^{e} ± 0.02	0.47^{d} ± 0.03
STM	5.46^{c} ± 0.01	2.01^{c} ± 0.01	3.17^{c} ± 0.03	0.72^{c} ± 0.02	2.04^{c} ± 0.01	0.57^{c} ± 0.01
FRM+SND	5.28^{d} ± 0.02	1.97^{d} ± 0.03	3.12^{d} ± 0.02	0.68^{d} ± 0.02	1.91^{d} ± 0.01	0.48^{d} ± 0.02
FRM+0VD	5.02^{f} ± 0.02	1.^{75g} ± 0.01	3.96^{g} ± 0.02	0.58^{f} ± 0.02	1.75^{g} ± 0.04	0.35^{e} ± 0.01
STM+SND	5.17^{e} ± 0.03	1.92^{e} ± 0.02	3.10^{e} ± 0.01	0.67^{d} ± 0.01	1.80^{f} ± 0.00	0.48^{d} ± 0.01
STM+OVD	4.96^{d} ± 0.01	1.71^{h} ± 0.01	2.89^{h} ± 0.03	0.52^{g} ± 0.01	1.63^{h} ± 0.01	0.32^{f} ± 0.02

*Each data is a mean of three replicates. *Figures followed by the same alphabets along the column are not significantly different at P = 0.05 using Duncan multiple Range Test (DMRT). * FRM = Fresh milling; SND = sun-drying; OVD = oven-drying; STM = steaming.

Table 8. Phytochemical composition in differently processed *O. gratissimum* leaves.

Processing method	Phytochemical composition (mg/100 g)					
	Alkanoid	Saponin	Tannin	Phenols	Hydrocyanic acid	Phytic Acid
FRM	12.63^{a} ± 0.01	0.73^{a} ± 0.01	0.62^{a} ± 0.02	0.50^{a} ± 0.02	8.46^{a} ± 0.02	0.36^{a} ± 0.01
SND	9.85^{b} ± 0.01	0.61^{b} ± 0.01	0.57^{b} ± 0.01	0.55^{b} ± 0.04	7.60^{b} ± 0.02	0.30^{b} ± 0.02
OVD	9.37^{d} ± 0.03	0.48^{e} ± 0.02	0.42^{d} ± 0.01	0.39^{e} ± 0.01	6.44^{d} ± 0.02	0.22^{c} ± 0.01
STM	9.56^{c} ± 0.02	0.52^{c} ± 0.01	0.44^{c} ± 0.02	0.46^{c} ± 0.02	6.48^{c} ± 0.02	0.22^{c} ± 0.02
FRM+SND	9.39^{d} ± 0.01	0.50^{d} ± 0.02	0.41^{d} ± 0.01	0.44^{d} ± 0.02	6.34^{d} ± 0.02	0.20^{d} ± 0.02
FRM+0VD	9.05^{e} ± 0.04	0.41^{f} ± 0.01	0.36^{e} ± 0.02	0.33^{f} ± 0.01	6.29^{e} ± 0.01	0.18^{e} ± 0.02
STM+SND	8.93^{f} ± 0.01	0.38^{g} ± 0.02	0.31^{f} ± 0.03	0.29^{g} ± 0.01	6.15^{f} ± 0.03	0.13^{f} ± 0.01
STM+OVD	8.81^{g} ± 0.01	0.30^{h} ± 0.00	0.24^{g} ± 0.02	0.21^{h} ± 0.01	6.08^{g} ± 0.02	0.09^{g} ± 0.03

*Each data is a mean of three replicates. *Figures followed by the same alphabets along the column are not significantly different at P = 0.05 using Duncan multiple Range Test (DMRT). * FRM = Fresh milling; SND = sun-drying; OVD = oven-drying; STM = steaming.

significantly (P = 0.05) with treatments. Raw (fresh milled) samples had higher concentrations followed by sun dried samples. Sun drying, oven drying, steaming and a combination of these caused significant reductions in the alkaloid, saponin, tannin, phenol, hydrocyanic acid (HCN) and phytic acid contents of all the tested leafy vegetables (P = 0.05). It is plausible that solubility in aqueous medium and volatility affect these phyto-chemicals during processing. Among the treatments, fresh milling followed by sun drying were the most effective methods in retaining all the phytochemicals while steaming combined with oven drying caused the highest reductions in the levels of all the phytochemicals in the tested vegetables. Since hydrocyanic acid, phytic acid and tannin act as anti-nutrients when present in excess in food (Ison and Idiong, 1997), methods leading to reduction in their levels are therefore desirable.

Conclusion

V. amygdalina, *G. africana*, *G. latifolium* and *O. Gratissimum* are important sources of vitamins and phyto-chemicals. There are nutritionally and medicinally relevant processing methods/treatments that produce diverse effects on the vitamin and phytochemical contents of vegetables. In all the vegetables tested, fresh milling followed by sun drying were the most effective methods of retaining the vitamins and phytochemicals while steaming combined with oven drying (STM + OVD) elicited the greatest loss of the vitamins and phyto-chemicals. Other treatments caused varying degrees of significant losses of vitamins and phytochemicals at P = 0.05 in all the tested vegetables. Methods that retain maximum nutrients and those causing loss of maximum anti-nutrients should be chosen to achieve any desired objective, so as to ensure the safety and wholesomeness of the vegetables.

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