Food Chemistry **23** (1987) 9–17

Changes in the Ascorbic Acid Content of Some Tropical Leafy Vegetables during Traditional Cooking and Local Processing

K. Oteng-Gyang* & J. I. Mbachu

Department of Biochemistry, University of Nigeria, Nsukka, Nigeria

(Received 13 December 1985; accepted 2 June 1986)

ABSTRACT

The ascorbic acid content of six tropical leafy vegetables (Vernonia amygdalina, Pterocarpus soyauxii, Manihot utilissima, Xanthosoma sagittifolium, Colocasia esculenta *and* Amaranthus hybridus) *and changes in the vitamin content during traditional West African cooking were measured. Vitamin C losses in* Vernonia amygdalina *during the squeezing and crushing procedure, aimed at reducing bitterness, prior to utilization in the home for food preparation, were also determined. Initial ascorbic acid levels were found to be 10·3–34·4 mg ascorbic acid/100 g fresh weight. Cooking led to significant losses (60–90% after 15 min). The squeezing and crushing of* Vernonia amygdalina *led to over 50% losses in the wash water. During market-sale, when the leaves remained exposed in the sun for several hours, losses as high as 97% of the remaining ascorbic acid were recorded. Some of the vitamin was leached into the water which was not sold to the consumer, but discarded.* Vernonia amygdalina *leaves, thus prepared, do not serve as a major source of ascorbic acid in local diets.*

INTRODUCTION

It is important for man to have ascorbic acid in his diet if the deficiency disease called scurvy is to be avoided (White *et al.*, 1978). In West Africa, principal sources of the vitamin include fresh fruits and vegetables. Fresh

* Present address: CESTAM International, 2 Res. Chateau de Courcelle, 160 Avenue de Général Leclerc, 91190 Gif-sur-Yvette. France.

fruits are often seasonal, whereas leafy vegetables are present all the year round. It was therefore suspected that leafy vegetables might constitute the principal source of the vitamin for the people in the region.

Although ascorbic acid is quite stable in the dry form (Dennison & Kirk, 1982), it will undergo destruction in solution, particularly when exposed to heat or light (Dennison & Kirk, 1978), or when certain metal ions like copper and iron are present in the solution (Weissberger *et al.*, 1943). In West Africa, leafy vegetables are boiled and often stewed prior to consumption. Very little is known about the nutrient changes of these vegetables during such processing procedures.

Equally lacking is information about nutrient changes when some of these leafy vegetables are 'semi-processed' and kept for long hours in the tropical sun during market sale. This is notably the case with leaves of *Vernonia amygdalina* (also called bitter leaf), which is consumed in appreciable quantities in Nigeria. During the preparation procedure prior to consumption, the freshly harvested leaves are squeezed and crushed in a given volume of water and the wash water is rejected. The objective of this procedure is to reduce bitterness. The half-squeezed leaves are then soaked in water and sent to market, where they remain exposed in open basins for several hours in the sun, prior to sale.

Our study, in two parts, was aimed at providing some information about the essential nutrient composition of some of the most popular leafy vegetables consumed in the region, during local processing prior to consumption, using losses in ascorbic acid as an index.

In the first part, an attempt was made to determine the initial ascorbic acid content of the six leafy vegetables and to follow changes in the concentration of the vitamin during cooking. In the second part, attention was focused on bitterleaf, the only leafy vegetable which is 'semi-processed' before sale. Changes in the ascorbic acid content of the leaves were monitored from the period of crushing/squeezing to the period of exposure in the sun for hours during market sale.

MATERIALS AND METHODS

All reagents used were analytical grade. All solutions were prepared using deionized water.

Leafy vegetables

The leafy vegetables (*Vernonia amygdalina* (bitter leaf), *Amaranthus hybridus*, *Pterocarpus soyauxii*, *Manihot utilissima*, *Colocasia esculenta* and

Xanthosoma sagittifolium) were all obtained from a local farm at the University of Nigeria.

Ascorbic acid determination

Ascorbic acid was determined by the 2,6-dichlorophenol indophenol method (Plummer, 1979).

Preparation of extract from leafy vegetables

Exactly 5 g of leaves were added to 3 g of acid-washed sand and 30 ml of 20% metaphosphoric acid in a mortar, and crushed. The macerate was continuously kept covered by the acid to minimize oxidation. After crushing and filtration through a muslin cloth, the residue was again re-crushed with 20 ml of 20% metaphosphoric acid and filtered. Tubes and flasks were kept covered with aluminium foil to minimize oxidation. After addition of 2·5 ml of glacial acetic acid to complex any SO_2 present, 20 ml of chloroform was added to the whole mixture and shaken. The upper layer was separated after settling and the volume noted. Similar extracts were prepared from leaves that were cooked for 5, 10 and 15 min.

Preparation of the bitter leaf

The traditional method employed locally was used. Exactly 30 g of leaves were partly squeezed and partly crushed, in about 150 ml of distilled water. The leaves were repeatedly washed with distilled water until the total volume of water used reached 300 ml. The ascorbic acid content of this first volume of mixture was then determined. A fresh volume of 300 ml was added to the crushed leaves; the suspension was stirred and exposed in the sun to simulate conditions during market sale. At hourly intervals, a sample of 5 ml was removed after stirring, homogenized, filtered and the ascorbic acid content of the filtrate determined.

pH determination

The pH of a filtrate from 10 g of fresh leaves crushed in 100 ml of deionized water was determined using a pH meter (PYE 292 Unicam model).

Dry weight determination

Fresh leaves were heated in an oven (Gallenkamp BS model) at 105°C until a constant weight was obtained.

RESULTS AND DISCUSSION

Changes in ascorbic acid content during cooking

The pH and dry weight of the different leafy vegetables are shown in Table 1. All reported results represent the average of five trials. The highest pH value observed was 6·7 for *Vernonia amygdalina*, and the lowest, 5·3 for *Manihot utilissima*. With such pH values, these leafy vegetables fall well into the category of low-acid foods. Significant variation was observed in the moisture content of these leafy vegetables.

In Table 2, initial ascorbic acid contents of the leaves are reported with the changes observed during cooking at 100°C (as boiling water is usually used in most households). The percentage loss of the vitamin as a function of time is represented in Fig. 1.

It is interesting to note that there is wide variation between the values observed for the two varieties of cocoyam tested; *Colocasia esculenta* contained only 45% of the vitamin content observed for *Xanthosoma sagittifolium*.

The lowest ascorbic acid value observed was in *Vernonia amygdalina* (10 mg of ascorbic acid/100 g fresh weight). This value is lower than the value reported by Achinewhu (1983) for the same plant species found in the Port Harcourt region of Nigeria (38 mg of ascorbic acid/100 g fresh weight). Varietal and geographical differences may explain these differences.

Initial ascorbic acid contents of all the leaves (except *Vernonia amygdalina*) are thus higher than reported values for carrots—7·8–8·0 mg of ascorbic acid/100 g fresh weight—and celery—6·0–9·0 mg of ascorbic acid/100 fresh weight—but comparable to higher values observed in asparagus (10·5–23·5 mg/100 fresh weight), tomatoes (15·3–23 mg of ascorbic acid/100 g fresh weight). (Klein & Perry, 1982; Watt & Merrill, 1975) and Nigerian garden eggs (21·3 mg of ascorbic acid/100 g fresh weight). (Achinewhu, 1983).

TABLE 1
pH and Dry Weight of Six Tropical Leafy Vegetables

Vegetable	*pH*	*Dry weight* (%)
Vernonia amygdalina	6·7	18·8
Pterocarpus soyauxii	5·7	42·0
Manihot utilissima	5·3	29·0
Colocasia esculenta	5·8	18·3
Xanthosoma sagittifolium	5·6	17·0
Amaranthus hybridus	5·5	15·8

TABLE 2

Ascorbic Acid Content of Leafy Vegetables (mg ascorbic acid/100 g fresh weight) after the Given Cooking Time in Water

Cooking time (min)	*Data*	Vernonia amygdalina	Pterocarpus soyauxii	Manihot utilissima	Colocasia esculenta	Xanthosoma sagittifolium	Amaranthus hybridus
0	Ranges	9·5–12·0	22·5–27·1	32·9–35·0	10·6–12·7	20·8–25·6	19·4–28·0
	Mean ± SD	10·3 ± 0·6	25·7 ± 1·1	34·4 ± 0·5	10·9 ± 0·4	21·4 ± 2·6	22·7 ± 2·6
5	Ranges	6·9–7·3	19·0–20·6	27·0–28·1	6·3–8·1	14·8–15·2	8·7–11·3
	Mean ± SD	7·2 ± 0·1	19·9 ± 0·4	27·7 ± 0·3	7·5 ± 0·5	15·0 ± 0·1	10·5 ± 0·6
10	Ranges	3·2–6·2	14·9–17·0	18·4–22·0	3·3–3·7	11·2–12·4	6·7–8·3
	Mean ± SD	5·3 ± 1·4	15·9 ± 0·1	19·9 ± 1·0	3·6 ± 0·1	11·6 ± 0·3	7·3 ± 0·4
15	Ranges	2·9–4·1	7·9–12·6	5·8–7·5	2·9–3·4	8·4–8·9	1·4–3·9
	Mean ± SD	3·7 ± 0·3	10·5 ± 1·2	6·8 ± 0·4	3·3 ± 0·3	8·6 ± 0·1	2·9 ± 0·6

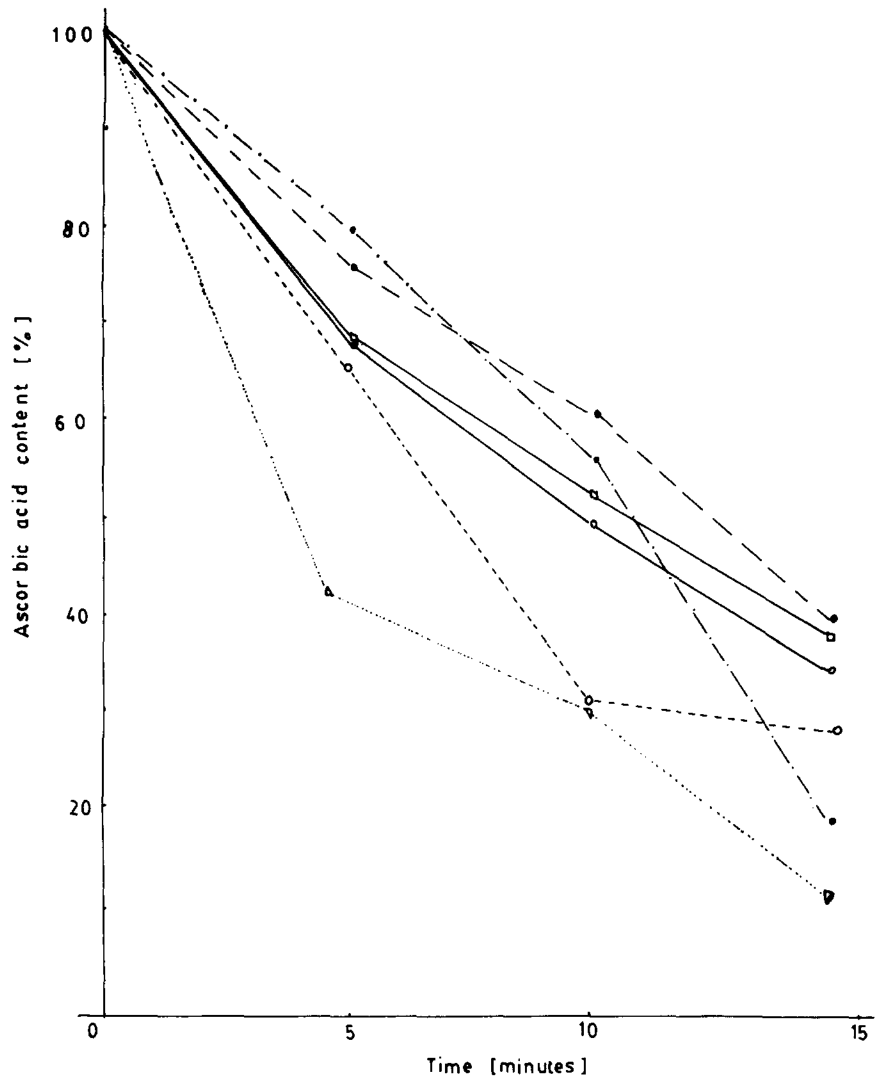

Fig. 1. Ascorbic acid loss during cooking of vegetables at 100°C. ○——○, *Vernonia amygdalina.* ●– – –●, *Pterocarpus soyauxii.* ●–·–●, *Manihot utilissima.* ○– – –○, *Colocasia esculenta.* □——□, *Xanthosoma sagitifolium.* ▽·····▽, *Amaranthus hybridus.*

With regard to percentage losses during processing, it was observed that after 5 min of cooking, ascorbic acid losses averaged 30%. At the end of 15 min, losses as high as 87% were observed in *Amaranthus hybridus*; lowest losses were about 59% (for *Pterocarpus soyauxii* and *Xanthosoma sagittifolium*). The values of ascorbic acid losses observed at the end of 5 min are comparable to values observed by Achinewhu (1983) for some Nigerian vegetables, cooked for a similar period of time.

It should be noted that, in most households, vegetable leaves are often cooked together with yams, plantains and other vegetables, and that the cooking times for these food items are 15 min or more. This therefore means that losses of ascorbic acid during the preparation of these vegetables could be still higher. It is even more important to realize that the cooking of these leafy vegetables usually constitutes only a first step in the overall cooking procedure; the vegetables are often pounded, or crushed, then stewed in oil before consumption. This process could lead to further ascorbic acid loss.

Changes in ascorbic acid content of *Vernonia amygdalina* during processing and market sale

The results presented here represent five experimental trials. The data in Table 3 show that 52% of initial acorbic acid was lost during the first squeezing/crushing procedure.

In Table 4, changes in the concentration of the ascorbic acid remaining in the crushed leaves were measured. Losses varied from 28% after 1 h to 97% of the remaining vitamin content after 6 h. Taking the initial ascorbic acid level into account, this represents an overall percentage ascorbic acid loss of 99%. This loss of vitamin is high and should be viewed with a great deal of concern, because other essential nutrients, notably riboflavin, thiamin and niacin, will also be lost.

These values are higher than the losses of 22–38% reported for some leafy vegetables studied under market sale conditions in the Port Harcourt area of Nigeria by Achinewhu (1983). However, it must be noted that, in his case, the vegetables were neither 'debittered', nor were they squeezed/crushed. Squeezing and crushing leads to the exposure of a much larger vegetable surface, thus resulting in increased losses from oxidation. Thus, for example, Klein & Perry (1982) observed an ascorbic acid loss of only 2% of the initial value in corn cooked on the cob, and attributed this high

TABLE 3

Values of pH, Initial Ascorbic Acid Content of Bitter Leaf and Loss during Squeezing/Crushing to Reduce Bitterness

pH	*Data*	*Initial ascorbic acid content of leaf (mg/100 g fresh weight)*	*Ascorbic acid lost in first wash-water (mg/100 g fresh weight)*	*% loss*
6·6	Range	9·5–12·0	4·8–5·7	
	Mean ± SD	10·3 ± 0·6	5·4 ± 0·2	52

TABLE 4
Changes in Remaining Ascorbic Acid Content of Squeezed/Crushed Leaves of *Vernonia amygdalina* During Market Sale (mg/100 g fresh weight)

Time prior to sale (h)	*Data*	*Present*	*Loss*	*% loss*	*Temperature of mixture (°C)*
0	Range	4·0–5·2			30
	Mean ± SD	4·5 ± 0·3			
1	Range	2·1–3·6			
	Mean ± SD	3·2 ± 0·4	1·3	28	34
2	Range	2·0–2·4			
	Mean ± SD	2·1 ± 0·1	2·4	53	36
3	Range	0·7–0·9			
	Mean ± SD	0·9 ± 0·1	3·5	79	39
4	Range	0·5–0·6			
	Mean ± SD	0·5 ± 0·1	4·0	89	40
5	Range	0·2–0·5			
	Mean ± SD	0·3 ± 0·05	4·2	93	40
6	Range	0·1–0·2			
	Mean ± SD	0·1 ± 0·05	4·4	97	38

ascorbic acid retention to the fact that the corn was cooked on the cob and not disrupted in any way prior to cooking.

It is interesting to note that high temperatures of the leaf can be attained after only 3 to 4 h of exposure of the mixture on an average tropical day (ambient air temperature, 24–28 °C).

CONCLUSION

Ascorbic acid losses from food items do not depend on temperature alone. In the case of cooked vegetables, apart from factors like light, pH, oxygen and the presence of trace metals (Eison-Perchonok & Downes, 1982), ascorbic acid losses are also dependent on cooking time, as well as the water to vegetable ratio during cooking (Erdman & Klein, 1982). Longer cooking times result in increased ascorbic acid losses; higher quantities of water for a given amount of vegetables lead to greater ascorbic acid losses.

Although ascorbic acid may not be critically lacking in most West African diets, the large losses observed indicate the probable loss of other essential nutrients, notably vitamins and amino acids, during the preparation of local diets. As such foods are never artificially supplemented with vitamins and essential nutrients, efforts should be made to find alternative processing methods reputed to lead to less vitamin losses.

Although comparison with data from losses during cooking and blanching processes is rather difficult owing to the varying range of conditions under which the various experiments have been carried out (Selman, 1978), it is possible that leafy vegetable processing by steam cooking could prove useful. In addition, a reduction in the amount of water used during cooking could be helpful. The possibility of selling in shady market places, as well as the use of opaque and covered containers which may absorb energy, could be encouraged. The practice of cooking these vegetables with others like yams and plantains should be discouraged, as this prolongs the cooking time unnecessarily and thus leads to high nutrient loss.

In general, these results confirm the assertion that leafy vegetables provide some ascorbic acid in West African diets; it is, however, unlikely that bitter leaf constitutes a significant source of the vitamin when prepared by traditional methods.

REFERENCES

Achinewhu, S. C. (1983). Ascorbic acid content of some Nigerian local fruits and vegetables. *Qualitas Plantarum: Plant Foods for Human Nutrition*, **33**(4), 261–6.

Dennison, D. K. & Kirk, J. R. (1978). Oxygen effect on the degradation of ascorbic acid in a dehydrated food system, *J. Food Sci.*, **43**, 609.

Dennison, D. K. & Kirk, J. R. (1982). Effect of trace metal fortification on the storage stability of ascorbic acid in a dehydrated model food system, *J. Food Sci.*, **47**, 1199.

Eison-Perchonok, M. H. & Downes, T. W. (1982). Kinetics of ascorbic acid oxidation as a function of dissolved O_2 and temperature, *J. Food Sci.*, **47**, 765.

Erdman, J. W. & Klein, B. P. (1982). Harvesting, processing and cooling influences on vitamin C in foods. In: *Symposium on Cooling Influences on Vitamin C in Foods.* Advances in Chem. Series., Am. Chem. Soc., Washington.

Klein, P. B. & Perry, A. K. (1982). Ascorbic acid and vitamin A activity in selected vegetables from different geographical areas of the US, *J. Food Sci.*, **47**, 941–7.

Plummer, D. T. (1979). *An introduction to practical biochemistry* (2nd ed.), Tata McGraw-Hill, New Delhi.

Selman, J. D. (1978). Vitamin C losses from peas during blanching in water—Review. *Food Chemistry*, **3**(3), 189–97.

Watt, B. K. & Merrill, A. L. (1975). *Composition of foods handbook*, USDA, Washington.

White, A., Handler, P., Smith, E. L. & Lehman, R. I. (1975). *Principles of biochemistry.* (6th edn), McGraw-Hill, New York.

Weissberger, A., Luvalle, J. E. & Thomas, D. S. (1943). Oxidation processes 16. The autooxidation of ascorbic acid, *J. Am. Chem. Soc.*, **65**, 1934.