Effect of Long-Term Storage of Processed Nigeria-Grown Edible Leafy Green Vegetables on Vitamin C Content

G. I. Okeibuno Badifu

Department of Food Science and Technology, University of Agriculture, Makurdi, Nigeria

Fresh edible green leaves from *Celosia argentea*, *Amaranthus hybridus*, *Solanum nodiflorum*, and *Corchorus olitorius* were studied. They had high contents of ascorbic acid. About 47–58% and 25–33% of the ascorbic acid contents were lost in the leaves by water blanch and steam methods, respectively. In the blanched but undehydrated leaves, the ascorbic acid content of the product was deleteriously affected under ambient storage. A loss of about 54–64% was observed after a 6-month storage period. The steam-blanched and dehydrated vegetable leaves kept for 6 months without much loss in ascorbic acid content. Sodium sulfite/sodium metabisulfite significantly ($P < 0.05$) enhanced the retention of ascorbic acid in the processed leaves.

INTRODUCTION

Leafy green vegetables *Celosia argentea*, *Amaranthus hybridus*, *Solanum nodiflorum*, and *Corchorus olitorius* are very popular vegetables used for food in most parts of Nigeria. *C. argentea* and *A. hybridus* belong to the Amaranthaceae family, while *S. nodiflorum* and *C. olitorius* belong to the families Solanceae and Malvaceae, respectively.

Kohman (1928) was among the first investigators to report that a short heat treatment (blanching) could inactivate the enzymes and stabilize frozen vegetables against off-flavor development for a considerable period. Peroxidase is one of the most heat-stable naturally occurring enzymes present in vegetables and fruit; consequently, the presence or absence of peroxidase activity is now widely used for the estimation of effectiveness of blanching procedures in the food industry (Mclellan and Robinson, 1981). Peroxidases in different vegetables and fruits have different heat stabilities, and hence the processor has to determine the time needed for each vegetable and fruit with the blanching equipment and conditions used (Williams et al., 1986).

Oke (1968) reported the changes in vitamin C content during various stages of growth of some Nigerian leafy vegetables. Vitamin C is reduced by cooking (Krehl and Winters, 1950; Gordon and Noble, 1964; Oke, 1967; Fafunso and Bassir, 1976; Imbamba, 1977; Keshinro and Ketiku, 1979; Ajayi et al., 1980) and the degree of vitamin C losses depended on the quantity, of cooking water used. Sreeramulu et al. (1983) reported small losses of vitamin C when the vegetable samples were cooked in 100 mL of water.

During the harvest season, there is a huge loss in leafy vegetables due mainly to spoilage resulting from a lack of adequate storage facilities. Therefore, a short period of plenty in the availability of leafy green vegetables is followed by a sudden and long period of acute scarcity of these commodities in Nigeria. Little research has been conducted on the fate of ascorbic acid during processing and a prolonged period of storage of processed leafy green vegetables in most tropical countries.

The purposes of this study were to determine the most appropriate blanching time for some common fresh, edible green vegetable leaves grown in Nigeria and to assess the ascorbic acid level of the processed leaves kept under different storage conditions for a specific period.

MATERIALS AND METHODS

Raw Material and Source. The leafy green vegetables used in this study were *C. argentea*, *A. hybridus*, *S. nodiflorum*, and *C. olitorius*. They were obtained from the Commercial Farm of the Obafemi Awolowo University, Ile-Ife, Nigeria. They were representative of samples obtainable in the local market. Samples were processed immediately, about 15 min, after they were harvested.

Determination of Ascorbic Acid. About 10 g of leaves was grouped in a ceramic mortar with pestle in the presence of water and freshly prepared metaphosphoric acid–acetic acid (Aldrich Chemical Co. Inc.) solution, total volume of 30 mL. This was filtered in a Büchner funnel lined with Whatman No. 1 filter paper, using Edwards high vacuum pump (Ed. 50). The filtrate (10 mL) was used to determine ascorbic acid content by the 2,6-dichloroindophenol (Sigma Chemical Co.) titrimetric method (AOAC, 1984).

Hot Water Blanch. The fresh leaves were washed in chlorinated water (0.5%), spread on a gauze wire tray, and allowed to drain dry under fan for 20 min at ambient temperature (27–30 °C). A portion (100 g) of the cleaned leaves was immersed in a solution (300 ppm of available SO_2) of a mixture of anhydrous sodium sulfite and sodium metabisulfite (3:1) for 45 min. The chemicals were purchased from the Sigma. The leaves were drain dried as previously described. The gauze wire tray with its content was immersed into boiling water (98 °C) (1 L) which covered the leaves. The leaves (chemically treated and untreated) were blanched for 1, 2.5, 3, 3.5, 4, or 4.5 min. The time for adequate blanching of the leaves was determined as described by Luh and O'Neal (1982). A sample (10 g) of blanched leaves was ground in a ceramic mortar with pestle. Water (30 mL) was added, mixed thoroughly, and filtered. Two milliliters of the filtrate was added into 20 mL of distilled water in a test tube. This was followed by the addition of 1 mL of 0.5% guaiacol solution and 1 mL of 0.08% hydrogen peroxide solution. The mixture was thoroughly mixed by inverting the tube, and color development was noted. If color did not develop in 3.5 min, the test was negative, which implied that the leaves were adequately blanched. If color developed before 3.5 min, the test was positive, which implied that the leaves were not adequately blanched. The most appropriate blanching time established was used to blanch 500 g each of fresh treated and untreated leaves. The blanched leaves were allowed to drain dry as previously mentioned. They were divided into three portions (ca. 166 g each). Each portion was further divided into four replicate samples (ca. 41 g each), and each sample was packed in a polyethylene bag. Part was stored under ambient temperature (27–30 °C), some in the refrigerator (7–10 °C) and the rest in the deep freezer (−18 °C).

Steam Blanch. The leaves were cleaned and chemically treated as in the water blanch method. They were put in a gauze wire tray and transferred to the steam blancher (Figure 1). A

0021-8561/91/1439-0538$02.50/0

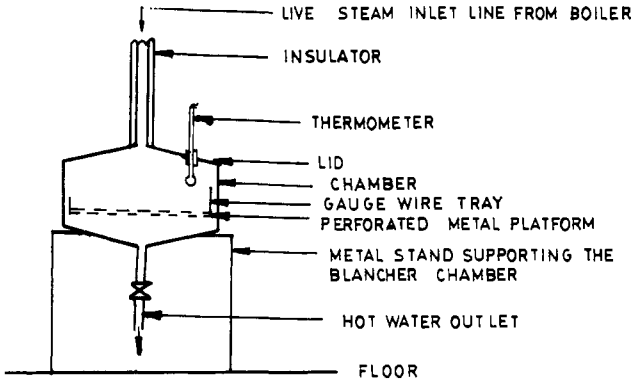

Figure 1. Sketch of the steam blancher used in the experiment.

Table I. Ascorbic Acid[a] Content of Unprocessed Leaves

vegetable species	ascorbic acid, mg %
C. argentea	216.07 ± 0.49
A. hybridus	176.56 ± 0.35
S. nodiflorum	164.57 ± 0.54
C. olitorius	234.67 ± 0.82

[a] Dry weight basis. Values are means of four determinations. Mean ± SD.

Table II. Blanching Time (in Minutes) of the Leaves[a]

vegetable species	water blanch	steam blanch
C. argentea	3.5 ± 0.14	2 ± 0.01
A. hybridus	3.5 ± 0.13	2 ± 0.11
S. nodiflorum	4.5 ± 0.20	3 ± 0.10
C. olitorius	4 ± 0.16	2.5 ± 0.13

[a] Values are means of three determinations. Mean ± SD.

live steam (100 °C) at 16–20 psi, i.e., 110–138 kN/m², was directed on the leaves for 1, 1.5, 2, 2.5, 3, or 4 min. The adequacy of blanching was determined as in the water blanch.

Dehydration. About 500 g of cleaned fresh leaves (chemically treated and untreated) were steam-blanched as previously described for the established blanching time. The blanched leaves were allowed to drain dry under fan as described for the water blanch. They were then put into a dryer (Memmert cabinet dryer: shelf size 670 × 330 mm; overall dimensions 1070 × 760 × 420 mm) and dried at 95 ± 1 °C for 6 h; *S. nodiflorum* was dried for 7 h. The moisture content of the dehydrated leaves was determined according to the AOAC (1984) method. They were packed in polyethylene bags and kept under different storage conditions as previously described, and the ascorbic acid content was determined (AOAC, 1984). Analysis of variance, using a microcomputer Model II Radioshack TRS-80, was carried out on the data from four replicate samples to determine the effect of pretreatment on the ascorbic acid content of the leaves.

RESULTS AND DISCUSSION

Ascorbic Acid. Table I presents the ascorbic content of the unprocessed vegetable leaves. All the vegetable species had high content of ascorbic acid. *C. argentea* and *C. olitorius* had interestingly high ascorbic acid contents. Factors such as climatic conditions, varieties, cultural practices, and maturity influence the composition of fresh vegetables. Albrecht et al. (1990) reported an ascorbic acid content of 157.7 mg % for savoy cabbage. Ifon and Bassir (1979) reported 160.17 mg % ascorbic acid for *Telfairia occidentalis*. Paul and Southgate (1988) reported a range of 100–200 mg % and 150–230 mg % of ascorbic acid for some vegetables (parsley) and fruits (currants), respectively.

Blanching Time. Table II shows the blanching time for the leaves in the water blanch and steam blanch methods. In the water blanch method, the time taken to adequately blanch *C. argentea* and *A. hybridus* was 3.5 min. *S. nodiflorum* and *C. olitorius* were adequately blanched in 4.5 and 4 min, respectively. The water temperature prior to the immersion of vegetable leaves was 98 °C. When the leaves were immersed, the temperature of the water dropped to about 85 °C. The effective temperature range for the water blanch method was between 85 and 98 °C.

For the steam blanch method, 2 min was required to adequately blanch *C. argentea* and *A. hybridus*, while 3 and 2.5 min were required for *S. nodiflorum* and *C. olitorius*, respectively. There was no appreciable temperature fluctuation in the steam blanch method.

The blanch time varied with species. *S. nodiflorum* took the longest time to show that it had been adequately blanched, and this was followed by *C. olitorius* in both blanch methods. The variation in blanch time could be due to differences in the rate of heat penetration into the tissues of the leaves. This in turn depended on the differences in tissue rigidity or heaviness as in the case of *S. nodiflorum*. The heat stability of the peroxidases present in the leaves could also explain the variation in blanching time. Baardseth and Slinde (1980) reported differences in the heat stabilities of the peroxidases from different vegetables. In general, the time required for steam blanching was shorter than for water blanching. Okoli et al. (1988) reported that either steam or hot-water blanching could be used to process low-acid indigenous vegetables and concluded that 2–4 min in steam produced the most acceptable results.

Ascorbic Acid. The results on the ascorbic acid content of water-blanched and steam-blanched–dehydrated vegetable leaves (moisture 4–5%) after 6 months of storage are presented in Table III. The quantity of ascorbic acid present varied with species. *C. olitorius* was found to contain the highest amount of ascorbic acid, closely followed by *C. argentea*. Blanching reduced the ascorbic acid. This was due to the leaching of ascorbic acid into the blanch water. This observation agreed with the results of previous investigators (Keshinro and Ketiku, 1979; Sreeramulu et al., 1983). The likely oxidation of ascorbic acid at the elevated temperature could also explain its reduction. More ascorbic acid was lost in *S. nodiflorum* and *A. hybridus* than in the other vegetable species due to blanching. The loss in ascorbic acid was about 47–57% for the water blanch method.

The ascorbic acid content of the steam-blanched leaves decreased when compared to that of the unblanched leaves. However, the loss was low (ca. 25–33%) when compared to the values obtained for the water-blanched–dehydrated leaves.

The amount of ascorbic acid retained in vegetable leaves blanched in water varied with the species of vegetable. Drake et al. (1981) compared the content of ascorbic acid in asparagus, bean, pea, and corn after blanching by water, steam, and microwave at the same temperatures for the same amount of time. They observed that water blanching resulted in the best retention for three of the products.

The ascorbic acid contents of the dehydrated vegetable leaves stored for 6 months were not appreciably affected by storage. The ascorbic acid retention ranged from 67% to 75% in all the vegetable species that were steam-blanched. For the water-blanched leaves, the ascorbic acid retention was 42–53%. Apart from the variation in the amount of ascorbic acid in the leaves due to the blanching method used, there was not much difference in ascorbic acid content resulting from the storage condition. This result showed that for well-treated and dehydrated leafy

Table III. Ascorbic Acid Content of Blanched Dehydrated Leaves after 6 Months of Storage and Various Temperatures[a]

vegetable species	blanch method	ascorbic acid, mg %, dry basis (% retention)		
		storage at 27–30 °C	storage at 7–10 °C	storage at −18 °C
C. argentea	water	113.84 ± 0.76 (52.7)	114.05 ± 0.79 (52.8)	114.12 ± 0.62 (52.8)
	steam	157.23 ± 0.68 (72.7)	157.98 ± 0.36 (73.1)	158.49 ± 0.52 (73.4)
A. hybridus	water	76.68 ± 0.64 (43.4)	77.41 ± 0.65 (43.8)	77.92 ± 0.46 (44.1)
	steam	132.38 ± 0.57 (75)	132.67 ± 0.41 (75.1)	133.02 ± 0.36 (75.3)
S. nodiflorum	water	68.31 ± 0.65 (41.5)	68.86 ± 0.71 (41.8)	69.10 ± 0.50 (42)
	steam	109.61 ± 0.72 (66.6)	110.06 ± 0.57 (66.9)	110.11 ± 0.44 (66.9)
C. olitorius	water	125.53 ± 0.02 (53.5)	123.58 ± 0.95 (52.7)	125.10 ± 0.73 (53.3)
	steam	169.33 ± 0.65 (72.2)	169.90 ± 0.45 (72.4)	170.04 ± 0.70 (72.5)

[a] Retention was calculated on the basis of the ascorbic acid content of the unprocessed (unblanched) leaves, which served as control. Values are means of four determinations. Mean ± SD.

Table IV. Ascorbic Acid Content of Undehydrated Leaves after 6 Months of Storage and Various Temperatures[a]

vegetable species	blanch method	ascorbic acid, mg %, dry basis (% retention)		
		storage at 27–30 °C	storage at 7–10 °C	storage at −18 °C
C. argentea	water	97.86 ± 0.33 (45.3)	111.32 ± 0.50 (51.5)	113.79 ± 0.67 (52.7)
	steam	141.17 ± 0.72 (65.3)	155.83 ± 0.67 (72.1)	158.53 ± 0.75 (73.4)
A. hybridus	water	69.73 ± 0.51 (39.5)	74.65 ± 0.43 (42.3)	77.84 ± 0.45 (44.1)
	steam	125.42 ± 0.54 (71.0)	130.75 ± 0.70 (74.0)	132.87 ± 0.49 (75.3)
S. nodiflorum	water	59.46 ± 0.62 (36.1)	66.81 ± 0.57 (40.6)	68.75 ± 0.56 (41.8)
	steam	100.59 ± 0.4 (61.1)	108.50 ± 0.56 (65.9)	109.79 ± 0.37 (66.7)
C. olitorius	water	108.79 ± 0.47 (46.4)	120.17 ± 0.39 (51.2)	124.83 ± 0.70 (53.2)
	steam	152.68 ± 0.69 (65.1)	167.79 ± 0.73 (71.5)	169.96 ± 0.58 (72.4)

[a] Retention was calculated on the basis of the ascorbic acid content of the unprocessed (unbalanced) leaves, which served as control. Values are means of four determinations. Mean ± SD.

Table V. Effect of Sodium Sulfite/Sodium Metabisulfite on the Ascorbic Acid Content of Processed Vegetable Leaves Dehydrated and Undehydrated after 6 Months of Storage under Various Temperatures[a]

vegetable species	treatment	ascorbic acid, mg %, dry basis					
		storage at 27–30 °C		storage at 7–10 °C		storage at −18 °C	
		water blanch	steam blanch	water blanch	steam blanch	water blanch	steam blanch
C. argentea	dehydrated	115.14 ± 0.37	158.52 ± 0.40	115.28 ± 0.56	159.26 ± 0.48	115.40 ± 0.61	159.37 ± 0.46
	undehydrated	98.95 ± 0.45	142.19 ± 0.30	112.35 ± 0.56	156.90 ± 0.52	115.12 ± 0.27	159.55 ± 0.48
A. hybridus	dehydrated	77.80 ± 0.45	133.54 ± 0.38	78.12 ± 0.42	134.08 ± 0.35	78.51 ± 0.29	134.29 ± 0.35
	undehydrated	71.14 ± 0.37	126.58 ± 0.51	76.13 ± 0.42	131.08 ± 0.45	78.90 ± 0.36	134.11 ± 0.52
S. nodiflorum	dehydrated	69.45 ± 0.40	110.73 ± 0.52	69.33 ± 0.34	110.89 ± 0.41	69.47 ± 0.37	111.03 ± 0.44
	undehydrated	61.07 ± 0.41	101.63 ± 0.35	67.86 ± 0.47	109.54 ± 0.31	69.79 ± 0.29	111.05 ± 0.43
C. olitorius	dehydrated	126.39 ± 0.56	170.65 ± 0.61	124.86 ± 0.39	171.54 ± 0.55	126.93 ± 0.53	171.97 ± 0.50
	undehydrated	110.10 ± 0.46	153.70 ± 0.49	121.21 ± 0.38	168.79 ± 0.39	125.74 ± 0.44	171.13 ± 0.47

[a] Values are means of four determinations. Mean ± SD.

vegetables subsequent storage conditions would not appreciably affect their ascorbic acid content.

Table IV presents data obtained from the water-blanched and steam-blanched–nondehydrated vegetable leaves kept under different storage conditions. The ascorbic acid content of the products stored under ambient condition was deleteriously affected. A loss of about 54–64% ascorbic acid was recorded after 6 months of storage under ambient temperature (27–30 °C). In addition, within 2 days mold growth on the leaves was observed and a very repulsive odor due to putrefaction also developed increasingly with storage time. Consequently, the product was not fit for human consumption. The depletion in ascorbic acid would be due to leaching and oxidation. Ascorbic acid is very easily oxidized, and if this oxidative process continues beyond the stage of dehydroascorbic acid, it becomes irreversible (Keshinro and Ketitu, 1979). However, various sugars and their corresponding sugar alcohols have been shown to exert protective effects against the aerobic destruction of ascorbic acid (Birch and Pepper, 1983). The steam-blanched leaves retained more ascorbic acid than those that were water-blanched. This was expected. However, there was a slight reduction in ascorbic acid when compared to the leaves that were steam-blanched and dehydrated. There was no appreciable difference in ascorbic acid content of the products stored under refrigeration and freezing conditions. Refrigeration and freezing are effective methods of preserving blanched vegetable leaves not dehydrated. However, in tropical countries, e.g., Nigeria, not every household can afford a refrigerator and/or deep freezer. A relatively simple but effective technique therefore should be used for the preservation of edible vegetable leaves in Nigeria.

The results on the effect of sodium sulfite/sodium metabisulfite on the ascorbic acid content of processed vegetable leaves are presented in Table V. After 2 weeks of storage at 27–30 °C of the nondehydrated leaves, mold growth was observed, and this was followed by a gradual development of off-flavor with storage time. After 1 month of storage under this condition (27–30 °C), the product was found not fit for human consumption. There was an appreciable increase in the retention of ascorbic acid (Tables III and IV) in the leaves. The difference was significant at 5% probability level. Albrecht et al. (1990) reported a strong correlation coefficient of 0.925 between initial ascorbic acid and total sulfur contents in some cruciferous and noncruciferous vegetables. They stated that sulfur-containing compounds might play a role in ascorbic acid content and retention. Sulfur dioxide aided in the retention of ascorbic acid, preserved color and flavor, and increased storage life of the vegetables. In Nigeria, like most tropical countries, the vegetables are used in pre-

paring soup and porridge (e.g., yam porridge). The mode of cooking involved would be enough to release the sulfur dioxide, leaving the product with a wide margin of safety.

CONCLUSIONS

Blanched and dehydrated edible vegetable leaves could be stored for months without deleterious effect on their ascorbic acid content. It was the pretreatment given to the leaves that influenced the level of ascorbic acid retention in them more than the storage conditions they were subjected to. Sodium sulfite/sodium metabisulfite improved the ascorbic acid retention of the processed leaves. Blanching and dehydration with or without sulfiting could be applied in Nigeria for the preservation of edible vegetable leaves.

ACKNOWLEDGMENT

I am grateful to the Heads, Forestry Research Institute of Nigeria, Ibadan, and Department of Food Science and Technology, Obafemi Awolowo University, Ile-Ife, Nigeria, where this investigation was carried out.

LITERATURE CITED

Ajayi, S. O.; Oderinde, S. F.; Osibanjo, O. Vitamin C losses in cooked fresh leafy vegetables. *Food Chem.* **1980**, *5*, 243–247.

Albrecht, J. A.; Schafer, H. W.; Zottola, E. A. Relationship of total sulfur to initial and retained ascorbic acid in selected Cruciferous and Noncruciferous vegetables. *J. Food Sci.* **1990**, *55*, 181–183.

AOAC. *Official Methods of Analysis*, 14th ed.; Association of Official Analytical Chemists: Arlington, VA, 1984; Methods 43.064, 43.065, and 43.067(d).

Baardseth, P.; Slinde, E. Heat inactivation and pH optima of peroxidase and catalase in carrot, swede and brussels sprouts. *Food Chem.* **1980**, *5*, 1969–174.

Birch, G. G.; Pepper, T. Protection of vitamin C by sugars and their hydrogenated derivative. *J. Agric. Food Chem.* **1983**, *31*, 980–985.

Drake, S. R.; Spayd, S. E.; Thompson, J. B. The influence of blanch and freezing methods on the quality of selected vegetables. *J. Food Qual.* **1981**, *4*, 271–273.

Fafunso, M.; Bassir, O. Effect of cooking on the vitamin C content of fresh leaves and wilted leaves. *J. Agric. Food Chem.* **1976**, *24*, 354–357.

Gordon, J.; Noble, I. "Waterless" versus boiling water cooking of vegetables. *J. Am. Dietet. Assoc.* **1964**, *44*, 378–380.

Ifon, E. T.; Bassir, O. The nutritive value of some Nigerian leafy green vegetables - Part 1: Vitamin and mineral contents. *Food Chem.* **1979**, *4*, 263–267.

Imbamba, S. K. Levels of vitamin A and C in some Kenyan vegetable plants. *East Afr. Agric. For. J.* **1977**, *42*, 316–321.

Keshinro, O. O.; Ketiku, A. O. Effect of traditional cooking methods on the ascorbic acid content of some Nigerian leafy and fruit vegetables. *Food Chem.* **1979**, *4*, 303–310.

Kohman, E. F. Enzymes and the storage of perishables. *Food Ind.* **1928**, *8*, 287–289.

Krehl, W. A.; Winters, R. W. Effect of cooking methods on retention of vitamin and minerals in vegetables. *J. Am. Dietet. Assoc.* **1950**, *26*, 966–972.

Luh, B. S.; O'Neal, R. Quality Control. In *Commercial Vegetable Processing*; Luh, B. S., Woodroof, J. G., Eds.; Avi: Westport, CT, 1982; Chapter 13.

Mclellan, K. M.; Robinson, D. S. The effect of heat on cabbage and brussels sprout peroxidase enzymes. *Food Chem.* **1981**, *7*, 257–266.

Oke, O. L. The ascorbic acid content of Nigerian vegetables. *J. Food Sci.* **1967**, *32*, 85–86.

Oke, O. L. Chemical changes in some Nigerian vegetables during growth. *Exp. Agric.* **1968**, *4*, 345–349.

Okoli, E. C.; Nmorka, O. G.; Unaegbu, M. F. Blanching and storage of some Nigerian vegetables. *Int. J. Food Sci. Technol.* **1988**, *23*, 639–641.

Paul, A. A.; Southgate, D. A. T. *McCane and Widdowson's The Composition of Foods*, 4th revised and extended ed.; Elsevier/North-Holland Biomedical Press: Amsterdam, 1988; pp 162–233.

Sreeramulu, N.; Ndossi, G. D.; 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*, 205–210.

Williams, D. C.; Lim, M. H.; Chen, A. O.; Pangborn, R. M.; Whitaker, J. R. Blanching of vegetables for freezing which indicator enzyme to choose. *Food Technol.* **1986**, *40*, 130–140.

Received for review February 8, 1990. Accepted September 11, 1990.

Registry No. Ascorbic acid, 50-81-7; sodium sulfite, 7757-83-7; sodium metabisulfite, 7681-57-4.