

**CHANGES IN BETA-CAROTENE, ASCORBIC ACID AND SENSORY
PROPERTIES IN FERMENTED, SOLAR-DRIED AND STORED COWPEA
LEAF VEGETABLES**

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ABSTRACT

This study was conducted to determine the effect of fermentation, solar drying and packaging on the nutritional, sensory and keeping properties of cowpea leaf vegetables. The cowpea leaves were purchased from the local markets, sorted to remove the blemished, leaves and foreign materials, washed in running tap water then drained. The vegetables were divided into three batches of 16kg. One batch was heat-treated in hot water for 3 minutes then cooled to ambient temperatures, drained and solar-dried. The second portion was acidified to a pH of 3.8, heat-treated, and then solar dried. The third portion was fermented for 21 days, heat-treated, and then solar dried. The three batches of vegetables were spread at different times on drying trays at the rate of 4kg/m² and dried in a solar drier to approximate moisture content of 10%. The dried vegetables were packaged in either polyethylene bags or Kraft company paper bags and stored for three months at 18°C, 22°- 26°C or 32°C.

Fermentation, heat-treating and drying of vegetables retained substantial levels of the vitamins: beta-carotene 91% and ascorbic acid 15%. Storage of the dried vegetables led to loss in both vitamins. The retention of beta-carotene and ascorbic acid at the end of storage, were 23% - 52% and 4% - 7% respectively, depending on storage conditions. Samples stored at 32°C had the highest losses, while those stored at 18°C had the lowest in both vitamins. Samples stored in Kraft paper bags had the highest losses in both vitamins. The duration and temperature of storage and the packaging material did not have significant effect on the sensory attributes of the dried vegetables. Increased acceptability of the fermented-dried vegetables in rural communities would assist in alleviating micronutrient malnutrition, help in dealing with the issue of seasonality and increase food security especially during the dry season.

KEY WORDS: Fermentation, solar-drying, Leafy Vegetables, beta-carotene

INTRODUCTION

Malnutrition due to nutritionally inadequate diets is one of the major concerns in Kenya and many other developing countries [1]. The prevalence rates of micronutrient malnutrition remain high, with devastating consequences for health and productivity [2]. In Africa, people have always depended on traditional leafy vegetables to meet their nutritional needs. The vegetables represent cheap but quality nutrition for large segments of the populations in both urban and rural areas. The vegetables are rich in vitamins especially A, B, and C, and minerals such as iron, zinc, calcium and phosphorus [3].

The cowpea (*Vigna unguiculata* syn *Vigna sinensis*) is one of the most important legumes in Kenya. It is cultivated all over Kenya mainly for seeds but the leaves are a popular local vegetable. The main problem with traditional vegetables is the lack of availability due to seasonality. However, in areas where seasonality is a critical factor in limiting availability, promotion of home gardening and appropriate local preservation technology can improve availability [4].

Fermentation of indigenous foods is considered to be an effective, inexpensive and nutritionally beneficial household technology, especially in the developing world. Likewise, sun drying has been a means of preserving food from earliest times [5]. The main problem with the conventional solar-drying is huge nutritional losses. This study aimed at reducing these nutritional losses by incorporating fermentation into solar-drying. The study also considered the problem of food security, which is devastating during the dry season. The beta-carotene, ascorbic acid and sensory properties of fermented solar-dried cowpea leaf vegetables were assessed.

MATERIALS AND METHODS

Cowpea leaves

The fresh cowpea leaves were purchased from the local markets in the morning and transported quickly to the laboratory of the University of Nairobi's Department of Food Technology and Nutrition. The vegetables were prepared for moisture content, beta-carotene and ascorbic acid analyses. For the fermentation trials, the stalks, withered and dried leaves, weeds, stones and other foreign materials were sorted out from the rest of the vegetables. The vegetables were then thoroughly washed and well drained. They were cut manually with a kitchen knife into slices of approximately 5mm thick.

Determination of optimal levels of salt and sugar for fermentation

To determine the optimal level for salt, the sorted cowpea leaves were divided into equal seven (7) portions and were fermented in lots of 500g. Each lot was mixed thoroughly with 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 or 5.0% concentration respectively of table

salt, followed by tight packing in 4-litre plastic beakers. Fermentation was carried out at ambient temperatures (22° – 26°C). To determine the optimal level for sugar, each sample was mixed with 3% salt (determined as the optimal level of salt for fermentation) and varying percentages of glucose and sugar i.e. 2.5%, 3.0% and 3.5%. The fermentation was carried out for 16 days and replicated two times. Sensory analyses were performed on the fermented vegetables to determine the effect of added sugar on acceptability of the fermented vegetables.

Product manufacture

The fermented-dried vegetables were prepared in comparative trials with control and acidified samples as follows: Procurement and preparation of the raw materials was similar to that carried out during the determination of optimal levels of salt and sugar for fermentation. The amount of the cowpea leaves used was larger. The vegetables were sliced then divided into three equal portions each of 16 kg.

One portion, was thoroughly mixed with 3% salt and allowed to stand for two hours, then heat-treated. This was treated as control sample. The second portion was thoroughly mixed with 3% salt and citric acid (EFF Chemicals Ltd, Kenya) to a final pH of 3.8 and allowed to stand overnight, then heat-treated. This was treated as an acidified sample. The third portion was thoroughly mixed with 3% salt and 3% sucrose, which were then tightly packed well in a 60-litre plastic bucket. The salted and sugared vegetable sample was allowed to stand for 10 minutes before a polyethylene bag full of water was placed inside the bucket as a weight to ensure that the vegetables were immersed under the brine and fermented for 21 days. After fermentation, the sample was heat-treated.

Dehydration and Storage

The fermented, acidified and control vegetable samples were heat-treated by boiling in their own liquor at 90° – 95°C for 3 minutes. Each vegetable sample was cooled and drained immediately after heat-treating and loaded onto a solar drier with shade provision [6]. The vegetables were spread on trays at the rate of 4kg/m² and the trays inserted into the drier. They were then dried until the weight was constant, which took on average 5 days. Samples were taken for beta-carotene, ascorbic acid and sensory analyses.

The fermented-dried vegetables were packaged in either kraft or polyethylene paper. Each package contained 50g of the fermented-dried vegetables. The packaged products were stored at: 32°C, ambient temperatures (22° – 26°C) and 18°C in enclosed dry places for three (3) months.

From each batch, one polyethylene and one kraft paper bags were opened each month and the vegetables analyzed for ascorbic acid and beta-carotene. Two bags were used every month for sensory evaluation. The fermented-dried vegetables were prepared in

comparative trials with control and acidified samples as shown in Figure 1. The experiments were replicated twice.

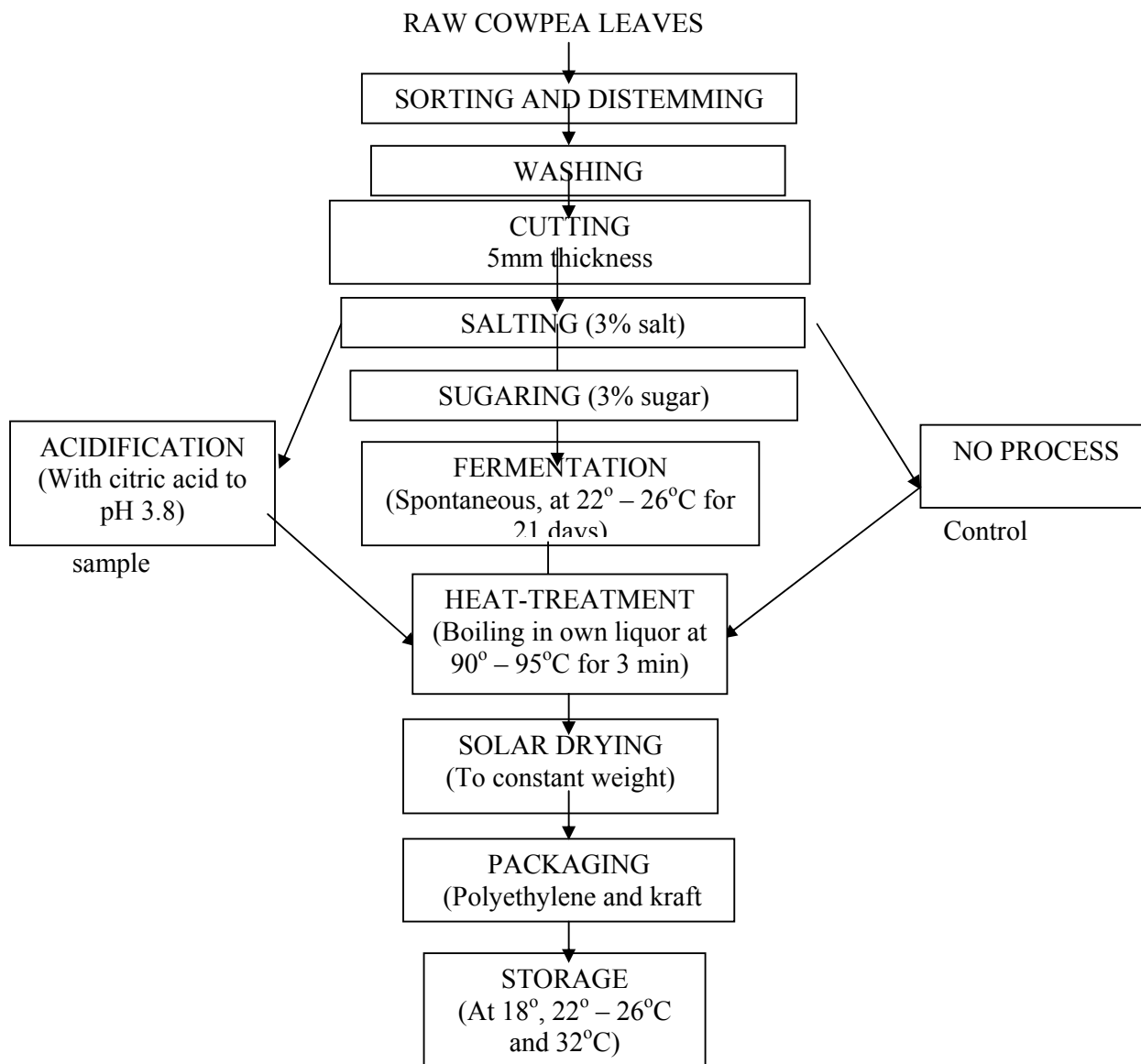


Figure 1. Product manufacture flow diagram.

Vitamins Analyses

Moisture content of fresh vegetables was determined by accurately weighing 5g of the sample and drying in an air oven at 105°C to constant weight [7]. The loss in weight

of the sample was calculated as moisture content. Vitamin A was determined as beta-carotene by the following method:

One gram of the sample was ground in a mortar and pestle in admixture with some acid-washed sand and then extracted completely with acetone. The volume of the combined extracts was raised to 50ml by adding acetone, then dewatered with anhydrous sodium sulphate. Twenty-five millilitres of this extract were evaporated to near dryness in a rotary vacuum evaporator. The separation was carried out in a chromatographic column packed with silica gel. The evaporated sample was dissolved in 2mls of petroleum spirit (40° – 60°C), then quantitatively spotted into the column, and eluted with petroleum spirit. The first yellow eluate was collected in a 25ml flask and made to the mark with the petroleum spirit.

The optical densities of the beta-carotene fraction was measured at 450nm using a CE 440 UV/Vis Double Beam Scanning Spectrophotometer, that had been calibrated with standard solutions of pure beta-carotene in petroleum spirit. The results were calculated as beta-carotene equivalents [9]. Ascorbic acid was determined by titration with 2, 6-dichlorophenolindophenol dye [7]. Ten gram of the sample were extracted in 30ml of 5% oxalic acid in a mortar and pestle, and then filtered. Standard indophenol solution was prepared by dissolving 0.05g of 2, 6-dichlorophenolindophenol in distilled water, diluted to 100ml and filtered.

Ascorbic acid standard solution was prepared by dissolving 0.05g of pure ascorbic acid in a small volume of 5% oxalic acid solution and then diluted to 250ml with the same oxalic acid solution. Ten millilitres of the ascorbic acid standard solution was titrated with the Indophenol solution to a slight pink end point. Ten millilitres of oxalic acid was titrated as a blank. The amount of ascorbic acid corresponding to 1ml of Indophenol solution was then calculated. Ten millilitres of the filtered sample extract was pipetted into a 50ml flask and made to the mark with the 5% oxalic acid solution. It was filtered quickly through glasswool after the first few millilitres of the filtrate were discarded. The standard Indophenol solution was used to titrate 10ml of the filtrate. The vitamin C content was calculated as mg/100g sample.

Sensory Evaluation

Sensory evaluation was performed on the fermented vegetables during the second preliminaries; and on dried fermented vegetable samples. Taste panelists, familiar with the taste of cooked cowpea leaves, assessed organoleptic quality characteristics such as appearance, colour, flavour, texture and overall acceptability. The test compared dried cooked, acidified-dried cooked and fermented–dried cooked vegetables. For presentation to panel members the dried vegetables were prepared as follows: Ten grams of finely chopped onions were weighed into an aluminium pot with 10g shortening.

The container was then heated on an electric plate at medium heat setting until the onions turned golden brown in colour. 100g of the fermented-drained (for the

preliminaries testing) or rehydrated leaves (for the dried samples) and 1g salt were added. The ingredients were thoroughly mixed and 150ml of water added. The pot was covered and heating continued for 10 minutes with occasional mixing of the vegetables. The heating setting was changed to low and vegetables simmered for another 10 minutes. The vegetables were then presented to the panelists as an accompaniment for *ugali* (a maize meal paste) and as coded randomized duplicates such that each taster had 6 samples, 3 products for testing. The panelists were asked to score the sensory attributes of the samples on a seven point hedonic rating scale with 1 = dislike very much and 7 = like very much.

Data analysis

All the experiments were arranged in a completely randomized factorial design with three main treatments of fermented vegetables, acidified vegetables and control vegetables. The sub-treatments were: two types of packaging material: Kraft paper and polyethylene, three different storage temperatures, i.e. 18°C, 22° – 26°C and 32°C and three different lengths of storage, for one month, two months and three months. The experiments were replicated twice. All data were then subjected to analysis of variance (ANOVA) and means were separated by Duncan Multiple Range Test using Genstat 6th Edition and Costat Statistical Software Programmes.

RESULTS

The levels of beta-carotene and ascorbic acid for raw, fermented-, acidified- and control-dried cowpea leaves are given in Table 1. The levels of ascorbic acid in the fermented, acidified and control-dried samples were significantly different ($P < 0.05$) from those of the raw cowpea leaves. There was no significant difference between the raw, the fermented-, the acidified- and the control-dried samples in beta-carotene content, though the raw sample levels were slightly higher.

The retention of beta-carotene during storage of fermented-, acidified- and control-dried cowpea leaves is presented in Figure 2. For the fermented-dried sample [Fig. 2 (a)], 100% represents 29.5mg of beta-carotene, the quantity present in 100g (dry weight basis) of fermented-dried cowpea leaves before storage. Loss during the first and second months of storage was higher than in the third month for samples stored in Kraft-paper bags, whilst for samples stored in polyethylene bags, the loss was higher during the first month and slight during the second and third months. The loss in beta-carotene was highest for the samples stored at 32°C and decreased with decrease in storage temperature. The higher the temperature of storage, the higher was the loss in beta-carotene. At the end of three months storage, the retention ranged between 7.6mg (sample stored at 32° C and packaged in Kraft- paper bag [32CK]) and 17.4mg/100g on dry weight basis (sample stored at 18°C and packaged in polythene bag [18CP]). At each storage temperature, the retention of beta-carotene was higher for samples stored in polyethylene bags than in samples stored in Kraft-paper bags.

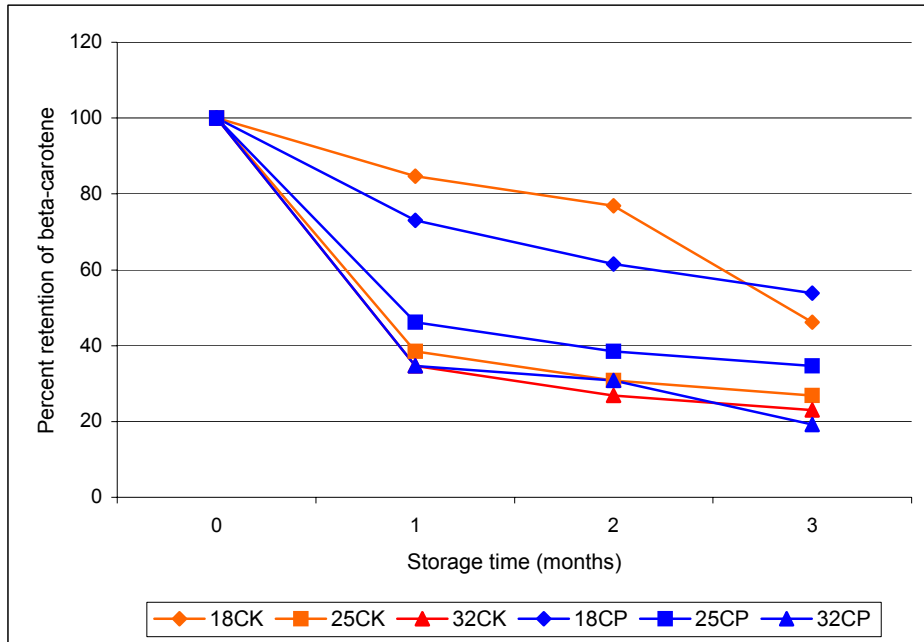


Fig. 2 (b): Retention of beta-carotene in acidified-dried cowpea leaves during storage for three months.

For acidified-dried sample, 100% represents 19.7mg/100g (dry weight basis) of beta-carotene [Fig. 2 (b)]. Loss of beta-carotene during the first month of storage was higher than in the second and third months. The loss in beta-carotene was highest for samples stored at 32°C and the losses decreased with decrease in storage temperature. At the end of the three months, the retention ranged between 0.5 for sample stored at 32°C and packaged in polyethylene bag and 1.4mg/100g (dry weight basis) for sample stored at 18°C and packaged in polyethylene bag. For the control-dried sample, 100% represents 18.9mg/100g (dry weight basis) beta-carotene [Fig. 2 (c)]. Percent loss of beta-carotene was highest during the first month of storage but decreased as storage period increased for all the samples. At each temperature of storage, the loss was higher for samples packaged in polyethylene bags than for those packaged in kraft-paper bags. At the end of the three months of storage, the retentions ranged between 1.5mg for sample stored at 32°C and packaged in polythene bag and 6.8mg/100g (dry weight basis) for sample stored at 18°C and packaged in Kraft-paper bag.

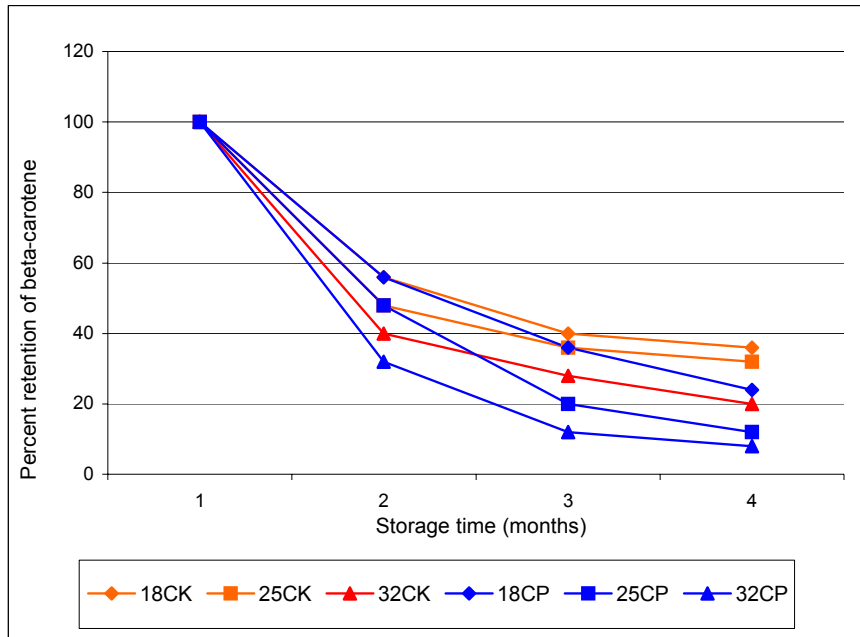


Fig. 2 (c): Retention of beta-carotene in control-dried cowpea leaves during storage for three months.

The retention of ascorbic acid during storage of fermented-, acidified- and control-dried cowpea leaves is presented in Figure 3. For fermented-dried sample, [Fig. 3 (a)] 100% represents 44.7mg ascorbic acid per 100g (dry weight basis) of fermented-dried cowpea leaves before storage. The percent loss was highest during the first month of storage, and was least during the third month for the samples. The total loss in ascorbic acid was highest for samples stored at 32°C and decreased with decrease in storage temperature. The samples stored in Kraft-paper bags had higher loss compared to those stored in polyethylene bags at each storage temperature. At the end of three months, the retentions ranged between 11.4mg for sample stored at 32°C and packaged in Kraft-paper bag and 22mg/100g (dry weight basis) for sample stored at 18°C and packaged in polyethylene bag.

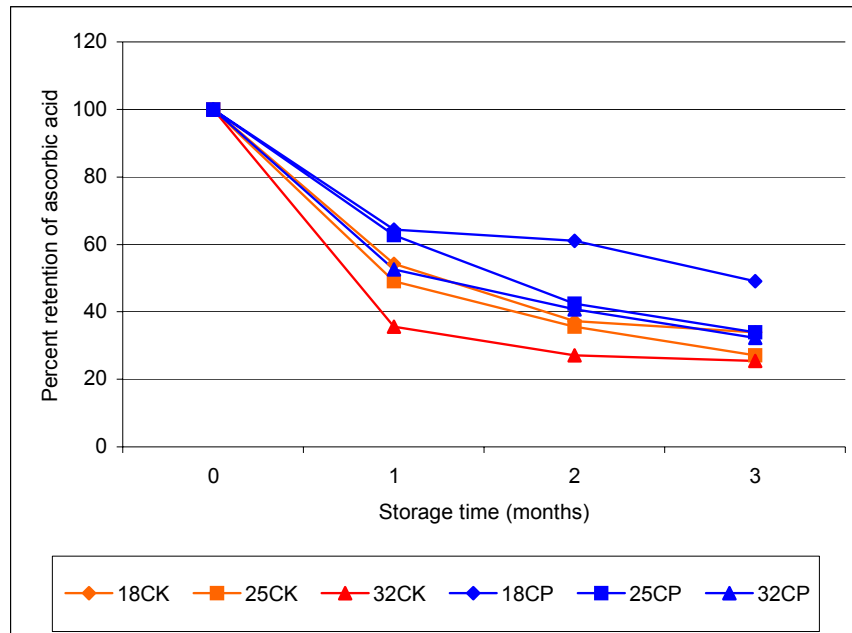


Fig. 3 (a): Retention of ascorbic acid in fermented-dried cowpea leaves during storage for 3 months.

For acidified-dried sample [Fig. 3 (b)] 100% represents 52.3mg/100g (dry weight basis) ascorbic acid before storage. The highest percent loss was in the first month of storage for all the samples. The total loss in ascorbic acid was highest for the samples stored at 32°C and decreased with decrease in storage temperature. At the end of the storage period, the retentions ranged between 12.1mg for sample stored at 32°C and packaged in Kraft-paper bag and 22.7mg/100g (dry weight basis) for sample stored at 18°C and packaged in polyethylene bag.

For control-dried samples [Fig. 3 (c)] 100% represents 42.4mg/100g (dry weight basis) ascorbic acid before storage. The control-dried sample had the highest percent loss in ascorbic acid. Hence we can conclude that fermentation and acidification resulted in better retention of ascorbic acid. In the first month of storage the samples experienced the highest loss in ascorbic acid, and the third month showed least loss. The loss in ascorbic acid was highest for samples stored at

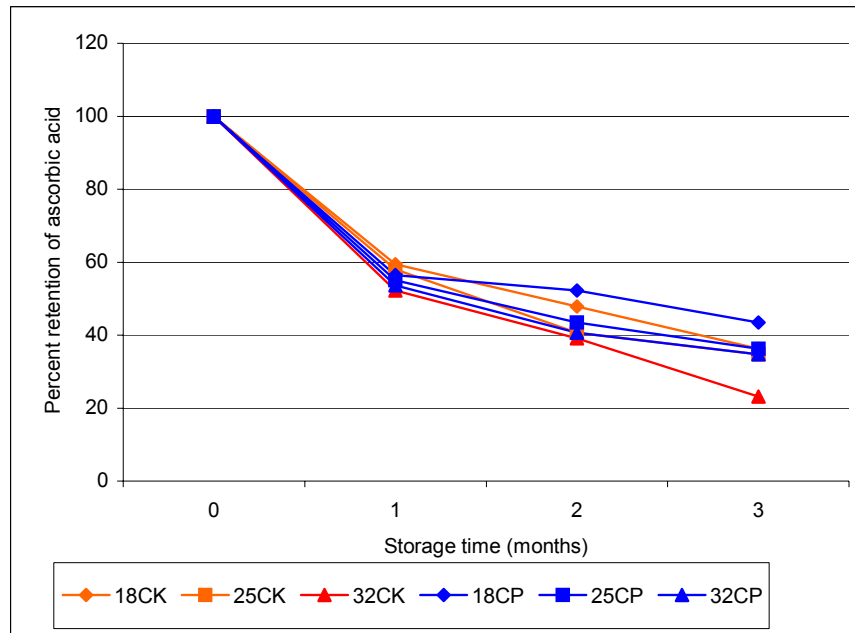


Fig. 3 (b): Retention of ascorbic acid in acidified-dried cowpea leaves during storage for 3 months.

32°C and decreased with decrease in storage temperature. At the end of the third

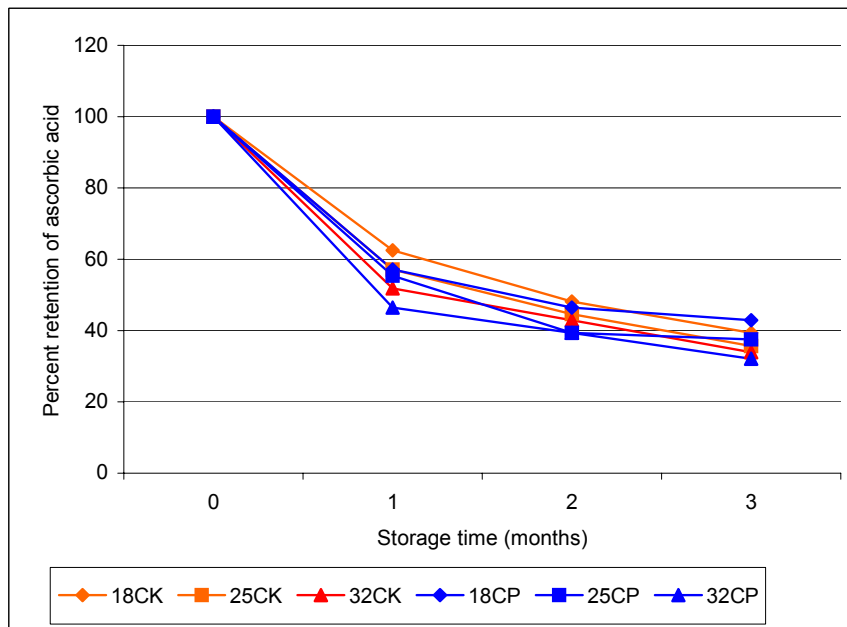


Fig. 3 (c): Retention of ascorbic acid in control-dried cowpea leaves during storage for 3 months.

month, the retention ranged between 13.6mg for sample stored at 32°C and packaged in Kraft-paper bag and 18.2mg/100g (dry weight basis) for sample stored at 18°C and packaged in polyethylene bag.

Sensory evaluation was carried out immediately after drying and after the third month of storage. The panelists' mean scores for appearance, colour, flavour, texture and overall acceptability of the fermented, acidified and control samples immediately after drying are presented in Table 2. The acidified-dried sample had significantly higher ($P < 0.05$) scores for appearance, flavour and colour than the fermented-dried sample. The scores for texture and overall acceptability were not significantly different. However, all the scores were above neither like nor dislike category. Table 3 gives a summary of sensory evaluation mean scores at the end of storage. The results showed that packaging in either Kraft-paper bags or polyethylene bags does not have significant effect on the sensory attributes. The temperature of storage also, had no significant effect on the sensory attributes. Fermentation or acidification did not significantly affect the sensory attributes of the samples.

DISCUSSION

The levels of beta-carotene and ascorbic acid for raw cowpea leaves in this study were comparable to values reported by other researchers [10-12]. These results indicate that heat-treating and sun drying of cowpea leaves under shade provision can result in significant reduction in levels of ascorbic acid. Such losses in ascorbic acid during drying have been reported for other vegetables [13]. It is generally recognized that dehydration of leafy vegetables results in losses of vitamins, the extent of loss depending on the type of vegetable [14-15]. There was significant destruction of both beta-carotene and ascorbic acid during heat-treatment and drying. The loss in beta-carotene, during processing, could have resulted from the heat-treatment. It has been reported that at high temperatures, the long chain polyunsaturated carbons undergo isomerization from the trans to the cis form, leading to loss of the vitamin activity [19]. The loss in ascorbic acid could have resulted from leaching during heat-treating, effects of the processing temperatures or due to enzymatic and chemical degradation especially in the presence of traces of heavy metal ions [20- 22, 14]. Nevertheless, the destruction would have been more pronounced if the drying were done without shade provision [16-18].

The Recommended Dietary Allowance (RDA) of ascorbic acid for adults is 30mg/day and 20mg/day for children. Therefore, consumption of 10g of fermented-dried cowpea per day can provide approximately 15% and 22.5% of RDA of ascorbic acid for adult and children respectively. Consumption of 10g of fermented-dried cowpea leaves per day would also provide more than 100% of RDA of beta-carotene for adult and children, as the group needing the highest levels require 750µg/day.

The high levels of beta-carotene loss during the first month of storage could have resulted from oxidation by the oxygen retained in the package which was obviously more during the first month than in the other months. Losses of beta-carotene in

stored dehydrated vegetables are usually due to oxidation mainly by the oxygen retained in the package and catalyzed by light [15]. It has been reported that losses of beta-carotene in stored dehydrated vegetables are usually due to oxidation. Hence, Kraft-paper being permeable to air, could have contributed to the higher losses in samples stored in Kraft paper compared to those packaged in polyethylene-paper which is impermeable.

The loss of beta-carotene during storage in the acidified sample was higher than that of the fermented sample. We can conclude that fermentation had a positive effect on the retention of the beta-carotene. Among the three samples, the control sample had the greatest loss in beta-carotene during storage. It can be concluded that both acidification and fermentation had a positive effect on the retention of beta-carotene. It has been reported that light and oxidants catalyze the oxidation of beta-carotene in stored dehydrated vegetables causing great losses [15]. This fact could have contributed to the higher losses in polyethylene-paper packaged samples compared to the Kraft paper packaged samples. Kraft-paper being opaque whereas polyethylene-paper is transparent could have contributed to these differences. Similar losses of beta-carotene in dried leaf vegetables have been reported by other researchers [17]. It is therefore recommended that dehydrated vegetables be stored away from direct sunlight.

The high rate of ascorbic acid loss during the first month of storage as compared to the second and the third months was probably due to the effect of the residual oxygen retained in the packaging material during the initial packaging [13]. As storage progressed, the residual oxygen in the package decreased and therefore the rate of oxidation of ascorbic acid also decreased. Such trends in the loss of ascorbic acid during storage of fruits and vegetables have been reported by other researchers [23; 24]. One researcher observed that the ascorbic acid content of stored products generally decreases more rapidly at higher storage temperatures [25]. He concluded that conservative processing and low storage temperature are critical for ascorbic acid retention. The fact that samples stored in Kraft-paper bags had higher loss compared to those stored in polyethylene bags at each storage temperature, was probably due to gas permeability of the Kraft-paper, leading to more oxidation of the ascorbic acid compared to the polyethylene bags. These results leads one to the conclusion that, fermentation and acidification resulted in better retention of ascorbic acid because the control-dried samples had the highest percent loss in ascorbic acid. Also that, acidification led to better retention of ascorbic acid than fermentation.

The sensory evaluation scores indicated that the consumers could easily accept the fermented product, as its sensory attributes do not significantly differ from those of the control sample. The storage of the dried cowpea leaves did not significantly affect their sensory attributes either, considering the results obtained for freshly dried cowpea leaves (Table 2). Thus, storage for three or so months would not lower the sensory attributes of the dried vegetables, but would ensure they are available for consumption for longer periods. This could help in reducing seasonality of the vegetables and increasing food security. It is recommended that:

1. A microbiological study should be carried out to ascertain which specific species of microorganisms are involved in fermentation of cowpea leaf vegetables to give a uniform product and for large-scale production.
2. A study should be carried out on the storage of the dried vegetables in other types of packaging material, especially those that are conventionally used by communities to store dry foods and on other popular traditional vegetables.
3. Storage of the dried vegetables should be carried out for longer periods than the three months in this study.
4. Lastly, this technology being cheap and effective should be transferred to the local communities and women groups for preservation of seasonal vegetables like cowpeas. Together with it, the promotion for increased acceptability and consumption of the fermented and dehydrated vegetables should be done among the rural communities, where the deficiency of vitamin A and iron is likely to be rampant during the period of drought.

TABLE 1

Beta-carotene and ascorbic acid contents of raw, fermented- acidified- and control-dried cowpea leaves expressed in mg/100g edible portion on dry matter basis

Sample	Ascorbic acid	Beta-carotene
Raw	308 ± 14 ^a	33 ± 12 ^a
Fermented-dried	45 ± 9 ^b	30 ± 4.5 ^a
Acidified-dried	52 ± 6.8 ^b	20 ± 1.5 ^a
Control-dried	42 ± 7.6 ^b	19 ± 1.5 ^a
L. s. d.	163.3	17.12

Mean ± Standard Deviation (n =4)

Means within columns superscripted by the same letter are not significantly different at (P<0.05).

TABLE 2

Mean scores for sensory attributes for freshly processed cowpea leaves.

Sensory attributes	Fermented-dried sample	Acidified-dried sample	Fresh-dried sample	L. s.d
Appearance	4.7 ^b	5.3 ^a	5.2 ^{ab}	0.54
Colour	4.7 ^b	5.3 ^a	5.3 ^a	0.49
Flavour	4.3 ^b	5.2 ^a	5.1 ^{ab}	0.74
Texture (Mouth feel)	4.6 ^a	4.4 ^a	4.7 ^a	0.80
Acceptability	4.8 ^a	5.3 ^a	5.3 ^a	0.58

Means within rows superscripted by the same letter are not significantly different at (P<0.05)

TABLE 3

Mean scores for sensory attributes after three months of storage

Attribute	Storage condition	Fermented-dried	Acidified-dried	
	Control-dried	sample	sample	
Appearance 5.8 ^{ab} (L.s.d. 0.92)	18°C (Kr)	4.3 ^d	4.8 ^{bcd}	
	18°C (Po)	4.8 ^{bcd}	5.3 ^{abcd}	6.1 ^a
	25°C (Kr)	4.6 ^{cd}	5.0 ^{abcd}	
	25°C (Po)	5.3 ^{abcd}	5.1 ^{abcd}	
	32°C (Kr)	5.5 ^{abc}	5.6 ^{abc}	
	32°C (Po)	4.9 ^{bcd}	5.6 ^{abc}	
	5.8 ^{ab}			
Flavour 5.0 ^{abc} (L.s.d. 1.06)	18°C (Kr)	3.6 ^e	3.7 ^{de}	
	18°C (Po)	4.5 ^{abcde}	4.3 ^{cde}	
	25°C (Kr)	5.1 ^{abc}	4.6 ^{abcde}	
	25°C (Po)	5.3 ^{abc}	5.2 ^{abc}	
	32°C (Kr)	5.5 ^{abc}	5.5 ^{abc}	
	32°C (Po)	5.1 ^{abc}	5.3 ^{abc}	5.7 ^a
	4.8 ^{abcd}			
Texture 5.0 ^{ab} (L.s.d. 1.04)	18°C (Kr)	4.7 ^{abc}	3.9 ^{bc}	
	18°C (Po)	4.3 ^{abc}	3.5 ^c	
	25°C (Kr)	4.8 ^{ab}	4.3 ^{abc}	
	25°C (Po)	4.9 ^{ab}	4.8 ^{ab}	
	32°C (Kr)	5.5 ^a	4.9 ^{ab}	
	32°C (Po)	5.0 ^{ab}	4.1 ^{bc}	
	4.5 ^{abc}			

Overall	18°C (Kr)	4.6 ^{cde}	4.2 ^e	
5.3 ^{ab}				
Acceptability	18°C (Po)	4.7 ^{cde}	4.8 ^{cde}	
5.5 ^{abc}				
(L.s.d. 0.82)	25°C (Kr)	5.2 ^{abcd}	4.9 ^{bcde}	5.9 ^a
	25°C (Po)	5.4 ^{abc}	5.3 ^{abc}	
4.3 ^{de}				
4.9 ^{bcde}	32°C (Kr)	5.8 ^{ab}	5.4 ^{abc}	
	32°C (Po)	5.1 ^{abcde}	5.3 ^{abc}	5.9 ^a

Means for an attribute superscripted by the same letter are not significantly different at P<0.05

Key: Kr : Kraft-paper bags

Po: Polyethylene bags

ABBREVIATIONS

In all the graphs the following abbreviations apply:

- 18CK - Sample stored at 18°C and packaged in Kraft paper bag.
- 25CK - Sample stored at 25°C and packaged in Kraft paper bag.
- 32CK - Sample stored at 32°C and packaged in Kraft paper bag.
- 18CP - Sample stored at 18°C and packaged in polyethylene bag.
- 25CP - Sample stored at 25°C and packaged in polyethylene bag.
- 32CP - Sample stored at 32°C and packaged in polyethylene bag.

REFERENCES

1. **Imungi JK and NN Potter** Nutrient Content of Raw and Cooked Cowpea Leaves. *Journal of Food Science*, 1983: **48**: 1252-1254.
2. **Underwood BA** Overcoming Micronutrient Deficiencies in Developing Countries: Is there a role for Agriculture? **In:** Food and Nutrition Bulletin, United Nations University Press. Tokyo, Japan. 2000: **21** (4).
3. **Mnzava NA** Comparing Nutritional Values of Exotic and Indigenous Vegetables. 1997: Pp 70-75. **In:** African Indigenous Vegetables proceedings of the NRI/IPGRI/CPRO Workshop, Limbe, Cameroon (Eds.) R S Schippers and L Budds. ODA, UK.1997: Jan. 13 – 28.
4. **Nest KP and A Sommer** Delivery of Oral Doses of Vitamin A to Prevent Vitamin A Deficiency and Nutritional Blindness a State-of-the-art review. Government of Netherlands. 1993.
5. **Mehas KY and SL Rodgers** Fermentation and food. **In:** Food Science and You. Macmillan/ McGraw-Hill. 1989.
6. **Kordylas JM** Processing and Preservation of Tropical and Subtropical Foods. Macmillan Publishers Ltd. London. 1990.
7. **AOAC** *Official Methods of Analysis*. 14th edition, Association of Official Analytical Chemists, Washington D.C. 1984.
8. **Astrup HN, Harbosen ES, Linstad P, Yvonne E, Mathews JC** A quick method for the simultaneous assay of tocopherol, carotene and plant pigments. Publication No. 373, Institute of Animal Nutrition, Agricultural Institute of Norway. 1971.
9. **Imungi JK and MN Wabule** Some Chemical Characteristics and availability of Vitamin A and Vitamin C from Kenyan varieties of Papayas (*Carica papaya L.*) *Ecology of Food and Nutrition*, 1990: **24**: 115 – 120.
10. **Onyango MA, H Obiero and M Miruka** Indigenous Green Leafy Vegetables in Kenya: A Case of a Neglected Resource. **In:** Participatory Technology Development for Soil Management by Smallholders in Kenya. KARI. Kenya. 2000.
11. **Bubenheim DL, Mitchell CA and SS Nielsen** Utility of Cowpea foliage in a Crop Production System for Space: 535-538. **In:** J Janick and J E Simon (Eds). Advance in New Crops. Timber Press, Portland, OR. 1990.

12. **Mandu PM and CHS Kabuye** Indigenous Food Plants Programme. **In:** Participatory Technology Development for Soil Management by Smallholders in Kenya. KARI. Kenya.1993.
13. **Mziray RS, Imungi JK and EG Karuri** Changes in Ascorbic Acid, Beta-Carotene and Sensory Properties in Sun-dried and Stored *Amaranthus hybridus* Vegetables. *Ecology of Food and Nutrition*, 2000: **39**: 459-469.
14. **Belitz HD** Food Chemistry. 2nd Edition. *Springer Verlag* Berlin. Heidelberg, Germany. 1987: 549 – 576.
15. **Gareth LO Gisela and M Rui** Productions of a carotenoid-rich product by alginate entrapment and fluid-bed drying of *Dunaliella salina*. *Journal of Science Food Agric.* 1998: **76**: 298 – 302.
16. **Mudambi RS** Effects of storage on ascorbic acid content of orange. *Journal of Food Technology*, 1977: **12**, 639 – 641.
17. **Gomez MI** Carotene content of some green leafy vegetable of Kenya and effects of dehydration and storage on carotene retention. *Journal of Plant Foods*. 1981: **3**: 231 – 234.
18. **Maeda EE and DK Salunkhe** Retention of ascorbic acid and total carotene in solar dried vegetables. *J. of Food Sci.* 1981: **46**: 1288 – 1290.
19. **Tannenbaum SR** Vitamins and Minerals. **In:** Principles of Food Science, Part I – Food Chemistry. Comm.54, Dept. Agric. Res. 1976.
20. **Labuza TP** Nutrient losses during drying and storage of dehydrated foods. CRC– Critical Reviews. *Journal of Food Tech.* 1972: **3**: 217 – 219.
21. **Ana MR and NG Lia** Influence of system composition on ascorbic acid destruction at processing temperatures. *Journal of Science of Food Agric.* 1997: **74**: 369 –378.
22. **FAO.** *Fruits and vegetables processing* FAO Agricultural services Bulletin 119. Food and Agricultural Organisation of the United Nations, Rome, 1995.
23. **Smooth JM and SN Nagy** Effects of storage temperature on total vitamin C content of canned single strength grape fruit juice. *Food Science Technology Abstract*, 1979: **10** (1), 1 - 70.
24. **Philip ES and GM Manuel** Ascorbic acid retention on Orange Juice stored under simulated consumer home conditions. *J. of Food Sci.*, 1991: **56** (3), 867- 868.

25. **Barth MM, Perry AK, Schmidt SJ and BP Klein** Misting effects on ascorbic acid retention in broccoli during cabinet display. *J. of Food Sci.* 1990: **55**:4, 1187 – 1188.