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## Sensory and storage qualities of elephant grass (*Pennisetum purpureum*) shoots packed in citric acid

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### ABSTRACT

Elephant grass (EG) shoots can make useful contribution in human nutrition. Nutrient-rich EG (1.0 g protein, 0.12% Ca, 0.07% P, 182-221 µg /g carotene, 195-260 µg/g α-tocopherol) is distributed in tropical countries such as Africa, South America, southern United States, Puerto Rico and Philippines. Tender EG shoots are predominantly utilized fresh and this limits its availability and shelf-life. This study examined the sensory and storage characteristics of EG cuts preserved in two media. Blanched EG cuts packed in 1% (w/v) citric acid or NaCl were vacuum-sealed in 300 × 208 enamel cans, heat-processed in a vertical retort for 15, 20, 25, 30 min at 115.6°C and stored for 0-3 months. Sensory and microbial properties of canned EG cuts were evaluated monthly for 3 months using standard protocols and its optimum processing conditions (20 min, 115.6°C, 1% (w/v) citric acid, 300 × 208 can size) were established. After 3 months shelf storage, evidence from microbial assay of canned EG cuts showed no growth in the citric acid-packed samples while NaCl-packed cuts had some microbial growth in a decreasing trend as heating time increased. Sensory scores (6-point scale) of optimally processed canned EG cuts stored for 3 months showed that cuts packed in citric acid medium had higher sensory scores (colour: 4.69, aroma: 4.14, appearance: 4.63, taste: 3.46, texture: 4.14, acceptability: 4.31) than NaCl-packed cuts (colour: 2.63, aroma: 3.17, appearance: 2.57, taste: 5.00, texture: 5.00, acceptability: 2.97) except for taste and texture. This indicates consumer acceptability and good storage quality for citric acid-packed cuts which retained most of its sensory qualities after 3 months. Effectively preserved and stored EG shoots can serve as a shelf-stable veggie product in malnutrition intervention programs for target populations.

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### KEYWORDS

Achara;  
Canning;  
Packing medium;  
Quality.

### INTRODUCTION

Canned vegetables represent the largest segment of the canning industry. Canning is a method of preserving food in air-tight vacuum-sealed containers and

heat processing sufficiently to enable storing the food at normal home temperatures<sup>[1]</sup>. Vegetables, some tomatoes, figures, all meats, fish, mushrooms, seafoods, and some dairy foods are low-acid. The acidity measure of a food that differentiates low-acid (pressure canning)

from high-acid (boiling water canning) is pH 4.6<sup>[2,3]</sup>. Above this invisible fence, low-acid foods must be processed at temperatures of 240°-250°F<sup>[1]</sup> to ensure that anaerobic pathogens (e.g. *Clostridium botulinum* spores) do not grow<sup>[2]</sup>. This temperature range usually dictates heating under pressure subsequent to filling and sealing in hermetic packages.

Canned vegetables can be classified as canned products in salt brine, tomato juice or in vegetable oil<sup>[4]</sup>. They provide a variety of vitamins, minerals, fibre and are low in fat. USDA nutritionists recommend 3 to 5 servings from the vegetable group each day and count as a serving ½ cup cooked vegetable or ¾ cup vegetable juice<sup>[5]</sup>. Vegetables are normally blanched before being packed into cans to (a) remove gas from tissues of the raw material; (b) shrink this material; and (c) inhibit enzymatic reactions, which if not checked, will adversely affect the colour and nutritive value of the food. One study<sup>[6]</sup> on some quality parameters of canned mushroom (colour, weight and grade) using different blanching times and two brines (with and without ascorbic acid) indicated that blanching improved the colour of the mushroom and decreased losses in its weight and grade. In another report<sup>[7]</sup>, green asparagus spears blanched for a short or long period by steam, water or microwave in two different systems showed that spears with similar or higher shear force values and lower vitamin C were obtained by microwave blanching than by steam or water.

Achara (*Pennisetum purpureum*) commonly known as elephant grass belongs to the grass family of gramineae<sup>[8]</sup>. It is grown mainly for the stems and leaves – portions eaten by animals. The fleshy stems are eaten by humans, and are made up of very tender layers of peels which are greenish-white in colour. The degree of tenderness increases as the layers are removed. At optimum maturity, the stems are cut by hand and held in bundles. *Pennisetum purpureum*, widely available in tropical Africa and most countries<sup>[9]</sup>, is a tall, clumped perennial of 3-5 m in height propagated by stem cuttings of 3-4 nodes<sup>[10]</sup>. One hundred grams of fresh elephant grass contains 77.8 g water, 1.0 g protein, 0.5 g fat, 17.6 g total carbohydrate, 3.1 g ash, 0.12% Ca, 0.07% P, 182-221 µg/g carotene and 195-260 µg/g α-tocopherol<sup>[9]</sup>. The main free sugars in elephant grass are glucose, sucrose and fructose, with fructose con-

tent always higher than glucose<sup>[11]</sup>. Achara cuts, predominantly consumed in its fresh form, are used in soups and salads – dishes valued as nutritious delicacies by most consumers. Despite the use of fresh achara shoots as a nutrient-rich food resource in south eastern Nigeria for generations (especially as a remedy for micronutrient deficiency in consumers), there is no report on its preservation or the effect of processing conditions (e.g. canning process) on the chemical, sensory and microbial quality of achara cuts. Therefore this study aims to (a) examine the influence of heating time and packing medium on the quality of canned achara cuts, (b) establish optimum canning conditions for the vegetable, and (c) provide pertinent information on its chemical, microbial and sensory qualities. The canning process turned the highly perishable achara cuts into a safe, nutrient-dense, well-preserved and easy-to-handle vegetable product. Achara shoots are high in moisture and bland in taste, and will not affect the flavour of foods when used as an ingredient. This report highlights the potentials of achara cuts as a high quality canned vegetable product which can meet the nutritional needs of some consumers.

## MATERIALS AND METHODS

### Source of materials and sample preparation:

All chemicals (NaCl, CaCO<sub>3</sub>, KCl, HNO<sub>3</sub>, citric acid powder, H<sub>2</sub>O<sub>2</sub>, crystal violet stain, iodine solution, acetone-alcohol solution, neutral red) used were certified reagent grade (Fisher Scientific Co., Fairlawn, NJ, USA).

### Raw materials preparation:

Fresh, edible achara shoots were purchased in batches from a market in Umuahia, Nigeria. Samples collected from each batch were thoroughly washed and peeled manually to carefully remove the tough, wild peels. The fleshy, tender achara cuts of desired lengths (about 1-2 cm) were obtained manually from the peeled shoots.

### Packing medium:

Two packing media A (10g citric acid/1000 mL tap water) or S (10g NaCl/1000 mL tap water) were used in this study. The use of tap water was considered appropriate since this is the conventional water used in most commercial food productions.

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### Canning of achara and experimental design

Achara batches used for canning were randomly divided into four sample lots. Each sample lot was processed under four conditions (salt brine; citric acid solution; water; fresh sample served as control) and each treatment was replicated 3 times. The experiment was conducted in two stages. In stage one, a series of experiments were conducted to produce canned achara cuts and characterize the vegetable product in terms of its sensory, microbial and chemical properties. The study examined 3 fixed and 2 variable factors. The 2 variable factors in 8 experiments include heating time (15, 20, 25, 30 min) and packing medium (brine, citric acid solution) while the 3 fixed factors include can size 300 × 208 (3 inch diameter × 2 ½ inch height), processing temperature (115.6°C) and packing medium concentration (1%, w/v). Because achara is a low acid food with pH > 5.0 and very high water activity, its sterilization was performed at 115.6°C (240°F) to ensure the destruction of *C. botulinum* and its spores. USDA<sup>[1]</sup> stipulated that the canning temperatures for low acid vegetables, meat and poultry in a pressure canner are 240°-250°F. A combination of acceptable quality characteristics (e.g. microbial load, sensory score, packing medium, heating time) was used to determine the optimum conditions for canning achara cuts. In stage two, experiments were carried out to verify the optimum processing conditions (115.6°C, 1% (w/v) citric acid, 20 min, 300 × 208 can size) for canned achara cuts obtained in stage one (i.e. confirmatory tests were performed at these optimum conditions). Achara cuts canned in water without storage and fresh achara samples served as control.

For the canning operation, respective sample portion was blanched in hot water for 2-3 min at boiling water temperature (≥100°C) and the hot-blanch water decanted. The respective packing medium (brine or citric acid solution) was heated to boil. The blanched achara cuts were filled into thoroughly washed and sterilized 300 × 208 cans while each heated packing medium was poured separately into the respective filled cans, and quickly sealed in a hand sealer (model 23H; Dixie Canner Co., Athens, GA, USA). The sealed cans were immediately sterilized in a stainless steel vertical retort (model 921; All American Pressure Canners,

Hillsville, VA, USA) for 15 min at 115.6°C (240°F). The remaining sample lots were processed as described above but at different times: 20, 25, 30 min. At the end of each operation, the cans were cooled in cold tap water, hand-dried, labelled and stacked for storage. This operation was conducted in batches and achara cuts canned in brine or citric acid solution were stored for 1, 2, 3 months prior to respective quality assessment. All experimental parameter measurements were done in triplicates.

### Chemical assessment

All measurements were done in triplicates. The Official Methods of Analysis<sup>[12]</sup> was used to determine the proximate and mineral (Ca, Na, K) composition of canned achara cuts. Carbohydrate was determined by difference (by subtracting the other values from 100). Energy was calculated from proximate composition according to standard method<sup>[13,14]</sup>.

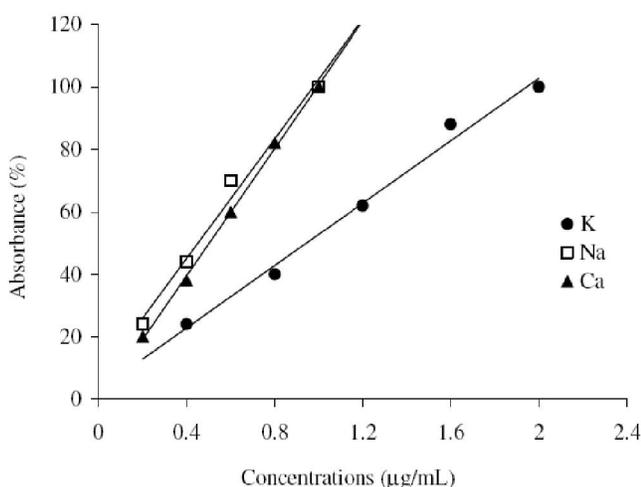
For mineral content: the standard curves for the three minerals (Figure 1) were calibrated by using various concentrations of standard CaCO<sub>3</sub>, NaCl and KCl solutions. Exactly 0.62g CaCO<sub>3</sub> powder, 0.32g NaCl and 0.48g KCl powder were separately dissolved, first in 12.5 mL 1N HCl and later in 500 mL deionised water in separate 500 mL volumetric flasks. Final dilutions containing 0.2, 0.4, 0.6, 0.8 and 1.0 µg/mL CaCO<sub>3</sub> and NaCl were prepared separately by pipetting 1, 2, 3, 4 and 5 mL, respectively, of the working solution with 5 individual 50 mL volumetric flasks. Final dilutions containing 0.4, 0.8, 1.2, 1.6 and 2.0 µg/mL KCl were prepared by pipetting 2, 4, 6, 8 and 10 mL, respectively, of the working solution into 5 individual 50 mL volumetric flasks. The contents of the flasks were made up to volume with deionised water. Each sample dilution was read against a blank in a Sherwood flame photometer, model 410 (Sherwood Scientific Ltd., Watford Herts, UK). The percent absorbance obtained was used to obtain the standard curves shown in Figure 1.

Exactly 0.5g of finely-ground oven dried sample was weighed into a crucible; then it was ignited in a muffle furnace for 6-8 hr (or overnight) at 450-500°C to obtain greyish ashes. It was cooled and 5 mL of 1 N HNO<sub>3</sub> solution were added and evaporated to dryness on a steam bath or hot plate (at low heat in a fume

chamber). The sample was returned to the furnace, heated at 400°C for 10-15 min until a white or greyish-white ash was produced and cooled. Exactly 100 mL of 1 N HCl were added and filtered into a 50 mL volumetric flask. The filter paper and crucible were further washed with 0.1 N HCl to make up to mark. The absorbance of the samples was read using a flame photometer. The sodium, potassium and calcium concentrations were calculated from the standard curves (Figure 1).

### Microbial assay

Microbial examination of the canned achara samples



**Figure 1** – Standard calibration curves for potassium, sodium and calcium

was performed after 3 months of storage using the protocols developed by the APHA<sup>[15]</sup> and AOAC<sup>[12]</sup>.

### Plate count method:

Aerobic plate counts (APC) were made by inoculating poured-plates of nutrient agar (using aseptic technique) with 0.01 mL inoculum from the packing media. A sterile wireloop was used to distribute the inoculum evenly over the medium surface. The plates were incubated at 37°C for 24 hr (overnight). The colonies were counted with the aid of a Leica Darkfield Quebec Colony counter, model RE-3325 (Fisher Scientific Inc., Epsom, UK). The total count was calculated as follows:

$$\text{Total count} = \text{colonies counted} \times 1/\text{amount plated} \\ = \text{count/g}$$

### Gram staining:

A thin film of a distinct colony was prepared by

smearing it on the slide with a drop of deionised water. The smear was dried and fixed using a flame, and the slide was flooded with crystal violet stain and allowed to stand for 10 sec. The stain was washed off with iodine solution which was applied for 10 sec; this was rinsed off with running cold water and the remaining stain was decolourized with acetone-alcohol solution. This was counter stained with neutral red for 10 sec, and then rinsed off with water and dried between sheets of blotting paper. The slide was then viewed under a CX21 compound microscope (Olympus UK Ltd., London, UK). The gram positive cells stained purple by the violet-iodine combination while the gram negative cells stained red by the neutral red.

### Identification tests:

Two confirmatory tests were performed as follows:

1) Coagulase test: With the aid of a wire loop, a thin film of the distinct colony was prepared by smearing it on a clean glass slide with a drop of sterile deionised water to form an emulsion. A drop of human plasma (Baxter Healthcare Ltd., Liverpool, UK) was added and further smeared or emulsified. It was observed for agglutination as the presence of agglutination would be positive for *Staphylococcus aureus*. 2) Catalase test: A drop of hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) was put on a clean glass slide and the test organism was picked up with a wireloop and dropped into the  $\text{H}_2\text{O}_2$ . The presence of bubbles shows a positive reaction for *Staphylococcus aureus*.

### Sensory evaluation

The respective canned achara samples (4 cans/soup) were used to prepare separate achara soup (achara cuts are predominantly used in soups). Each achara soup was scored by a 35-member untrained panel for attributes of colour, taste, texture, aroma, appearance and overall acceptability using a 6-point scale where 6 = excellent, 5 = good, 4 = satisfactory, 3 = fair, 2 = poor, and 1 = unacceptable. Analysis of variance was subsequently performed on the data<sup>[16]</sup>.

## RESULTS

### Nutrient composition of canned achara

The nutrient components of canned achara are presented in TABLE 1. The protein content of the samples did

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not show any trend and did not vary very much at different heating times. The results showed a trend in fat content of the canned achara cuts packed in two different media, cuts packed in citric acid solution (2.88%) had higher average fat content than those packed in brine (1.70%). Also shown in TABLE 1 is the average carbohydrate content of brine-packed (12.1%) and citric acid-packed (13.62%) cuts. Fresh achara cuts had higher carbohydrate content (15.38%) than canned cuts. The average energy content of canned achara packed in brine and citric acid solution is 3.19 and 3.95 kJ/g sample, respectively (TABLE 1). Ash content of the canned vegetable product varied among packing media with samples packed in brine (4.88%) higher in ash than those packed in citric acid solution (2.78%).

### Microbial profile of canned achara

Total aerobic plate count (APC) of canned achara cuts is presented in TABLE 2. Results showed no growth in the citric acid-packed samples, confirming the bactericidal efficacy of citric acid. Brine-packed canned achara cuts had microbial growth and the data had a decreasing trend as the processing time increased.

### Sensory characteristics of canned achara

The mean scores of sensory attributes of canned achara cuts are presented in TABLE 3. The results show that citric acid-packed achara cuts are quite acceptable. The colour, aroma, appearance and overall acceptability of the vegetable product did not differ significantly ( $P < 0.05$ ) between heating time (15, 20, 25, 30 min) and storage time (1, 2, 3 months) except for the aroma (3.06) and acceptability (3.74) of 25 min-processed samples stored for 3 months. In contrast, the colour, aroma, appearance and overall acceptability of brine-packed samples differed significantly ( $P < 0.05$ ) between heating and storage times and did not follow any trend.

### Optimum processing conditions for canned achara

Using the data shown in TABLES 1-4, an optimum processing conditions for canned achara cuts was developed. Heating time: 20 min; Processing temperature: 115.6°C; Packing medium: 1% (w/v) citric acid solution; and Can size: 300 × 208 (3 inch diameter × 2 ½ inch height).

**TABLE 1 : Composition of canned (115.6°C, 20 min) achara cuts after 3 months of storage (%)<sup>b</sup>**

| Component     | Packing medium            |              |              |
|---------------|---------------------------|--------------|--------------|
|               | Fresh achara <sup>b</sup> | Salt         | Citric acid  |
| Moisture      | 73.00 ± 1.41              | 78.50 ± 1.63 | 77.50 ± 0.71 |
| Protein       | 3.72 ± 0.14               | 3.28 ± 0.44  | 3.46 ± 0.14  |
| Ether extract | 3.90 ± 0.28               | 1.50 ± 0.39  | 3.65 ± 0.28  |
| Ash           | 4.00 ± 0.14               | 5.15 ± 0.14  | 2.30 ± 0.42  |
| Carbohydrate* | 15.38 ± 0.54              | 11.57 ± 0.76 | 13.09 ± 0.04 |
| Energy (kJ/g) | 4.67 ± 0.03               | 3.05 ± 0.17  | 4.15 ± 0.28  |
| K (mg/g)      | ND                        | 10.00 ± 0.71 | 27.00 ± 0.71 |
| Na (mg/g)     | ND                        | 28.00 ± 0.71 | 14.00 ± 0.66 |
| Ca (mg/g)     | ND                        | 0.08 ± 0.03  | 0.08 ± 0.02  |

<sup>b</sup>Mean ± SD; \*By difference; ND = Not determined.

**TABLE 2 : Total plate counts (bacteria) of canned achara cuts processed at 115.6°C after 3 months of storage: Effects of packing medium.**

| Packing medium-Heating time (min) | Colonies | EAPC/g sample |
|-----------------------------------|----------|---------------|
| A-15                              | 0        | 0             |
| A-20                              | 0        | 0             |
| A-25                              | 0        | 0             |
| A-30                              | 0        | 0             |
| S-15                              | +++      | TNTC          |
| S-20                              | 43       | 4300          |
| S-25                              | 5        | 500           |
| S-30                              | 1        | 100           |

A = Citric acid solution; S = Brine; Dilution = 1:100

EAPC = Estimated aerobic plate count; TNTC = Too numerous to count

**TABLE 3 : Mean scores of sensory properties of canned achara cuts processed at 115.6°C: Effects of heating time, packing medium and storage time.**

| M-H  | Colour                |      |      |      | Aroma |      |      |      | Appearance |      |      |      | Acceptability |      |      |      |      |      |      |      |      |      |      |      |
|------|-----------------------|------|------|------|-------|------|------|------|------------|------|------|------|---------------|------|------|------|------|------|------|------|------|------|------|------|
|      | Storage time (months) |      |      |      |       |      |      |      |            |      |      |      |               |      |      |      |      |      |      |      |      |      |      |      |
|      | 1                     | 2    | 3    | 1    | 2     | 3    | 1    | 2    | 3          | 1    | 2    | 3    | 1             | 2    | 3    |      |      |      |      |      |      |      |      |      |
| A-15 | 4.37                  | 4.06 | 4.51 | 4.49 | 4.23  | 4.29 | 4.31 | 4.00 | 4.46       | 4.17 | 4.17 | 4.29 | 4.37          | 4.06 | 4.51 | 4.49 | 4.23 | 4.29 | 4.31 | 4.00 | 4.46 | 4.17 | 4.17 | 4.29 |
| A-20 | 4.03                  | 4.57 | 4.69 | 4.17 | 4.49  | 4.14 | 3.97 | 4.51 | 4.63       | 4.11 | 4.57 | 4.31 | 4.03          | 4.57 | 4.69 | 4.17 | 4.49 | 4.14 | 3.97 | 4.51 | 4.63 | 4.11 | 4.57 | 4.31 |
| A-25 | 4.23                  | 4.40 | 4.06 | 4.51 | 4.34  | 3.06 | 4.17 | 4.34 | 4.00       | 4.17 | 4.66 | 3.74 | 4.23          | 4.40 | 4.06 | 4.51 | 4.34 | 3.06 | 4.17 | 4.34 | 4.00 | 4.17 | 4.66 | 3.74 |
| A-30 | 4.20                  | 4.49 | 4.34 | 4.31 | 4.26  | 4.09 | 4.14 | 4.43 | 4.29       | 4.26 | 4.43 | 4.11 | 4.20          | 4.49 | 4.34 | 4.31 | 4.26 | 4.09 | 4.14 | 4.43 | 4.29 | 4.26 | 4.43 | 4.11 |
| S-15 | 2.23                  | 5.09 | 4.54 | 3.51 | 4.63  | 4.14 | 2.20 | 5.03 | 4.49       | 2.57 | 4.91 | 4.29 | 2.23          | 5.09 | 4.54 | 3.51 | 4.63 | 4.14 | 2.20 | 5.03 | 4.49 | 2.57 | 4.91 | 4.29 |
| S-20 | 4.69                  | 2.77 | 2.63 | 4.37 | 3.54  | 3.17 | 4.60 | 2.72 | 2.57       | 4.46 | 3.17 | 2.97 | 4.69          | 2.77 | 2.63 | 4.37 | 3.54 | 3.17 | 4.60 | 2.72 | 2.57 | 4.46 | 3.17 | 2.97 |
| S-25 | 2.60                  | 3.43 | 3.29 | 3.46 | 3.31  | 3.66 | 2.54 | 3.37 | 3.29       | 2.74 | 3.46 | 3.60 | 2.60          | 3.43 | 3.29 | 3.46 | 3.31 | 3.66 | 2.54 | 3.37 | 3.29 | 2.74 | 3.46 | 3.60 |
| S-30 | 2.29                  | 3.46 | 4.23 | 3.34 | 3.34  | 3.83 | 2.26 | 3.40 | 4.17       | 2.49 | 3.43 | 4.00 | 2.29          | 3.46 | 4.23 | 3.34 | 3.34 | 3.83 | 2.26 | 3.40 | 4.17 | 2.49 | 3.43 | 4.00 |

M-H = Packing medium-Heating time (min); A = Citric acid solution; S = Brine

Scores: 1 = unacceptable; 2 = poor; 3 = fair; 4 = satisfactory; 5 = good; 6 = excellent

**TABLE 4 : Mean scores of sensory properties of achara cuts canned under optimum conditions (20 min, 1% (w/v) citric acid solution, 115.6°C, 300 × 208 can size) after 3 months of storage.**

| Packing medium | Taste*                   | Texture*                 | Acceptability*           |
|----------------|--------------------------|--------------------------|--------------------------|
| Acid-packed    | 3.46 <sup>b</sup> ± 0.21 | 4.14 <sup>a</sup> ± 0.21 | 3.57 <sup>b</sup> ± 0.14 |
| Brine-packed   | 5.00 <sup>a</sup> ± 0.26 | 5.00 <sup>a</sup> ± 0.16 | 4.97 <sup>a</sup> ± 0.23 |
| Water-packed** | 5.34 <sup>a</sup> ± 0.14 | 5.40 <sup>a</sup> ± 0.18 | 5.49 <sup>a</sup> ± 0.16 |

\*Mean ± SD. For a given parameter (taste, texture, acceptability), column values with different superscripts are significantly different (P<0.05); \*\*Samples were not stored for 3 months and served as control.

## DISCUSSION

### Nutrient composition of canned achara

The protein content values (TABLE 1) indicate that higher heating time examined in this study (up to 30 min) was not detrimental to the protein content of canned achara cuts. This finding is similar to earlier reports<sup>[17,18]</sup> which stated that proteins (plus fat and carbohydrates) are not significantly affected by canning. Another study on canned potato, carrot and green beans (retort temperature: 110, 120, 130°C) showed that higher temperatures produced vegetables with better retention of texture and desirable colour<sup>[19]</sup>. However, the packing medium affected the results since samples packed in brine (3.13%) had lower average protein content than those packed in citric acid medium (3.48%). This could be due to the fact that salt (brine) solubilized some of the protein in the vegetable product and made it more available in the liquid portion than in the achara cuts. The protein content was hardly affected by canning since the result was for the achara cuts alone and did not include the packing medium. However, the results of this study were higher than that of Duke<sup>[9]</sup> which showed that the protein content of fresh elephant grass was 1.0%. One explanation for the difference in the results could be attributed to the species and genetic make-up of the achara cuts.

Higher fat content of achara cuts (TABLE 1) packed in citric acid solution suggests that salt may have diluted the fat in the brine-packed achara cuts, thus lowering it. Our result on fresh achara cuts (3.9% fat) is higher than that reported by Duke<sup>[9]</sup> for fresh elephant grass (0.5% fat). This may be due to the type of cut or species of the elephant grass. Percent carbohydrate (CHO) data showed that fresh achara cuts had higher CHO content

than canned cuts. It is practical that some soluble CHO in the canned samples solubilized in the packing medium, indicating that canning was not detrimental to the carbohydrate content. The presence of salt (NaCl) in the brine accounted for the observed higher ash content of canned achara cuts packed in brine. Analysis of the ash content (TABLE 1) showed that canned achara cuts are good sources of minerals such as potassium (K), sodium (Na), and calcium (Ca). On the average, samples packed in citric acid (26 mg/g) were higher in potassium (K) than those packed in brine (11.5 mg/g). However, brine-packed (19 mg/g) samples had higher sodium (Na) content than citric acid-packed (11.3 mg/g) samples, the reason being the salt in the brine. Packing medium did not alter the calcium content of the canned vegetable samples. Overall, canned achara cuts packed in citric acid solution had higher nutrient composition than those packed in brine, except for ash and sodium content. Obviously, the salt in the brine explains the higher ash and sodium content of samples packed in brine. Generally, the data demonstrated that fresh achara cuts had slightly higher nutrient content than canned samples. It is known that once vegetables are harvested, deterioration of quality (nutritional, organoleptic and biological) takes place due to the activity of the enzyme systems.

### Microbial profile of canned achara

Total aerobic plate count (APC) of canned achara cuts is presented in TABLE 2. APC indicates the level of microorganisms in a product<sup>[20]</sup>. For instance, APC of fish and fishery products generally do not relate to food safety hazards, but sometimes can be useful to indicate quality, shelf life and post heat-processing contamination. Fresh fish and fishery products often have an APC of 10<sup>4</sup>-10<sup>5</sup>/g, although there are examples of seafoods with an APC of 10<sup>6</sup>-10<sup>8</sup>/g without objectionable quality changes<sup>[21]</sup>. The bactericidal effect of citric acid was evident in the results since there was no growth in the citric acid-packed samples (TABLE 2). In a review on the mechanisms of microbial inactivation of chelators, Brul and Coote<sup>[22]</sup> reported that citric acid inhibits growth of gram-negative bacteria (e.g. *C. botulinum*) due to its Ca<sup>2+</sup> chelating activity. Effect of chelating agents on the outer membrane of gram-negative bacteria had been discussed<sup>[23]</sup>. In addition, citric acid acts

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by lowering the pH of product, thereby inhibiting microbial growth and spoilage. These properties combined with heat processing explain why citric acid-packed achara cuts had no microbial growths.

Microbial growth occurred in brine-packed canned achara cuts; the growth decreased as heating time increased. Growth was highest in 15 min-processed samples and lowest in samples processed for 30 min. The decreasing trend indicated that the longer the processing time the higher the destruction rate of spoilage organisms. The sole aim of all food preservation processes, especially canning operation, is the total destruction of all spoilage organisms. Salt (NaCl) is a widely used preservative in food processing and the growths could be due to contamination from the salt source. Gram-negative and gram-positive bacteria were suspected and the assay confirmed the gram-positive bacterium as *Staphylococcus aureus*. Nevertheless, results showed that there were few colonies, suggesting that the brine-packed canned achara cuts were still safe after 3 months of storage on the shelf except for samples processed for 15 min.

### Sensory characteristics of canned achara

A look at the effect of heating time (15, 20, 25, 30 min) and storage time (1, 2, 3 months) on the sensory score of canned achara cuts showed that cuts packed in citric acid solution had good sensory appeal except for the aroma (3.06) and acceptability (3.74) of cuts heat-processed for 25 min and stored for 3 months. However, brine-packed cuts had lower scores in the colour, aroma, appearance and overall acceptability, indicating that cuts packed in brine were not as acceptable as those packed in citric acid solution. The colour stabilizing effect of citric acid is based on its ability to chelate trace metals (e.g. Fe, Cu) which may cause haze formation or deterioration. Also, citric acid lowers the pH of the medium, and thus prevents oxidation and microbial activity which lead to colour and aroma deterioration.

### Optimum processing conditions for canned achara

The nutrient composition of canned achara (TABLE 1) indicates that citric acid-packed samples had higher mean nutrient values than brine-packed samples except for ash and sodium. Therefore, the citric acid-packed canned achara could be considered to be more

nutritious than the brine-packed samples. Data from the microbial assessment (TABLE 2) showed that there was no microbial growth in the citric acid-packed canned achara while growth occurred in the brine-packed samples. This observation supports that citric acid is a better preservative and thus makes samples packed in citric acid solution safer. The sensory scores (TABLE 3) indicate canned achara packed in citric acid to be better in most of the organoleptic attributes thereby making citric acid a better preservative than salt. Due to the adverse effect of prolonged heat treatment on the nutritive and sensory qualities of vegetables, appropriate processing times for citric acid-packed samples were narrowed down to 15 and 20 min. However, 20 min was deemed to be the most appropriate for processing achara cuts. Based on the findings highlighted above, an optimum processing conditions for canned achara cuts was established as follows: Processing time: 20 min, processing temperature: 115.6°C, packing medium: 1% (w/v) citric acid solution, and can size: 300 × 208 (3 inch diameter × 2 ½ inch height).

The taste, texture and acceptability scores of canned achara cuts processed using the developed optimum conditions are presented in TABLE 4. Results show that panellists preferred the taste and acceptability of brine- and water-packed samples to citric acid-packed samples (the water-packed samples served as control). It is evident that the inherent sour taste of citric acid as well as the concentration (1%) used accounts for the lower scores. Texture of citric acid-packed samples was rated lower although the difference between treatments was not significant ( $P < 0.05$ ). The maturity and section of achara cuts may explain the textural difference since the samples were not graded before canning.

## CONCLUSIONS

Achara cuts were used to produce nutritious, safe and acceptable canned vegetable product. It retained most of its sensory qualities when packed in citric acid than in brine. However, achara cuts canned in citric acid had sour taste at 1% concentration and this influenced its acceptability. This novel canned vegetable product provides basic nutrient requirements such as protein, ash, fat and especially minerals which is the main con-

tribution of leafy vegetables in human nutrition. Of the heating times examined, 20 min was the most appropriate. This study provides benchmark information on canned Nigerian achara. Achara cuts canned in citric acid solution and heat-processed for 20 min could serve as a specialty ingredient in human nutrition.

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