ELSEVIER

Food Chemistry 68 (2000) 201–209

Food Chemistry

www.elsevier.com/locate/foodchem

Effects of different preservative treatments on the chemical changes of pounded white yam (*Dioscorea rotundata*) in storage at 28 ± 2°C

S.E. Omonigho*, M.J. Ikenebomeh

Department of Microbiology, University of Benin, P.M.B. 1154, Benin City, Nigeria

Received 18 January 1999; received in revised form 29 June 1999; accepted 29 June 1999

Abstract

The effects of different preservative treatments on the chemical changes of pounded white yam (*Dioscorea rotundata*) upon storage were investigated. Preservative treatments adopted include steaming at 100°C for 30 min, addition of 0.1% sodium benzoate, treating with 0.1% sodium benzoate plus heating at 85°C for 30 min and finally the samples at room temperature (28 ± 2°C). Changes occurred in the chemical composition of stored untreated pounded yam samples with the product becoming staled. The pH value (6.00), total solids content (30.88%) and crude protein content (5.56%) of fresh untreated samples initially increased before decreasing to 4.80, 25.60% and 5.50%, respectively, after storage for 8 days. Titratable acidity, moisture content and reducing sugars content of fresh samples initially decreased but subsequently increased. Extractable fat, crude fibre and ash contents continually increased from 1.25, 1.20 and 1.90% to 4.10, 2.90 and 8.60% respectively. The rate of change in chemical properties/composition of treated pounded yam samples was affected by the preservation method adopted and time of storage. Samples treated with 0.1% sodium benzoate plus heating at 85°C for 30 min had stable chemical compositions over 8-day periods of storage and possibly longer.

1. Introduction

Yam has been classified as one of the important perishable staples and among the tropical root crops that provide staple food for about 400 million people (Coursey & Haynes, 1970). Food yams are members of the genus *Dioscorea* and are grown principally for the carbohydrate they provide (Hahn, Osiru, Akoroda & Otoo, 1995). White yam (*Dioscorea rotundata*) is the most valued species of edible yams in terms of the vital role they play. The crop remains the most preferred by millions of people in Africa, particularly those in the yam zone.

The preferred method of preparation is boiling and pounding to improve the 'feel' of the food in the hand and for easy swallowing. There have been some attempts to market a range of dried products that simulate fresh pounded yam; the developed products are not yet competitive with the fresh-pounded product because of higher costs and inferior hand feeling with taste (Hahn et al., 1995).

Even though pounded yam is cheaper to process and of superior quality than other products, the production is hindered by storage problems. Upon storage for about 12 h, pounded yam loses its acceptability because of the loss of stickiness (hand feel) and becomes a deteriorated food. Microorganisms, including bacteria, yeasts and moulds, have been reported to be associated with pounded yam (Omonigho, 1988) as a result of the high nutritive value of yam and yam products. The primary activities of these microorganisms on foods bring about spoilage (Jay, 1978).

Yams and their products are sources of energy, primarily, since their dry matter consists largely of carbohydrates (Francis, Halliday & Robinson, 1975). Crude protein, ether extract, crude fibre and ash contents of yam have been reported (Osagie & Opute, 1981; Oyenuga, 1968). Studies of the composition and amount of vitamins A, B_1, B_2, B_6 and C in raw yams and cooked fufu have been carried out by Umoh and Bassir (1977). Bell and Favier (1980) reported that yam and its derivatives are rich in minerals.

Microorganisms require a minimum of a carbon and energy source, a nitrogen (amino acids and vitamins) source, inorganic nutrients, and water for growth, and

* Corresponding author.

0308-8146/99/$ - see front matter
PII: S0308-8146(99)00183-1

these are readily provided by pounded yam (Omonigho, 1988). Methods for controlling the growth of micro-organisms in pounded yam will therefore preserve the food quality. Methods adopted in this study include steaming at 100°C for 30 min, chemical preservation using sodium benzoate at a concentration of 0.1%, though concentrations of 0.2 to 0.3% are permitted in foods (Sodeko, Izuagbe & Ukhun, 1987) and chemical preservative (0.1% sodium benzoate) plus heat treatment at 85°C for 30 min. In this paper, the chemical changes associated with the storage of treated pounded yam samples are reported.

2. Material and methods

2.1. Preparation of pounded yam samples

Healthy yam tubers (*D. rotundata*) used for this study were obtained from Ovie farms, Izikhirihi village near

Table 1
Effects of preservation treatments on chemical composition of pounded yam samples immediately after treatment

Parameters	Untreated sample	Steaming at 100°C for 30 min	0.1% sodium benzoate	0.1% sodium benzoate plus heating at 85°C for 30 min
Dry matter (%)	30.88 ± 3.06	31.75 ± 2.65	30.19 ± 2.76	31.60 ± 2.60
pH value	6.00 ± 0.00	6.00 ± 0.00	5.30 ± 0.10	5.60 ± 0.10
Titratable acidity (ml) 0.1 M NaOH	1.10 ± 0.13	1.10 ± 0.00	0.90 ± 0.10	0.60 ± 0.10
Crude protein (% dry mass)	5.56 ± 1.15	5.66 ± 0.93	5.60 ± 1.07	5.59 ± 0.95
Reducing sugars (mg/g dried sample)	2.16 ± 0.82	2.24 ± 0.61	2.19 ± 0.49	2.40 ± 0.56
Total available carbohydrate (% dried sample)	90.08 ± 1.95	90.81 ± 1.20	90.60 ± 1.70	90.58 ± 1.90
Fat content (% dry mass)	1.23 ± 0.26	1.28 ± 0.21	1.34 ± 0.49	1.25 ± 0.18
Fibre content (% dried sample)	1.20 ± 0.30	1.10 ± 0.36	1.16 ± 0.34	1.29 ± 0.25
Ash content (% dry mass)	1.93 ± 0.24	1.88 ± 0.33	1.76 ± 0.29	1.71 ± 0.28

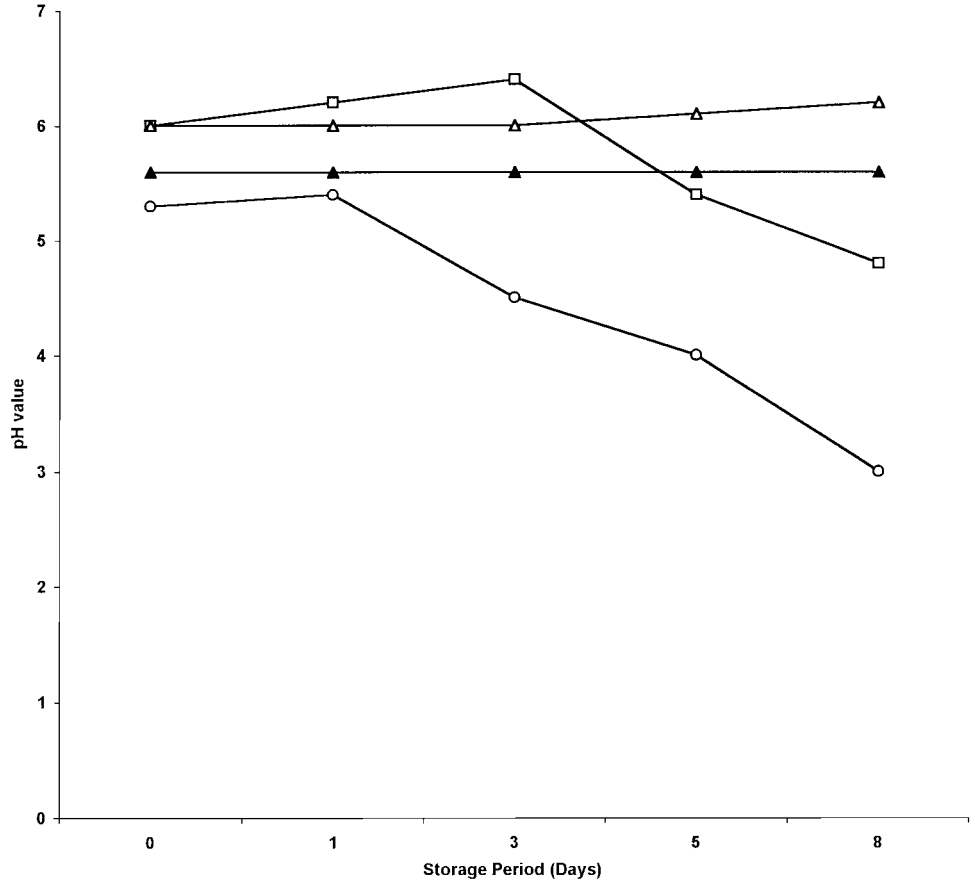

Fig. 1. Changes in pH value of pounded yam samples during storage at 28 ± 2°C. □, Fresh untreated; △, steamed at 100°C for 30 min; ○, 0.1% sodium benzoate; ▲, 0.1% sodium benzoate + heating at 85°C for 30 min.

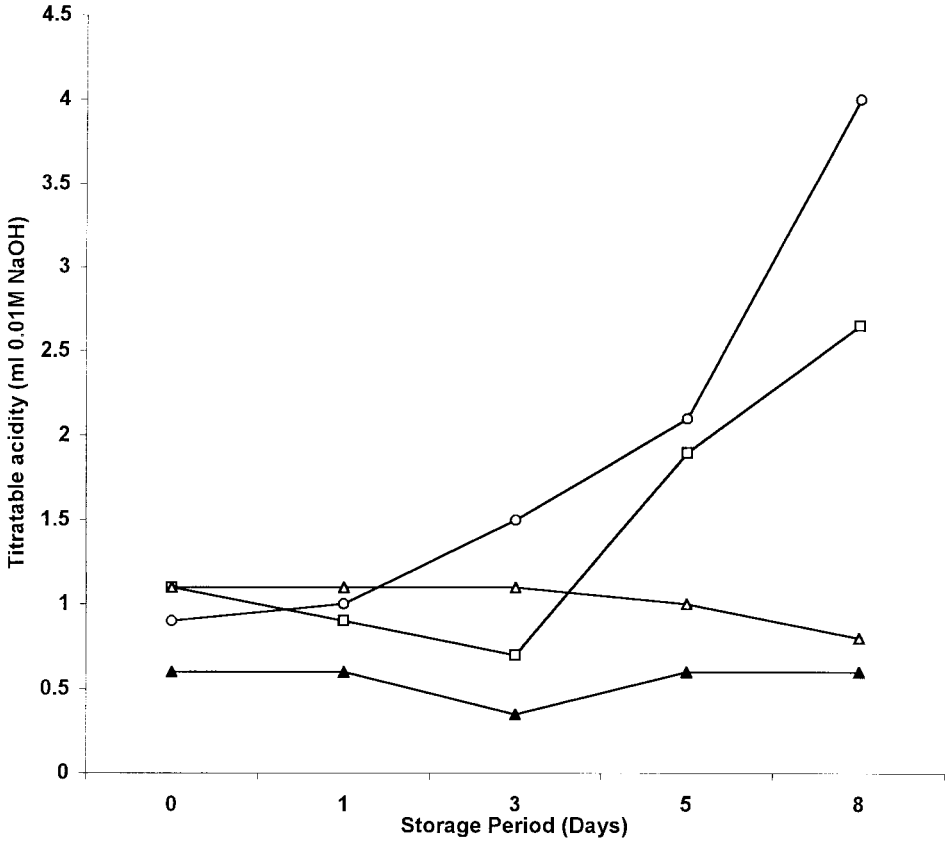

Fig. 2. Changes in titratable acidity associated with storage at room temperature of pounded yam samples. □, Fresh untreated; △, steamed at 100°C for 30 min; ○, 0.1% sodium benzoate; ▲, 0.1% sodium benzoate + heating at 85°C for 30 min.

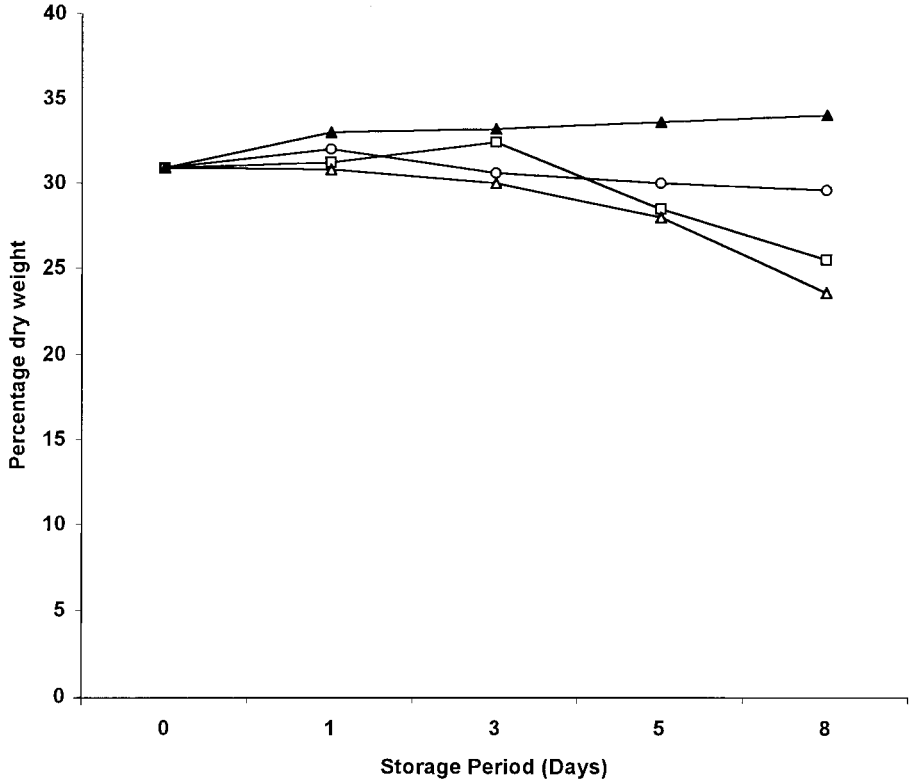

Fig. 3. Changes in percentage dry weight (solid content) of pounded yam samples (fresh and treated) during storage at 28 ± 2°C. □, Fresh untreated; △, steamed at 100°C for 30 min; ○, 0.1% sodium benzoate; ▲, 0.1% sodium benzoate + heating at 85°C for 30 min.

Benin City, Nigeria. The pounded yam samples were prepared by boiling peeled slices of yam in water until cooked (usually 30 min) and then pounded using a National pounding machine (National Electronic Co. Ltd, Tokyo). Samples were pounded for 5 min with addition of 30.0 ml of hot water (80°C) at intervals to 1.0 kg of yam. Samples were then divided into four batches for preservation treatment: (A) where left as untreated fresh samples (B) treated by steaming at 100°C for 30 min, (C) chemical preservation using sodium benzoate at a concentration of 0.1% and (D) chemical preservative treatment (0.1% sodium benzoate) plus heat treatment at 85°C for 30 min. These batches were dispensed into covered aluminium plates in 100 g portions before heat treatments for batches B and D. Initial chemical analyses were carried out on the untreated samples and treated samples were then stored at room temperature (28 ± 2°C) for a period of 8 days. Subsequent chemical analyses were carried out on each batch during this period.

2.2. Chemical analyses

Chemical properties of fresh pounded yam samples were assayed during the 8-day storage period. Determination of pH values of the pounded yam samples was carried out with a single electrode pH meter (Corning Ltd, UK). Samples were prepared by homogenizing 20.0 g portions of pounded yam in 180 ml of boiled glass-distilled water, using a Moulinex wet mill blender (Moulinex Ind. Ltd, France). The homogenates were tested with the pH meter and sample mean pH readings were obtained. Titratable acidity of each sample was determined using the AOAC procedure. The method of titration was that of acid-base reaction as reported by Bevan, Redhead and Foley (1965).

The method described by Osborne and Voogt (1978) was used to assess the total solid and moisture contents. Crude protein was determined by using Nessler's modified Kjedahl method of protein analysis (William, 1968). For the colorimetric determination of nitrogen in the medium, a Bausch and Lomb Spectronic 20 spectrophotometer (A. Gallenkamp and Co. Ltd, UK) was used.

Total reducing sugar in samples was determined using Nelson Somogy's method (Pearson, 1976). The sample was prepared by suspending 1.0 g of dried sample in 10.0 ml 80% ethanol, homogenised in a mortar with a pestle and filtered through Whatman No. 541 filter paper. The reducing sugar content of the filtrate was then determined. The extinction was read at 600 nm in a Spectronic 20 spectrophotometer, and the concentration of reducing sugar was extrapolated from a D-glucose standard curve.

The amount of total extractable fat in each sample was determined using the Soxhlet extraction method as described by Howard and Leonard (1963). The samples were first dried in an oven at 103°C for 8 h and ground in a dry mill (Moulinex Ind Ltd., France). The extraction solvent used was petroleum ether (BDH, UK).

The crude fibre determination was carried out using the method described by Osborne and Voogt (1976). Each sample was treated with boiling sulphuric acid (BDH, UK) and subsequently with boiling potassium hydroxide (BDH, UK). The residue, after subtraction of its ash content, is regarded as fibre. The ash content of each sample was determined by dry-ashing in a muffle furnace at 550°C (Osborne & Voogt).

Determination of total available carbohydrate was by the method described by Osborne and Vooght (1978). For the quantitative determination of sugars formed by perchloric acid extraction or hydrolysis (Hansen & Ib, 1975), 10 ml of the sample extract was diluted to 100 ml with distilled water. A 1.0 ml of diluted filtrate was added into a test-tube in duplicate. Duplicate blanks, each with 1.0 ml of water and standards using 1.0 ml of dilute glucose (10 μg–100 μg/ml) were prepared. A measured 5 ml portion of freshly prepared anthrone reagent (0.1% anthrone in 75% sulphuric acid) was added to the content of each tube and the tubes were vortexed. The mixtures were placed in a boiling water bath for 12 min, cooled quickly to room temperature (28 ± 2°C) and absorbance was read at 620 nm against a reagent blank using a spectrophotometer. Total available carbohydrate of each sample was then extrapolated directly from the standard D-glucose curve.

3. Results

The effects of preservation treatments, (steaming at 100°C for 30 min, chemical preservation treatment with

Table 2
Changes in percentage moisture contents of untreated and treated samples of pounded yam when stored at room temperature (28 ± 2°C)

Storage period (days)	Untreated sample	Treated samples		
		Steamed at 100°C for 30 min	0.1% sodium benzoate	0.1% sodium benzoate plus heating at 85°C for 30 min
0	69.12 ± 3.06	68.25 ± 2.65	69.81 ± 2.76	68.40 ± 2.60
1	68.80 ± 2.80	69.20 ± 2.88	68.00 ± 2.59	67.00 ± 2.65
3	67.60 ± 2.50	70.00 ± 2.50	69.40 ± 2.30	66.50 ± 2.30
5	71.50 ± 3.00	72.00 ± 2.95	70.00 ± 2.75	66.40 ± 2.40
8	74.46 ± 2.70	76.40 ± 2.76	70.40 ± 2.50	66.00 ± 3.10

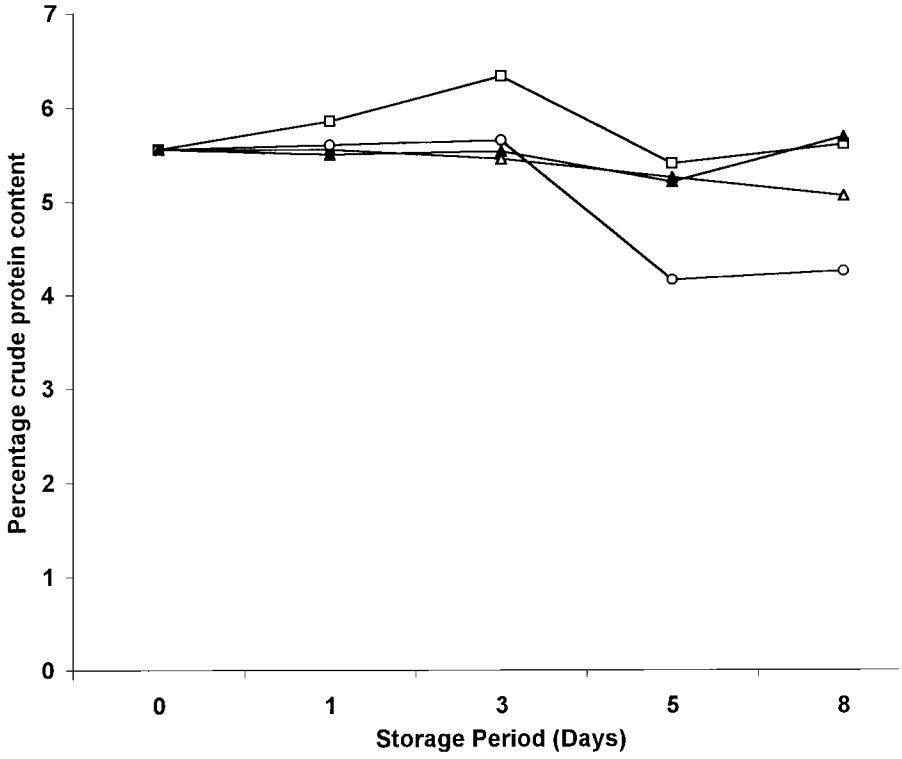

Fig. 4. Changes in the concentration of crude protein associated with storage of fresh and treated pounded yam samples at ambient temperature. □, Fresh untreated; △, steamed at 100°C for 30 min; ○, 0.1% sodium benzoate; ▲, 0.1% sodium benzoate + heating at 85°C for 30 min.

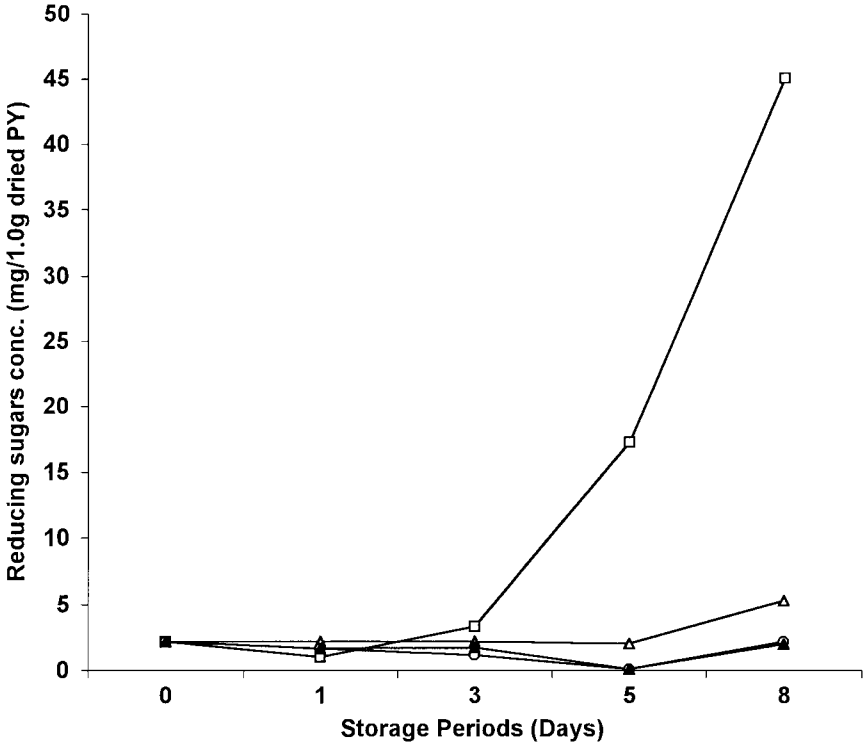

Fig. 5. Amount of reducing sugars in fresh and treated pounded yam samples during storage at room temperature. □, Fresh untreated; △, steamed at 100°C for 30 min; ○, 0.1% sodium benzoate; ▲, 0.1% sodium benzoate + heating at 85°C for 30 min.

0.1% sodium benzoate and 0.1% sodium benzoate treatment plus heating at 85°C for 30 min) on the chemical composition of pounded yam immediately after treatment are summarized in Table 1. Freshly prepared untreated pounded yam samples and those steamed at 100°C for 30 min had pH values of 6.00 ± 0.00, those treated with 0.1% sodium benzoate had a pH value of 5.30 ± 0.10 while samples treated with 0.1% sodium benzoate plus heating at 85°C for 30 min had a 5.60 ± 0.00 pH value. These values increased slowly to 6.20 ± 0.05 on the 8th day of storage for steamed samples, while untreated samples and samples treated with 0.1% sodium benzoate only decreased to 5.50 ± 0.35 and 3.00 ± 1.00, respectively. The 0.1% sodium benzoate plus heating at 85°C for 30 min gave a constant pH value during the storage period as shown in Fig. 1. Illustrated in Fig. 2 are the changes in titratable acidity of untreated and treated pounded yam samples during the storage period.

The changes in percentage dry weight of pounded yam (untreated and treated) samples during storage at 28 ± 2°C are shown in Fig. 3. Except for samples treated with 0.1% sodium benzoate plus heating at 85°C for 30 min, that increased total solids content percentage, all other samples decreased in dry weight concentration. The percentage moisture contents of untreated and treated samples of pounded yam are shown in Table 2 when stored for 8 days. Changes in the concentration of protein of pounded yam samples associated with their storage are shown in Fig. 4.

Changes in amounts of reducing sugars associated with storage of pounded yam samples (untreated and treated) are shown in Fig. 5. There was an initial decrease in reducing sugars content (2.16 ± 0.82 mg/g of dried fresh samples) of all deteriorating untreated, steamed and 0.1% sodium benzoate-treated samples before a rapid increase with time of storage. The samples treated with 0.1% sodium benzoate plus heating at 85°C for 30 min remained constant in reducing sugars content throughout the storage period of 8 days. Total carbohydrate of untreated and treated pounded yam samples changed during their storage as shown in Fig. 6. The samples treated by steaming and 0.1% sodium benzoate only recorded decreases in carbohydrate content while those treated with 0.1% sodium benzoate plus heating at 85°C for 30 min gave no detectable changes in the carbohydrate content with progressive storage time.

Changes in amounts of extractable fat associated with storage of pounded yam samples at room temperature

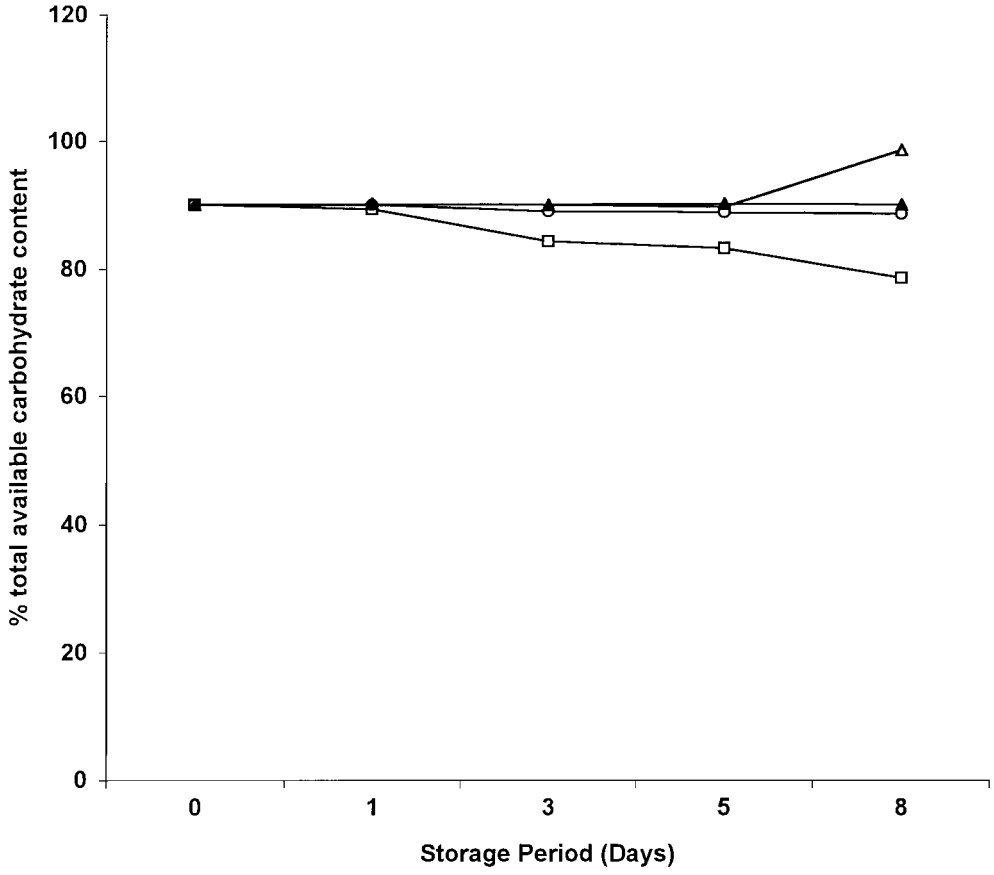

Fig. 6. Changes in percentage total available carbohydrate content of fresh and treated pounded yam samples as a result of storage at room temperature. □, Fresh untreated; △, steamed at 100°C for 30 min; ○, 0.1% sodium benzoate; ▲, 0.1% sodium benzoate + heating at 85°C for 30 min.

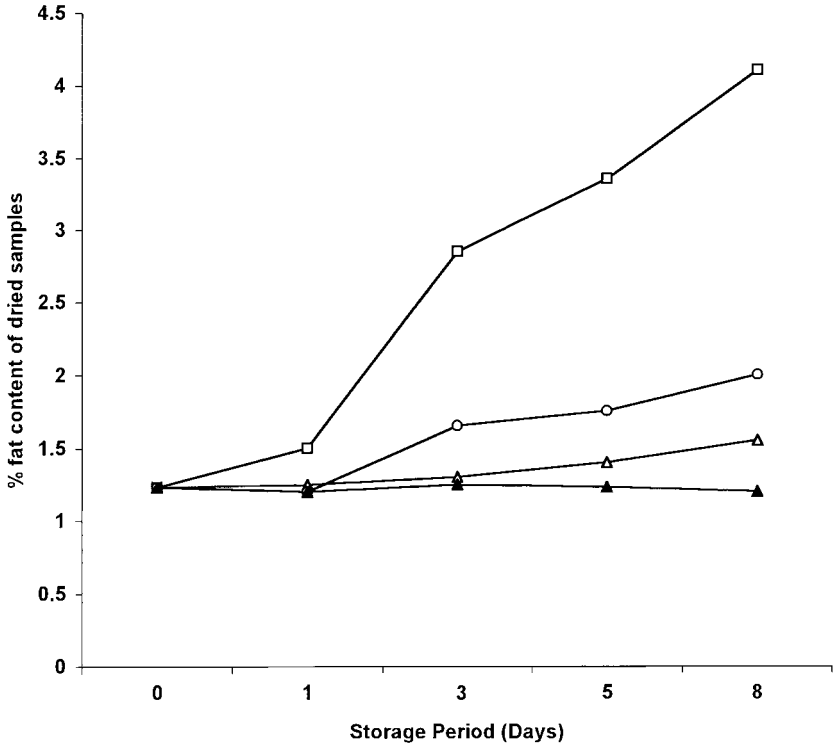

Fig. 7. Changes in percentage extractable fat content of fresh and treated pounded yam samples during storage at ambient temperature. □, Fresh untreated; △, steamed at 100°C for 30 min; ○, 0.1% sodium benzoate; ▲, 0.1% sodium benzoate + heating at 85°C for 30 min.

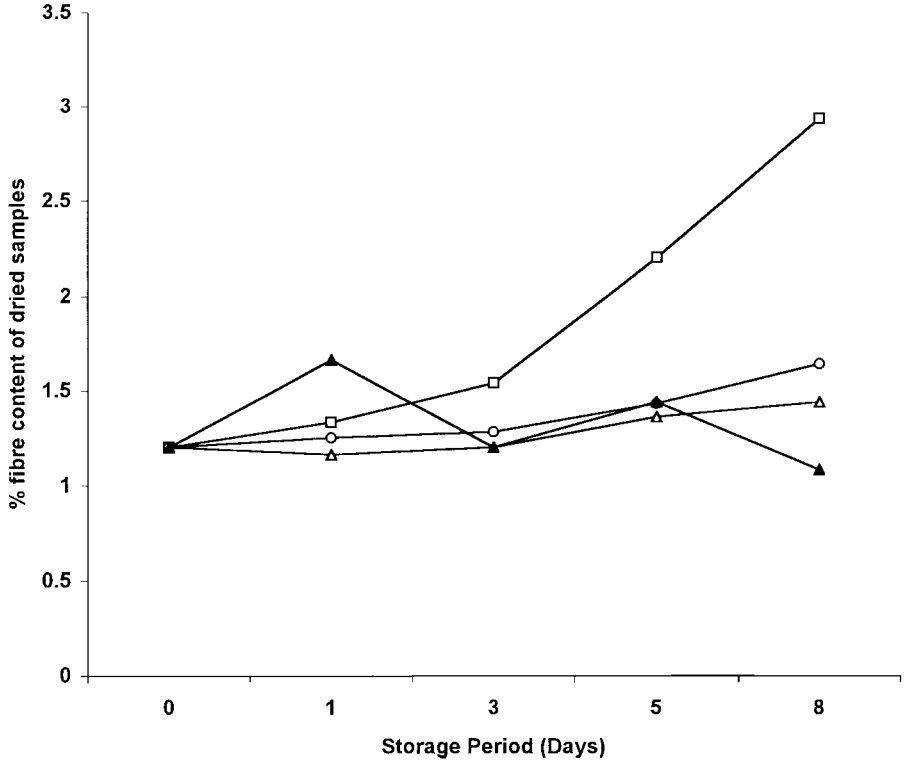

Fig. 8. Changes in crude fibre content percentage of fresh and treated pounded yam samples associated with storage at 28 ± 2°C. □, Fresh untreated; △, steamed at 100°C for 30 min; ○, 0.1% sodium benzoate; ▲, 0.1% sodium benzoate + heating at 85°C for 30 min.

are illustrated in Fig. 7. The fat content of deteriorating untreated samples increased very rapidly reaching 4.1% on the 8th day of storage from 1.25% of fresh samples. The steamed and 0.1% sodium benzoate-treated samples also had increased fat concentration with storage period while 0.1% sodium benzoate plus heating at 85°C for 30 min treated samples had nearly constant fat content throughout the period of storage (Fig. 7).

Illustrated in Fig. 8 are the percentage fibre contents of untreated, steamed and 0.1% sodium benzoate only-treated samples of pounded yam that increased with storage period while 0.1% sodium benzoate plus heating at 85°C for 30 min-treated samples had a stable fibre content throughout the storage period of 8 days. The percentage changes in ash content of pounded yam (untreated and treated) samples during storage are shown in Fig. 9.

4. Discussion

The initial pH-values (6.00) of fresh pounded yam samples made them vulnerable to bacterial spoilage, (Frazier & Westhoff, 1978; Jay, 1978). There was a gradual increase in pH of steamed pounded yam samples from 6.00 to 6.20 on the 8th day of storage at room temperature, probably due to production of ammonia by the putrefactory ability of certain microbes (Omonigho, 1988). There was a steady fall in pH of samples treated with 0.1% sodium benzoate from 5.30 to 3.00 upon storage for 8 days. The steady decrease was attributed to the production of more acids by isolated yeasts (Omonigho). The initial drop in pH of samples immediately after treatment resulted from the low pK (=4.20) of sodium benzoate used (Jay) which dissociated to ions (Na^+ and $C_7H_5O_2^{2-}$). The pH of sodium benzoate plus heating at 85°C for 30 min-treated samples remained constant throughout the storage period at 5.60 because there were no microbial activities taking place to increase or decrease the value (Omonigho).

Changes in titratable acidity associated with storage of pounded yam samples are opposite to those of pH value (Fig. 2). The fall in initial titratable acidity of samples treated with sodium benzoate may have resulted from side reactions between the dissociated ions of the sodium benzoate and inherent ions present in the food samples. The decrease in titre value of steamed pounded yam samples during storage at room temperature (28 ± 2°C) may be due to possible production of ammonia from the proteins (Omonigho, 1988).

Fresh pounded yam samples assayed had dry weight and moisture contents of 30.88 ± 3.06 and 69.12 ± 4.06%, respectively, which changed during storage as presented in Fig. 3 and Table 2. There was an initial increase in dry

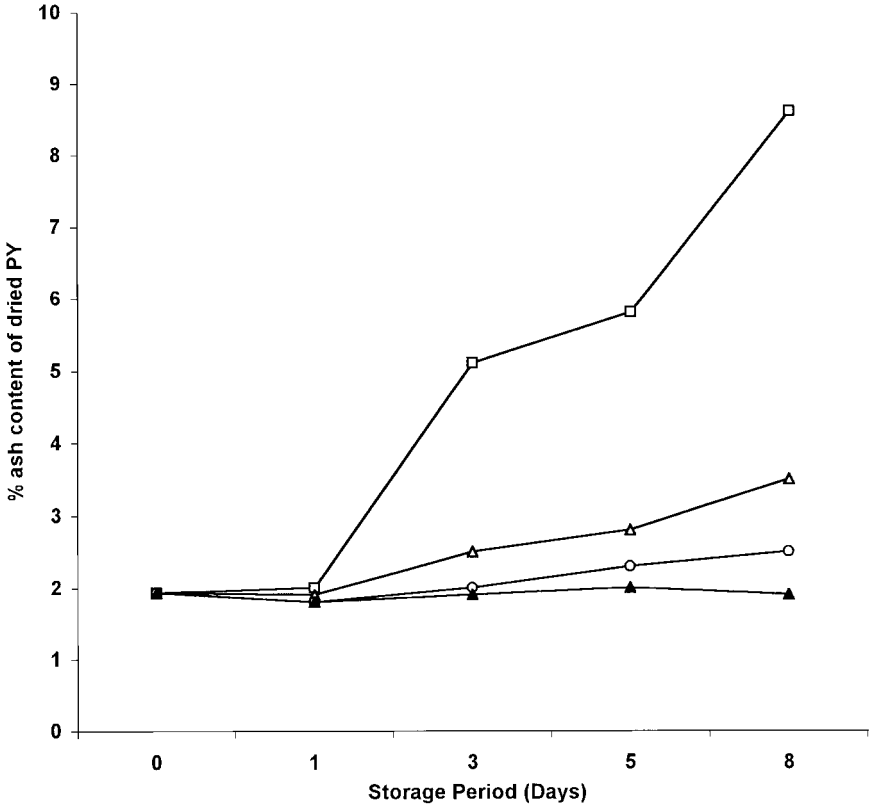

Fig. 9. Changes in percentage ash content of untreated and treated pounded yam samples as a result of storage at room temperature. □, Fresh untreated; △, steamed at 100°C for 30 min; ○, 0.1% sodium benzoate; ▲, 0.1% sodium benzoate + heating at 85°C for 30 min.

mass of samples during storage due to evaporation of water from them at room temperature ($28 \pm 2°C$). But, as storage progressed, the relative amount of water produced by spoilage microorganisms from metabolic reactions was higher relative to the amount evaporated. The samples treated with 0.1% sodium benzoate plus heating at 85°C for 30 min increased steadily in moisture content because of continuous evaporation and no microbial activity to produce water.

Except for the samples steamed at 100°C for 30 min, there was an initial increase in protein concentration followed by a decrease before finally increasing in all other samples (Fig. 4). The continuous fall in protein concentration of steamed samples may be due to the putrefactory action of microbes that hydrolysed some of the crude proteins to ammonia (Omonigho, 1988). All protein values obtained remained within the protein range of $5.56 \pm 1.15\%$ of fresh samples (Table 1).

There was an initial decrease in sugar concentration before increasing during storage, depending on the treatment applied. The initial fall was due to sugar utilization by spoilage microorganisms while the final upsurge resulted when amylase produced by some of the microbes hydrolysed starch molecules to reducing sugars (glucose) (Omonigho, 1988). Since microorganisms (yeasts) present in the samples treated with 0.1% sodium benzoate plus heating at 85°C are not active (Omonigho, 1988), there was no utilization of sugars and non-production of amylase leading to a constant sugar content throughout the storage period. The percentage total carbohydrate content of fresh samples decreased rapidly from 90.1 ± 1.95 to 78.5 ± 4.30 upon storage for 8 days and this change resulted from the utilization of sugars, and subsequently starch, by spoilage microorganisms, as reported by Omonigho.

The spoilage microorganisms in the untreated, steamed and 0.1% sodium benzoate treated samples may also have produced lipids through de-novo-synthesis from available carbohydrates to form cell membrane and other cell organelles. The increase in crude fibre contents of untreated, steamed and 0.1% sodium benzoate-treated samples (Fig. 8) may be due to continuous utilization of the total available carbohydrates, thereby increasing the fibre content. There was a rapid increase in ash content of untreated samples from 1.93 ± 0.24 to $8.74 \pm 0.45\%$ upon storage at room temperature ($28 \pm 2°C$) for 8 days and this also happened in steamed and 0.1% sodium benzoate-treated samples (Fig. 9). The increase may be similarly attributed to utilization of the available carbohydrates and other organic matter by spoilage microorganisms, leading to a decrease in the ratio of available organic matter to inorganic ash content. The fat, fibre and ash contents of samples, treated with 0.1% sodium benzoate plus heating at 85°C for 30 min, remained stable throughout the storage period (Figs. 7–9).

This investigation has shown that the use of 0.1% sodium benzoate plus heating at 85°C for 30 min, out of all the preservation treatments applied, will preserve the chemical composition of pounded yam and therefore form the basis of a microbiological preservation method for the food.

References

Bell, A., & Favier, J. C. (1980). Effect of traditional food processing methods on the nutritional value of yams in Cameroon. In E. R. Oduro, K. A. Oduro, & F. Caveness, *Tropical root crops* (pp. 214–224). Ibadan: Longman.

Bevan, C. W. L., Redhead, J., & Foley, A. J. (1965). *Intermediate practical chemistry* (p. 158). Lagos: Thomas Nelson (Nigeria) Ltd.

Coursey, D. G., & Haynes, P. H. (1970). Root crops and their potential as in the tropics. *World Crops, 22*, 261–265.

Francis, C. A., Halliday, D., & Robinson, J. M. (1975). Yam as source of edible protein. *Tropical Science, 17*, 103–110.

Frazier, W. C., & Westhoff, D. C. (1978). *Food microbiology* (3rd ed., p. 540). New York: McGraw–Hill Book Co.

Hahn, S. K., Osiru, D. S. O., Akoroda, M. O. & Otoo, J. A. (1995). *Production of yams: present role and future prospects. IITA research guide 46* (p. 34). Training program. Ibadan, Nigeria: International Institute of Tropical Agriculture (IITA).

Hansen, J., & Ib, M. (1975). Percolation of starch and soluble carbohydrates from plant tissue for quantitative determination with anthrone. *Analytical Biochemistry, 68*, 87–94.

Howard, S., & Leonard, V. (1963). *Food composition and analysis* (p. 367). London: Van Nostrand D. Co. Inc. Pub.

Jay, J. M. (1978). *Modern food microbiology* (2nd ed., p. 479). New York: Van Nostrand D. Co. Inc. Pub.

Omonigho, S. E. (1988). *Deterioration of pounded yam and its shelf-life extension* (p. 162). M.Sc. thesis, University of Benin, Benin-City.

Osagie, A. U., & Opute, F. I. (1981). Total lipid and fatty acid composition of tropical tubers. *Nigerian Journal of Nutritional Sciences, 2*, 39–46.

Osborne, D. R., & Voogt, P. (1978). *The analysis of nutrients in foods* (p. 251). New York: Academic Press.

Oyenuga, V. A. (1968). *Nigeria's foods and feeding-stuffs* (p. 99). Ibadan: Ibadan Univ. Press.

Pearson, D. (1976). *The chemical analysis of foods* (7th ed., p. 575). New York: Churchill Livingstone.

Sodeko, O. O., Izuagbe, Y. S., & Ukhun, M. E. (1987). Effect of different preservative treatments on the microbial population of Nigerian orange juice. *Microbios, 51*, 133–143.

Umoh, I. B., & Bassir, O. (1977). Nutrient changes in some traditional Nigerian foods during cooking. I: vitamin changes. *Food Chemistry, 2*, 155–160.

William, P. C. (1968). The colorimetric determination of total nitrogen in feeding stuffs. *Analyst (London), 89*, 276–281.