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Effect of temperature treatment on the chemical composition of pounded white yam during storage

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Abstract

The effects of various temperature treatments on the chemical composition of pounded white yam *(Dioscorea rotundata)* during storage were studied. Temperature treatments employed were refrigerating at 4±1°C, freezing at −18±2°C and sterilization at 121°C for 15 min before storing at ambient temperature. The rates of chemical changes of untreated and treated pounded yam samples were affected by the preservation method adopted and time of storage, with the untreated ones quickly becoming staled. Parameters examined were the pH values, titratable acidity, solid and moisture contents, concentration of crude protein, amount of free reducing sugars, concentration of total available carbohydrates, amount of ether-extractable fat, fibre and ash contents. At the end of the storage period (8 days), chemical components of the untreated yams statistically differed from those of the fresh pounded yam while the treated samples were not statistically different in chemical composition from the fresh ones

1. Introduction

Yams, the edible tubers of various species of the genus *Dioscorea,* are important items in the diets of many tropical countries (Waitt, 1963) because of the carbohydrate they provide (Hahn, Osiru, Akorada & Otoo, 1995). They are widely used in most parts of West Africa including Eastern Ivory Coast, Ghana, Togo, Dahomey and Nigeria (Coursey & Aidoo, 1966). Yam is composed mainly of starch with small amounts of proteins, lipids and most vitamins except vitamin C and is very rich in minerals (Abe, 1973; Coursey, 1967; Omonigho, 1988). White yam (*D. rotundata*) is the most valued species of edible yams in terms of the vital role they play.

The various edible species of *Dioscorea* can be eaten, either by chewing or swallowing, depending on the preparation procedure. The preferred method of preparation is boiling and pounding to improve the texture of the food in the hand and for easy swallowing (Coursey, 1965). Bell and Favier (1980) have reported that pounded yam is the most important culinary product made from yams. 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 texture and taste (Hahn et al., 1995).

The production of pounded yam is hindered by storage problems, even though it is cheaper to process and of superior quality compared to other products. Upon storage for about 12 h, pounded yam losses its acceptability because of the loss of texture and becomes staled with changes in its chemical composition (Omonigho, 1988). Micro-organisms, such as bacteria, yeasts and moulds, have been reported to be associated with pounded yam (Omonigho) as a result of the high nutritive value of yam and yam products. The primary activities of these micro-organisms on foods brings about deterioration (Jay, 1978). Jay enumerated several methods of food preservation that included the use of low or high temperature as a means of killing or inhibiting the growth of micro-organisms in foods. The metabolic activities of food-borne micro-organisms can be slowed down or stopped at temperatures above freezing and generally stopped at subfreezing temperatures. The use of low temperature to preserve food is based on this fact while the use of temperature above ambient is based on their destructive effects on spoilage microorganisms.

The dry matter of yams and their products consists largely of carbohydrates which are primarily sources of energy (Francis, Halliday & Robinson, 1975). Oyenuga

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(1968) and Osagie and Opute (1987) have reported on the crude protein, ether extract, and crude fibre and ash contents of yam. Reports on the composition and amount of vitamins A, B1, B2, B6 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. Omonigho (1988) has shown evidence of free reducing sugars in pounded yam while Mozie (1978) identified free sugars in yam tubers.

Pounded yam readily provides required nutrients consisting of a minimum of a carbon and energy source, a nitrogen (amino acids and vitamins) source, inorganic nutrients, and water for growth of microorganisms (Omonigho, 1988). Methods for controlling the growth of microorganisms in pounded yam will therefore preserve the food quality. Preservation treatments adopted in this study included low temperature storage by freezing at $-18\pm2^{\circ}C$ and cold temperature at $4\pm1^{\circ}C$ using a deep freezer and cooled incubator, respectively, in addition to heat treatment involving sterilization at 121°C for 15 min. The chemical changes associated with the storage of treated pounded white yam samples are reported in this paper.

2. Materials and methods

2.1. Preparation of pounded yam samples

Healthy yam tubers (*D. rotundata*) used for this research were obtained from Ovie Farms, IZIKHIRIHI village near Benin City. 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) left as untreated fresh samples, (b) treated by freezing at $-18\pm2^{\circ}C$, (c) sample refrigerated at $4\pm1^{\circ}C$ and (d) heat treatment at 121°C for 15 min and later storage at room temperature ($28\pm2^{\circ}C$). These batches were dispensed into covered aluminium plates in 100 g portion before temperature treatments for batches, B, C and D. Initial chemical analyses were carried out on the untreated and treated samples before storage. Subsequent chemical analyses were carried out on each batch during the storage period.

2.2. Chemical analyses

Chemical properties of fresh untreated and treated pounded yam samples were assayed during the 8 day storage period. The pH value was determined with a single electrode pH meter (Corning Ltd, UK). A weighed 20 g sample was homogenized in 180 ml of boiled glass-distilled water using a Moulinex wet mill blender (Moulinex Ind. Ltd, France). Titratable acidity of each sample was determined using the AOAC procedure. The method of titration was that of acid-base reaction (Bevan, Redhead & Foley, 1965). The method described by Osborne and Voogt (1978) was used to determine the total solid and moisture contents. Crude protein was estimated by using Nessler's modified Kjedahl method of protein analysis (William, 1968).

Total reducing sugars 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, homogenized 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 sugars 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 blender (Moulinex Ind. Ltd, France). The extraction solvent used was petroleum ether (BDH, UK).

The ash content of each sample was estimated by dry-ashing in a muffle furnace. 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 the previously determined ash content is regarded as fibre.

Total available carbohydrate determination was by the method described by Osborne and Voogt (1978), using perchloric acid hydrolysis (Hansen & Ib, 1975). In this, 10.0 ml of the sample extract were diluted to 100 ml with distilled water. One millilitre of diluted filtrate was added into a test-tube in duplicate. Duplicate blanks, each with 1.0 ml of distilled water and standards using 1.0 ml of dilute glucose (10–100 μg/ml) were prepared. Measured 5.0 ml portions of freshly prepared anthrone reagent (0.1% anthrone in 75% sulphuric acid) were added to the content of each tube and vortexed. The mixtures were placed in a boiling water bath for 12 min, cooled quickly to room temperature ($28\pm2^{\circ}C$) and the absorbance was read at 620 nm against a reagent blank using a spectrophotometer. Total available carbohydrate of each sample was then obtained directly from the standard curve.

3. Results

The effects of temperature preservation treatments, freezing at $-18\pm2^{\circ}C$, refrigerating at $4\pm1^{\circ}C$ and

sterilization at 121°C for 15 min before storage at 28±2°C, on the chemical composition of pounded yam immediately after treatment, are summarized in Table 1. All batches of pounded yam samples had a pH value of 6.00±0.00. The pH value of the fresh untreated sample gradually increased to 6.40±0.10 on day 3 of storage at room temperature before falling to the value of 5.30±0.35 on day 8 of storage. Refrigerated samples had a constant pH value of 6.00±0.00 for the 8 days of storage as in frozen and autoclaved samples.

The changes in titratable acidity of untreated and treated pounded yam samples during the storage period are illustrated in Table 2. The titre value of refrigerated, frozen and autoclaved samples remained within the normal range of 1.00±0.13 ml of 0.1 M NaOH (used to neutralise 20 ml of 10-1 sample homogenate) while the untreated varied.

The changes in percentage dry weight (30.88±3.06%) of untreated and treated pounded yam samples during storage at ambient temperature are shown in Table 3. Except for samples autoclaved, that increased in dry weight concentration, all other samples decreased in total solids content. Changes in the concentration of crude protein (5.56±1.15%) of pounded white yam samples associated with their storage are shown in Table 4.

Changes in the amounts of reducing sugars during storage of pounded white yam samples (untreated and treated) are shown in Table 5. There was an initial decrease in reducing sugars content (2.16±0.82 mg/g of dried fresh samples) of deteriorating untreated and refrigerated samples before increasing rapidly with time of storage. Samples treated by freezing and autoclaving gave constant reducing sugars throughout the storage period of 8 days. Total available carbohydrate of untreated and treated pounded yam samples changed during storage as shown in Table 6. The total available carbohydrate of fresh untreated samples stored at room temperature changed gradually from initial 90.1±1.95% to 78.5±2.50% after 8 days. Treated samples gave no detectable changes in the starch content with progressive storage time.

Changes in the amount of extractable fat associated with storage of pounded white yam samples are shown

Table 1
Effects of various temperature treatments on the chemical composition of pounded white yam samples immediately after treatment

Parameters[a]	Fresh untreated sample	Treated		
		Stored frozen at −18±2°C	Stored refrigerated at 4±1°C	Sterilized at 121°C for 15 min[b]
Dry weight (%)	30.88±3.06	31.20±3.52	30.93±3.02	32.73±2.54
pH value	6.00±0.00	6.00±0.00	6.00±0.00	6.00±0.00
Titratable acidity (ml 0.1 M NaOH)	1.10±0.13	1.10±0.13	1.10±0.13	1.10±0.13
Crude protein (% dry weight)	5.56±1.15	5.86±0.50	5.70±0.71	5.54±0.38
Reducing sugars (mg/g dry weight).	2.16±0.82	2.25±0.48	2.13±0.67	2.43±0.52
Total carbohydrate (% dry weight)	90.1±1.95	91.2±1.50	89.5±1.80	90.1±1.95
Fat content (% dry weight)	1.23±0.26	1.40±0.15	1.28±0.29	1.23±0.26
Fibre content (% dry weight)	1.20±0.03	1.24±0.20	1.20±0.40	1.25±0.20
Ash content (% dry weight)	1.93±0.24	2.36±0.25	2.35±0.14	1.98±0.35

[a] Values of parameters of pounded yam samples at 95% confidence level; $n = 5$ samples/replicates.
[b] Samples stored at room temperature (28±2°C).

Table 2
Changes in titratable acidity associated with storage of untreated, frozen, refrigerated and sterilized pounded white yam samples (%)

Storage period (days)	Titre value[a]			
	Fresh untreated	Stored frozen at −18±2°C	Stored refrigerated at 4±1°C	Sterilized at 121°C for 15 min[b]
0	1.10±0.13	1.10±0.11	1.10±0.12	1.10±0.13
1	0.90±0.10	1.00±0.13	1.10±0.10	1.15±0.15
3	0.70±0.20	1.10±0.10	1.15±0.15	1.00±0.10
5	1.90±0.40	1.10±0.10	1.00±0.15	1.00±0.15
8	2.65±0.45	1.00±0.15	1.05±0.15	0.95±0.15

[a] Titre value (ml 0.1 M NaOH to neutralize 20 ml of sample homogenate) of pounded yam samples at 95% confidence level; $n = 5$ samples/replicates.
[b] Samples stored at room temperature (28±2°C).

Table 3
Changes in percentage dry weight (solid content) associated with storage of untreated, frozen, refrigerated and sterilized pounded white yam samples

Storage period (days)	Percentage dry weight (solid content)[a]			
	Fresh untreated	Stored frozen at −18±2°C	Stored refrigerated at 4±1°C	Sterilized at 121°C for 15 min[b]
0	30.88±3.06	31.20±3.52	30.93±3.02	32.73±2.54
1	31.20±2.80	30.94±3.23	30.00±2.55	32.73±2.40
3	32.40±2.50	31.05±307	30.50±3.06	33.07±2.50
5	28.50±3.00	31.00±2.95	29.10±3.49	33.98±2.79
8	25.54±2.70	30.75±3.29	27.14±3.50	33.70±2.50

[a] Percentage dry weight (solid content) of pounded yam samples at 95% confidence level; $n = 5$ samples/replicates.
[b] Samples stored at room temperature (28±2°C).

Table 4
Changes in the concentration of crude protein associated with storage of fresh, frozen, refrigerated and sterilized pounded white yam samples

Storage period (days)	Concentration of crude protein[a]			
	Fresh untreated	Stored frozen at −18±2°C	Stored refrigerated at 4±1°C	Sterilized at 121°C for 15 min[b]
0	5.56±1.15	5.86±0.50	5.70±0.71	5.54±0.38
1	5.85±082	5.70±0.47	5.49±0.39	5.37±0.38
3	6.33±0.76	5.37±0.39	5.55±0.55	5.67±0.48
5	5.40±0.58	5.67±0.58	5.96±0.64	5.39±0.33
8	5.60±0.85	5.34±0.62	6.17±0.38	5.35±0.80

[a] Concentration of crude protein of pounded yam samples at 95% confidence level; $n = 5$ samples/replicates.
[b] Samples stored at room temperature (28±2°C).

Table 5
Changes in amounts of free reducing sugars of fresh and treated (frozen, refrigerated and sterilized) pounded yam samples during storage

Storage period (days)	Amount of free reducing sugars[a]			
	Fresh untreated	Stored frozen at −18±2°C	Stored refrigerated at 4±1°C	Sterilized at 121°C for 15 min[b]
0	2.16±0.82	2.25±0.48	2.13±0.67	2.43±0.52
1	1.00±0.53	2.01v0.57	2.17±0.48	2.27±0.44
3	3.30±0.84	2.23±0.66	2.05±0.27	2.15±0.38
5	17.3±4.33	2.95±0.56	1.87±0.80	2.46±0.59
8	45.0±4.82	2.13±0.45	1.76±0.80	2.46±0.59

[a] Amount of free reducing sugars of pounded yam samples at 95% confidence level; $n = 5$ samples/replicates.
[b] Samples stored at room temperature (28±2°C).

Table 6
Changes in percentage of total carbohydrate content of fresh, frozen, refrigerated and sterilized pounded white yam samples associated with storage

Storage period (days)	Percentage of total carbohydrate content[a]			
	Fresh untreated	Stored frozen at −18±2°C	Stored refrigerated at 4±1°C	Sterilized at 121°C for 15 min[b]
0	90.1±1.95	91.2±1.50	89.5±1.80	90.1±1.95
1	89.3±1.75	91.0±0.80	90.5±1.60	89.6±2.40
3	84.3±1.40	91.8±1.20	88.8±2.50	90.6±1.60
5	83.3±1.80	89.2±1.70	89.8±1.90	91.4±0.80
8	78.5±2.40	90.6±1.30	89.4±1.50	90.2±0.90

[a] Percentage of total carbohydrate content of pounded yam samples at 95% confidence level; $n = 5$ samples/replicates.
[b] Samples stored at room temperature (28±2°C).

in Table 7. The fat content of deteriorating untreated samples increased very rapidly reaching 4.10±0.82% on day 8 of storage from 1.25±0.26% of fresh samples. The frozen, refrigerated and autoclaved samples had nearly constant fat content throughout the storage period (Table 7).

The percentage fibre content of untreated and treated pounded white yam samples during storage are illustrated in Table 8. Samples that were frozen, refrigerated and sterilized had fibre contents within the 1.20±0.30% range of fresh untreated samples throughout the storage period while the untreated samples increased to 2.90±0.62% on day 8 of storage. The percentage changes in ash content of pounded yam (untreated and treated) samples during storage are shown in Table 9.

4. Discussion

The initial pH-value (6.00±0.00) of fresh untreated pounded yam makes the product vulnerable to bacterial spoilage. Jay (1978) and Frazier and Westhoff (1978) have noted that foods with ultimate pH of about 5.60 and above are more susceptible to bacterial spoilage. Initial increase in pH of untreated samples (Table 1) may be due to proliferation of non-acid producing constitutive bacterial flora. The later decrease in pH was due to constitutive yeasts and moulds that produced acids from sugars (Omonigho, 1988). The pH values of treated samples remained constant during the storage period because of the non-microbial activity. The refrigerated samples had very low microbial activities, possibly due to the selective environment.

Table 7
Changes in percentage extractable fat content associated with storage of fresh (untreated) and treated pounded yam samples

Storage period (days)	Percentage extractable fat content[a]			
	Fresh untreated	Stored frozen at −18±2°C	Stored refrigerated at 4±1°C	Sterilized at 121°C for 15 min[b]
0	1.23±0.26	1.40±0.15	1.28±0.29	1.23±0.26
1	1.50±0.52	1.31±0.47	1.42±0.14	1.23±0.33
3	2.85±0.42	1.24±0.18	1.18±0.49	1.46±0.25
5	3.35±0.84	1.42±0.28	1.25±0.35	1.27±0.21
8	4.10±0.82	1.35±0.17	1.37±0.27	1.16±0.40

[a] Percentage extractable fat content of pounded yam samples at 95% confidence level; $n = 5$ samples/replicates.
[b] Samples stored at room temperature (28±2°C).

Table 8
Changes in percentage of crude fibre content of untreated and treated (frozen, refrigerated and sterilized) pounded white yam samples associated with storage

Storage period (days)	Percentage of crude fibre content[a]			
	Fresh untreated	Stored frozen at −18±2°C	Stored refrigerated at 4±1°C	Sterilized at 121°C for 15 min[b]
0	1.20±0.30	1.24±0.20	1.20±0.40	1.25±0.20
1	1.33±0.34	1.18±0.30	1.32±0.25	1.10±0.35
3	1.54±0.46	1.26±0.35	1.15±0.35	1.15±0.20
5	2.20±0.37	1.16±0.30	1.18±0.30	1.25±0.30
8	2.93±0.62	1.22±0.30	1.25±0.40	1.18±0.35

[a] Percentage of crude fibre content of pounded yam samples at 95% confidence level; $n = 5$ samples/replicates.
[b] Samples stored at room temperature (28±2°C).

Table 9
Changes in percentage ash content of fresh, frozen, refrigerated and sterilized samples of pounded white yam as a result of storage

Storage period (days)	Percentage ash content[a]			
	Fresh untreated	Stored frozen at −18±2°C	Stored refrigerated at 4±1°C	Sterilized at 121°C for 15 min[b]
0	1.93±0.62	2.36±0.25	2.35±0.14	1.98±0.35
1	2.00±1.04	2.48±0.32	2.09±0.44	2.15±0.40
3	5.10±1.79	2.31±0.28	2.34±0.15	2.37±0.10
5	5.80±2.15	2.52±0.45	1.95±0.45	2.01±0.29
8	8.60±3.44	2.19±0.54	2.05±0.35	2.22±0.45

[a] Percentage ash content of pounded yam samples at 95% confidence level; $n = 5$ samples/replicates.
[b] Samples stored at room temperature (28±2°C).

Fresh untreated pounded yam samples assayed had dry weight and moisture contents of 30.88±3.06 and 69.12±3.06%, respectively, which changed during storage as presented in Table 3. Initial increase in dry weight of untreated and refrigerated samples during storage may be due to evaporation of water from them. But, as storage progresses, the relative amount of water produced by spoilage micro-organisms from metabolic reactions will be higher relative to the amount evaporated. Frozen samples remained constant in their moisture content, possibly due to the cooled environment preventing evaporation of the samples, while sterilized ones increased steadily because of continuous evaporation and no water production by micro-organisms.

The increased protein concentration of untreated pounded yam samples (Table 4) may have resulted from preferential usage of sugars by contaminating micro-organisms, a type of protein-saving mechanism, as well as from the increased protein-rich microbial population in staled samples. All values obtained fell within the protein content range of 5.56±1.15% of fresh samples. There was a decrease in reducing sugar concentration of untreated and refrigerated samples before increasing as storage progressed (Table 5). The initial surge in reducing sugar concentration may have resulted from sugar utilization by spoilage micro-organisms, while the final increase may be due to amylase hydrolysis from starch by fungi (Omonigho, 1988). Since micro-organisms were not present or active in the non-deteriorating samples (frozen and sterilized), there was no utilization of the reducing sugars and non-production of amylase so that their sugar contents remained constant throughout the 8 day storage period.

The concentration of total available carbohydrate of fresh untreated samples decreased rapidly from the initial percentage of 90.1±1.95 to 78.5±4.30% upon storage for 8 days. This resulted from the utilization of sugars, and subsequently starch, by spoilage micro-organisms while the concentration of treated samples remained within the 90.1±1.95% range (Table 6).

The spoilage micro-organisms of untreated samples may also have produced lipids through de novo-synthesis from available carbohydrates to form cell membrane and other organelles. The fat content of treated samples (frozen, refrigerated and autoclaved) remained constant within the range of 1.23±0.26% dry mass during the storage period (Table 7). The increase in crude fibre content of untreated samples may be due to continuous utilization of the total available carbohydrate, thereby increasing the fibre content. The rapid increase in ash content may be similarly attributed to utilization of the available carbohydrate and other organic matter by spoilage micro-organisms, leading to a decrease in the proportion of available carbohydrate to inorganic ash content (Tables 8 and 9).

From this report, the use of temperature treatments could form a basis for preservation procedures of pounded white yam since samples treated were able to retain their chemical composition during the storage period.

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