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Cyanide Reduction, Functional and Sensory Quality of Gari as Affected by pH, Temperature and Fermentation Time

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Abstract: The effects of control pH, temperature and fermentation time on the cyanide reduction, functional and sensory properties of gari were investigated. Freshly harvested cassava roots (local variety) were peeled, washed and grated into a mash. The meal was divided into five equal portions and mixed thoroughly with already prepared buffer solutions from citric acid, sodium orthophosphate, -analytical grade (10% by weight buffer and kept in stainless containers to ferment at room temperature (30°C). Samples were withdrawn at intervals of 12, 24, 36, 48 and 72 h, dewatered, sifted and toasted into gari and packaged in cellophane bags. The process was again carried out at 35 and 40°C. The product gari was subjected to functional analysis (swelling index, pH, titrable acidity, water absorption capacity and residual cyanide) and sensory evaluation (appearance, taste and general acceptability) for the uncooked gari. The results obtained show that the buffer treated samples had high pH than the control sample. The highest mean pH was recorded for the BS = 8.0, (7.19), followed by BS = 7.0 (6.55) and BS = 6.0 (5.97), while the control had the lowest 4.5. The highest Swelling Index (SI) (17.45 ml/ml) was obtained for BS = 5.0 and closely followed by BS = 6.0 (17.14 ml/ml) while BS = 8.0 recorded the least 16.91 ml/ml. The buffer at pH 7.0 reduced the cyanide content to 7.69 mg HCN/kg, which is lower than the safe level of 10 mg HCN/kg. Moreover the gari from BF = 5.0 (5.4) and BF = 6.0 were the preferred in terms of general acceptability while the gari from the control BF = 0.0 (4.8) was rated the least. The buffer treated samples also performed better than the control in bulk density and general acceptability as rated by the panelists. Therefore controlling the process variables (pH, temperature and fermentation time) while fermenting cassava mash for gari production is sure way to enhance product quality and safety.

Key words: Cassava, buffer, titrable acidity, hydrogen cyanide, sensory property

INTRODUCTION

Cassava (*Manihot esculenta Crantz*) is a major root crop in the tropics and its starchy roots are significant source of calories for more than 500 million people world-wide (FAO, 2000). Cassava is diversified into different food products and these products are available year round thus making cassava an important staple food for many rural households in Nigeria (Onabolu, 2001).

Gari is the most popular of the cassava products in Africa (Oluwole *et al.*, 2004). To prepare gari, fresh cassava roots are peeled, washed and grated. The resultant pulp is put in a porous sack (polypropylene bag) and weighed down with heavy object or with hydraulic press while it is fermenting. The dewatered and fermented lump of pulp is pulverized, sifted and the resulting semi dried mash is toasted in a pan (Nweke *et al.*, 2002). The resultant granulated product which is preferred because it can be consumed dry or with cold water and or reconstituted with hot water to form "dough" which is eaten with soup (Oluwole *et al.*, 2004).

A safety concern among gari consumers arises from the presence of cyanogenic glucoside which upon hydrolysis produces cyanohydrin that further breaks down to release hydrogen cyanide - a known plant toxin (Bokanga, 1994; Ernesto *et al.*, 2000). The traditional developed methods of processing cassava products have been found to be grossly inadequate in the removal of cyanogens, irrespective of whether the roots are from low or high cyanide variety (Koch *et al.*, 1994; Achinewhu and Owuamanam, 2001).

Presence of cyanide above the safe level of 10mg HCN/kg cassava flour by FAO/WHO (1999), may pose health risk to the consumers. Some of the health conditions associated with cassava meals include: Tropical Ataxic Neuropathy (TAN); (Oshuntokun *et al.*, 1968; Akintonwa *et al.*, 1994); Konso - a spastic paraparesis of the leg attributable by consumption of insufficiently processed cassava (Cliff, 1994; Lambien *et al.*, 2004).

Bradbury (2004) had proposed that processing is the suitable strategy to reduce cyanide in cassava products. However, grating remains the critical process step in gari processing in that hydrolysis is initiated by intimate contact between naturally compartmentalized linamarin and the degrading enzyme linamarase (Vasconcelos *et al.*, 1990).

Researchers have observed that the extent of hydrolysis and liberation of hydrogen cyanide is pH dependant (Sokari and Karibo, 1992; Vasconcelos *et al.*, 1990). In the current study, traditional method of processing gari is modified by introduction of buffer solution in grated pulp at varying temperature and time. This study is aimed at optimizing hydrolysis and removal of cyanide in the resultant product while monitoring the implications of the treatments on the functional and sensory qualities of gari.

MATERIALS AND METHODS

The raw cassava roots (local variety,) were harvested in the month on January 2009 from the farm the farm of Federal University of Technology Owerri, Nigeria. The chemicals used were procured from a store in Owerri, Imo State Nigeria.

Preparation of buffer solution: Buffer solutions were prepared from the following: citric acid and sodium orthophosphate - analytical grade. 0.1 M citric acid solution was prepared by dissolving 10.5 g of citric acid in 500 cm³ of distilled water. Similarly, 0.1 M sodium orthophosphate solution was prepared by dissolving 17.8 g in 1000 cm³ of distilled water. The two solutions were used in preparing acetate buffers by appropriate combination following the ratio below. pH meter was used to confirm the reliability of buffer strength as were prepared.

Table 1: Preparation scheme for buffer

NaHPO ₄ (cm ³)	Citric acid (cm ³)	pH
51.60	48.50	5.0
63.15	36.85	6.0
32.50	17.65	7.0
97.25	2.76	8.0

The freshly harvested cassava roots were peeled, washed and grated. 1000 kg of the cassava mash was divided into five equal portions. Each portion of the mash was thoroughly mixed with 10% by weight of the buffer solution and put into stainless containers. They were left to ferment at room temperature (30°C). Samples were withdrawn at intervals of 12, 24, 36, 48 and 72 h, dewatered, sifted and toasted into gari. The process was again carried out at 35 and 40°C for the various duration of fermentation. All the determinations were replicated thrice. The (gari) samples were packaged in cellophane bags and used for analysis.

Analyses: The samples were analyzed for the functional properties (swelling index, pH, titrable acidity, water absorption capacity and residual cyanide). Sensory evaluation was performed for the appearance, taste and general acceptability for the uncooked gari.

pH determination: The pH of the sample was determined using the method of Association of Official Analytical Chemists (AOAC, 1990). Ten (10) grammes of the sample were put into a 100 ml beaker and was added 100 ml of distilled water. The pH was analyzed using a standardized pH meter (Prazisions pH meta ES10 model). Triplicate values were obtained and the mean value taken as the pH value.

Total titrable acidity (TTA): The percent titrable acidity was determined following the method of FAO (1970). Five (5 g) grammes of the sample was dissolved in a beaker and made up to 100 ml with distilled water and allowed to stand for 30 min. The solution was filtered with whatman filter paper. 25 ml of the filtrate was titrated against 0.1 M NaOH, using phenolphthalein as indicator. The end point was obtained when the colour became colourless. The mean (TTA) was obtained from triplicate determination. The percent titrable acidity (TTA %) was calculated using the formula:

$$TTA (\%) = 0.01X$$

Where X = mean titre value

Swelling index: The method of Ukpabi and Ndimele (1990) was followed with slight modification. Ten (10 g) grammes of the sample was transferred into a clean, dried, calibrated measuring cylinder. The gari was gently leveled by tapping and the initial volume recorded. 50 ml of distilled water was poured into the measuring cylinder containing the sample and allowed to stand for 4 h. The value for Swelling Index (SI) was taken as the multiples of the original volume.

Water absorption capacity (WAC): The method of Sosulski (1962) as described by Abbey and Ibeh (1988) was followed. One (1.0 g) gramme of the sample was weighed out and transferred into clean dried centrifuge tube, which the weight has previously been determined. 20 ml of distilled water was poured into the centrifuge tube and stirred properly. The centrifuge tube with the sample was placed inside and operated at a speed 3500 rpm for 45 min. The supernatant was discarded and the tube and its content reweighed. The gain in mass was taken as the water absorbed. Mean value of water absorption was obtained from triplicate determinations.

Bulk density: The method of Akpapunam and Markakis (1981) was followed. Ten (10 g) grammes of the sample were transferred into 50 ml measuring cylinder. The cylinder was tapped repeatedly for 5 min. The bulk density of gari was calculated as the mass of gari over the volume at the end of tapping. The mean value was recorded from triplicate determinations.

Determination of residual hydrogen cyanide: The residual cyanide content of gari was determined using the method of Esser *et al.* (1993).

Preparation of enzyme linamarase from freshly harvested roots: Freshly harvested cassava roots were peeled to remove the cortex. The cortex was shredded to small pieces of about 1 cm in size and refrigerated after wards. 25 g of the shredded cortex was homogenized with 250 ml of 0.1 M acetate buffer pH 5.5. The homogenate was filtered through cheese cloth. The filtrate was used to homogenize another batch of 25 g of cortex and again on the third batch. A total of one litre of the extract was prepared and stored in the refrigerator.

Preparation of KCN standard: A stock solution was prepared by dissolving 50 mg of KCN in 0.2 M NaOH. The stock solution was diluted 1:50 with 0.2 M NaOH. The automatic pipette was used to pipette into marked tubes: 0.025, 0.050, 0.075 and 0.100 ml of the diluted KCN stock, the volume was made up to 0.100 ml corresponding to 5, 10, 15 and 20 µg/ml with 0.2 M NaOH. 0.5 ml of 0.1 M phosphate buffer pH 6.0 was added followed by addition of 0.6 ml, chloramines -T and 0.8 ml of the colour reagent. The absorbance reading was obtained using (visible) spectrophotometer against blank at 605 nm wavelength.

Determination of cyanide in gari: Thirty (30 g) grammes of gari was milled and homogenized with 250 ml of 0.1 M orthophosphoric acid. The homogenate was centrifuged. The supernatant was taken as the extract; 0.1 ml of the enzyme was added into 0.6 ml of the extract. 3.4 ml of the acetate buffer (pH 4.5) was added and stirred to mix well. After which 0.2 ml of 0.5% chloramin-T and 0.6 ml of colour reagent were added and allowed to stand for 15 min for colour development. The absorbance value was obtained at 605 nm against a blank similarly prepared containing all reactants but 0.1 ml phosphate buffer added instead of KCN.

Calculation: The data from the standard were used to obtain a standard curve and its slope (b) by plotting absorbance values (Y-axis) against standard concentrations (X-axis). The unknown mean absorbance (A) and the weight of the sample (g) "w" were used to calculate the residual cyanide content using the formula:

$$\text{Residual cyanide} = A \times 250 \times 0.4151b \times w$$

The unit of cyanide content = mg HCN equivalent per kg sample.

Sensory evaluation of gari: Sensory evaluation was conducted to determine consumer preferences and acceptability of the samples, using a 9-point hedonic scale as described by Watt *et al.* (1985) for the degree of likeness. In scaling, 9 represents "like extremely", mid point 5 represents "neither like nor dislike" and runs down to one which represents "dislike extremely". The quality parameters assessed include; appearance, taste and general acceptability. Twenty (20) panelists were used, 10 males and 10 females of ages ranging from 23 to 44. These panelists were usual consumers of gari. The samples were presented to them in clean dried plates and the panelists recorded their responses on the form provided.

Statistical analysis: The mean values of physicochemical properties were addressed as functions of Buffer solution (five), fermentation temperature (three) and fermentation duration (five) which fitted into 5 buffer solutions x 3 fermentation temperature x 5 fermentation duration. The 3-way analysis of variance procedure as described by Steel and Torrie (1980) was followed. The means were separated using Fisher's (LSD) least significant difference as described by Roessler (1984).

RESULTS

Functional properties of Gari as affected buffer strength (BS): Table 2 shows the functional properties of gari as affected by the Buffer Strength (BS). The mean pH differed significantly ($p < 0.05$) under the condition of the study. The highest mean pH was recorded for the BS = 8.0, (7.19), followed by BS = 7.0 (6.55) and BS = 6.0 (5.97), while the control had the lowest 4.5. BS = 0.0. Buffer solution used in the treatment of cassava mash was found to leave high pH in the product up to a pH 7.18 at BS = 8.0.

The control sample (BS = 0.0) performed better in TTA% than the rest of the samples treated with buffer. It was also observed that all the samples that were treated with the buffer did not significantly ($p < 0.05$).

The highest Swelling Index (SI) (17.45 ml/ml) was obtained for BS = 5.0 and closely followed by BS = 6.0 (17.14 ml/ml) while BS = 8.0 recorded the least 16.91 ml/ml. However, no significant difference ($p < 0.05$) occurred for BS = 0.0 (17.04 ml/ml), BS = 6.0 (17.14 ml/ml) and BS = 7.0 (17.04 ml/ml).

The Bulk Density (BD) increased as the buffer strength increased from BS = 0.0 to BS = 7.0 and declined afterward. The values obtained for BD differed significantly at $p < 0.05$. Highest mean Water Absorption Capacity (WAC), 1.33 ml/g solid was recorded for BS = 6.0. The WAC increased from the control (BS = 0.0) and reached the peak at BS = 6.0 and declined marginally to BS = 8.0.

Table 2: Mean values of functional properties of gari as affected by Buffer Strength (BS)

Buffer strength	pH	S.I. (ml)	TTA (%)	BD (g/cm ³)	WAC (ml/g)	HCN (mg/kg)
0	4.5±0.46 ^c	17.04±3.24 ^{ab}	0.0056±0.002 ^b	0.9993±0.23 ^c	1.05±0.19 ^b	25.52±4.81 ^a
5.0	5.02±1.05 ^b	17.45±3.19 ^a	0.0064±0.001 ^a	1.0686±0.41 ^{ab}	1.31±0.33 ^a	15.92±4.43 ^b
6.0	5.07±1.07 ^{ab}	17.14±2.86 ^{ab}	0.0065±0.002 ^a	1.1633±0.50	1.33±0.31 ^a	11.78±4.46 ^c
7.0	5.15±1.10 ^{ab}	17.04±2.85 ^{ab}	0.0064±0.002 ^a	1.1700±0.51 ^a	1.32±0.31 ^a	7.69±3.72 ^d
8.0	5.19±10.9 ^a	16.91±2.68 ^b	0.062±0.002 ^a	1.687±0.531 ^{ab}	1.32±0.37 ^a	9.26±3.39 ^c
LSD	0.167	0.4817	0.0004	0.09991	0.0977	0.6739

Means are values of triplicate determination. Means not followed by similar letter of alphabet differed significantly at $p \leq 0.05$

The residual cyanide obtained for the samples treated with buffer solution differed among their means at ($p < 0.05$). The residual cyanide, HCN decreased with increasing buffer strength. The lowest HCN (7.69 mg HCN/kg) was obtained from BF = 7.0. While the control (BS = 0.0) had the highest 25.52 mgHCN/kg.

Functional properties of gari as affected by temperature of fermentation in buffer: The result of functional properties of gari as affected by Fermentation Temperature (FT) is shown in Table 3. The mean pH obtained for the samples differed at $p < 0.05$. Highest mean pH was recorded for FT = 30°C (5.71). However, the pH obtained for FT = 35°C (4.61) and FT = 40°C (4.67) did not differ under the condition of the study ($p < 0.05$).

The data for Swelling Index (S.I.) shows that the values differed significantly ($p < 0.05$). Incidentally, the mean S.I. gari from 30°C (17.73 ml/ml) did not differ from that recorded for FT = 35°C, (17.72 ml/ml). The samples obtained from FT = 35°C and FT 40°C were found to be higher in titrable acidity, 0.0069 and 0.0075 respectively while the FT = 30°C had the least TTA% (0.0042). The SI of the control sample compared well with the sample from 35°C fermentation temperature, while it declined at 40°C. This might suggest that it would be technologically and economically advantageous to limit fermentation of cassava mash at a maximum of 35°C when S.I. as quality factor is desired.

For the Bulk Density (BD) of the sample from FT = 35°C had the highest mean BD (1.4860 g/cm³) while that from FT = 30°C had the least BD (0.5804 g/cm³). On the other hand the means obtained for WAC of the showed that they differed significantly ($p < 0.05$). The highest WAC (1.48 ml/g solid) was obtained from FT = 35°C. However, the mean WAC for FT = 30°C (1.13 ml/g solid) did not differ from the score for FT = 40°C (1.18 ml/g solid) under the condition of study ($p < 0.05$).

The least mean HCN (12.78 mgHCN/Kg) was recorded by gari from FT = 40°C while the highest residual HCN was obtained for FT = 30°C (15.30 mgHCN/Kg) which shows that more cyanide was liberated at 40°C.

Functional properties of gari as affected by duration of fermentation in buffer: The results of functional properties of gari as affected by Duration of Fermentation (DF) are shown in Table 4. The pH were high for the samples from DF = 12 (h) (5.7) and DF = 24 (h) (5.3) and declined gradually below pH = 5.0 from the

DF = 36 (h). The least mean pH was recorded for DF = 72 (h) (4.37). However, the mean pH for DF = 36 (h) (4.68) did not differ from DF = 48 (h) (4.61) at $p > 0.05$. Similarly, the mean TTA differed significantly ($p < 0.05$). The DF = 72 h recorded the highest mean TTA% (0.008). The least TTA% was scored by DF = 12 h (0.0049) and DF = 24 (0.0049) respectively. The pH was found to decrease with increases in process time for cassava mash, while the TTA increased in response to increase in acidity.

The Swelling Index (S.I) recorded for the samples increased from DF = 12 h (13.40ml/ml) to a peak at DF = 24 h (20.36 ml/ml) and declined afterward to DF = 72 h (15.15 ml/ml).

The S.I. and BD had optimum performance at 24 and 48 h respectively. Optimum WAC was obtained at 24 h and decline after word to 72 h.

The bulk density also differed significantly at $p < 0.05$. The highest BD g/cm³ was obtained from DF = 48h (1.2773). The results for DF = 24 h (1.1470) and DF = 36 h (1.1320), also DF = 72 h (1.1520) did not differ ($p > 0.05$). However, the least BD was obtained for DF, 12 h (0.9140).

On the other hand, the mean WAC (ml/g solid) obtained for the samples differed significantly at $p < 0.05$. The increased from DF = 12 (h) (0.91) to 1.49 ml/g solid DF = 24 (h) gradually declined to 1.26 (ml/g solid) for DF = 72 (h) sample.

The mean HCN (mg HCN kg-1) differed significantly at $p < 0.05$. However the least residual HCN was obtained for DF = 72 (h) (9.28), while the highest residual HCN was recorded for DF = 12 h (19.39).

Sensory properties of gari as affected by buffer strength: The result of sensory properties of gari as affected by buffer strength is as shown in Table 5. The panelists preferred the appearance of the control sample (6.39) to the rest, followed by the gari from BF = 7.0 (6.26), while the sample from BF = 5.0, was rated lowest (6.0).

The taste of the gari differed significantly at the condition of study $p < 0.05$. The panelists rated the sample from BF = 7.0 (5.3) as the best, followed by BF = 8.0 (5.2), while the control sample (BF = 0.0) was the least preferred in taste (4.6).

Moreover the gari from BF = 5.0 (5.4) and BF = 6.0 were the preferred in terms of general acceptability while the gari from the control BF = 0.0 (4.8) was rated the least.

Table 3: Mean values of physicochemical properties of gari as affected by Temperature of Fermentation (TF)

Temperature	pH	S.I. (ml)	TTA (%)	BD (g/cm ³)	WAC (ml/g)	HCN (mg)
30	5.71±1.43 ^a	17.73±3.23 ^a	0.0042±0.002 ^b	0.5804±0.01 ^c	1.13±0.31 ^b	15.30±7.99 ^a
35	4.61±0.10 ^b	7.72±2.46 ^a	0.0069±0.002 ^a	1.4860±0.030 ^a	1.48±0.32 ^a	14.02±7.53 ^b
40	4.6±0.25 ^b	15.89±2.67	0.0075±0.001 ^a	1.2876±0.28 ^b	1.18±0.20 ^b	12.78±7.42 ^c
LSD	0.1293	0.3731	0.0003	0.0767	0.0757	0.522

Means are value of triplicate determination. Means not followed by similar letter of alphabet differed significantly at p≤0.05

Table 4: Means values of physicochemical properties of gari as affected by the Duration of Fermentation (DF)

Ferm. time (h)	pH	S.I. (ml)	TTA (%)	BD (g/cm ³)	WAC (mlg)	HCN (mg/kg)
12	5.77±1.26 ^a	13.4±0.99 ^a	0.0049±0.002 ^a	0.9140±0.25 ^c	0.91±0.24 ^c	19.39±8.17 ^d
24	5.53±1.36 ^b	20.36±0.65 ^a	0.0049±0.002 ^d	1.1147±0.46 ^b	1.49±0.27 ^a	16.36±6.19 ^b
36	4.06±0.18 ^c	19.05±1.34 ^b	0.005±0.001 ^c	1.1320±0.46 ^b	1.35±0.26 ^b	14.89±6.26 ^c
48	4.61±0.14 ^c	17.61±2.18 ^c	0.0069±0.001 ^b	1.2773±0.55 ^a	1.131±0.28 ^b	10.32±6.65 ^d
72	4.37±0.18 ^d	15.15±1.14 ^d	0.008±0.001 ^a	1.1520±0.43 ^b	1.26±0.25 ^b	9.28±6.46 ^e
LSD	0.167	0.4817	0.0004	0.0991	0.0977	0.6739

Means are values of triplicate determination. Means not followed by similar letter of alphabet differed significantly at p≤0.05.

Ferm. = Fermentation

Table 5: Mean Value of sensory properties of gari as affected by buffer strength

Buffer strength	Appearance	Taste	General acceptability
0	6.39±0.75 ^a	4.6±0.84 ^d	4.8±0.99 ^c
5.0	6.0±0.69 ^b	5.0±0.92 ^{bc}	5.4±1.05 ^a
6.0	6.21±0.99 ^{ab}	4.9±1.02 ^c	5.4±0.74 ^a
7.0	6.26±0.74 ^{ab}	5.3±0.99 ^a	5.2±0.71 ^{ab}
8.0	6.27±0.69 ^{ab}	5.2±0.92 ^{ab}	5.0±0.66 ^{ab}
LSD	0.3824	0.3009	0.3206

Means are values of triplicate determination means with similar letters of alphabets did not differ at <0.05

Table 6: Mean Value of sensory properties of gari as affected by temperature of fermentation

Temp. of ferment	Appearance	Taste	General acceptability
30	5.80±1.00 ^b	4.3±0.74 ^b	4.5±0.79 ^b
35	6.52±0.35 ^a	5.3±0.83 ^a	5.5±0.64 ^a
40	6.35±0.79 ^a	5.4±0.78 ^a	5.6±0.64 ^a
LSD	0.3824	0.3009	0.3206

Means are values of triplicate determination, means followed by similar letters of alphabets did differ significantly p<0.05.

Temp. = Temperature

Sensory properties of gari as affected by temperature of fermentation in buffer: The results of sensory evaluation of gari fermented at 30, 35 and 40°C are shown in Table 6. The gari from 35°C (6.52) fermentation temperature was preferred to that from 30°C (5.80) and 40°C (6.35) in terms of appearance. The performance of gari from 40°C was adjudged second by the panelist while the 30°C (5.8) was the least preferred. The means of gari from 35°C (6.52) and 40°C (6.35) did not differ at p>0.05.

The gari fermented at 40°C (5.5) was rated best by the panelists in terms of taste. There were no significant difference for samples from 35°C (5.3) and 40°C (5.4) at p>0.05. Incidentally the gari from 30°C fermentation temperature had the lowest score. Of all the samples fermented at varying fermentation temperature, the 40°C (5.6) was preferred by the panelists to the rest. The data also show that score for 35°C (5.5) did not differ from that of 40°C in general acceptability at p>0.05.

Table 7: Mean values sensory properties of gari as affected by duration of fermentation (h)

Ferm. tim (h)	Appearance	Taste	General acceptability
12	5.80±1.14 ^c	4.0±0.84 ^d	4.5±0.78 ^d
24	6.13±0.87 ^{bc}	4.8±0.68 ^c	5.0±0.94 ^c
36	6.21±0.63 ^{ab}	5.1±0.69 ^b	5.4±0.93 ^b
48	6.45±0.56 ^{ab}	5.6±0.82 ^a	5.8±0.53 ^a
72	6.55±0.62 ^a	5.5±0.64 ^a	5.09±0.43 ^{cd}
LSD	0.3824	0.3009	0.3206

Means are values of triplicate determination means not followed letter of alphabet did not differ at p<0.05. Ferm. = Fermentation

Sensory properties of gari as affected by duration of fermentation in buffer: The data in Table 7 shows that the rating of appearance gari differed significantly (p<0.05) as the fermentation time increases. The sample from 72 h fermentation had the highest score, 6.55, which is followed by 48 h (6.45) while sample from 12 h had the least score (5.80). The panelists rated sample from 48 h fermentation duration as the best in gari taste (5.6), followed by 72 h (5.6) while the 12 h had the lowest score (4.0).

Moreover the 24 h fermented gari was most preferred in general acceptability (5.8), followed by 36 h (5.4) fermented sample while the 12 h was poorly rated (4.5).

DISCUSSION

Buffer solution used in the treatment of cassava mash was found to leave high pH in the product up to a pH 5.19 when used at BF = 8.0 level. The final pH of the gari was above the recommendation (pH 3.9-4.3) by Achinewhu (1994). High pH is rather undesirable in gari as it might predispose the product to bacterial spoilage. On the other hand, the tritable acidity improved marginally when the buffer treated samples were compared with the control (BF = 0), but very low when compared with 0.75-0.95% obtained by Achinewhu *et al.* (1998) and Achinewhu and Owuamanam (2001). However TTA range of 0.85-1.20% has been judged as satisfactory to good for gari quality (Achinewhu, 1994). It might be suggested, that the low TTA resulted from the

unfavorable growth medium for certain organisms in the natural flora of cassava mash. Gari is cherished for its sour taste, which is due to organic acids such as lactic, acetic, propionic, succinic, pyruvic acid and other flavor compounds: esters, aldehydes etc. produced by fermentative organisms (Collard and Levi, 1959).

The Swelling Indexes (SI) of the buffer treated samples were superior to that of the control. The swelling of gari when soaked either hot or cold water is due to partial dextrinization starch component during roasting such that when the product is rehydrated it swells considerably (Onwueme, 1978). Volume increase ranging from 300-500% has been reported as acceptable for quality gari (Achinewhu, 1994). It is an important quality index as consumers of gari would expect maximum swelling when the product is reconstituted in hot or cold water.

The performances of bulk density of the buffer treated samples were better than the control. However bulk density of the sample are found to be influence by grain size, which is affected by the agglomeration of partially gelatinized product during roasting stage (Achinewhu and Owuamanam, 2001). Intermittent scrubbing between the walls of the roasting pan is needed to disintegrate the lumpy portions of the mash in order to control agglomeration (Onwueme, 1978). It might be suggested that the perceived increase in BD and SI with increasing buffer strength, could be due to poor starch conversion by microorganisms to organic acid.

The lowest residual cyanide recorded for buffer at pH = 7.0 is in agreement with the works of Hahn (1989); Sokari and Karibo (1992) which suggested that maintaining the pH of cassava mash at 5.0-6.0 facilitate the liberation of cyanogenic glucoside. High residual cyanide has been implicated in some degenerative diseases such as tropical ataxic neuropathy, spastic paraparesis, "Konso" etc. (Rosling, 1988).

When cassava mash is fermented in buffer solution, the pH of the resulted product was found to reduce and the TTA marginally increased. Thus, suggesting that activity of microorganism may have been promoted by fermentation temperatures.

The optimum BD and WAC obtained at 35°C could mean that it is the technical temperature condition for fermentation of cassava mash.

On the other hand, residual cyanide was liberated more at 40°C, which supports the finding by Sokari and Karibo (1992) on the role of elevated temperature in bound cyanide reduction.

The pH was found to decrease with increases in process time for cassava mash, while the TTA increased substantially. The gradual decline in pH might be as a result of activities of which managed to thrive in the buffer environment to produce acid far beyond what the buffer can cope. The S.I. and BD where found to reach the optimum at 24 and 48 h respectively.

The residual HCN decreased with process time of cassava mash. The residual cyanide 9.28 mg HCN/kg obtained from sample from 72 h fermentation, which is below the safe level recommended by FAO/WHO (1999) reinforced the need to ferment cassava up to 72 h. Adindu and Aprioku (2006) obtained cyanide content up to 26.1 ppm in commercial gari sold in Rivers South - South Nigeria. Therefore keeping the pH of fermenting mash a little longer after grating cassava might have considerable reduction on cyanide content of gari.

The appearance of gari fermented in buffer solution compared well with the control.

The appearance of gari to a great extent depends on the level of hygiene exhibited by the processor, also depends on the amount wash water, neatness of utensils that come in contact mash before and after roasting (Achinewhu and Owuamanam, 2001).

The taste of the buffer treated sample was judged by the panelists to be superior to the control. Moreover, the samples from BF = 5.0 and BF = 6.0 were preferred to the rest. Thus, it might be possible to improve sensory quality by adjusting the pH of cassava mash up to pH (6.0) for better sensory quality.

The panelists preferred the taste and appearance of gari from cassava mash fermented at 35 and 40°C to the control. While the gari from cassava mash fermented at 40°C was preferred to the rest by the panelists in terms of general acceptability. The preferences of the 35 and 40°C samples over the control might suggest that the fermentation temperature enhanced activities microbes for the production of useful metabolites.

Conclusion: The study has shown that treatment of cassava mash with buffer solution was able to reduce the residual cyanide in gari below the level, 10 mgHCN/kg that is considered safe (FAO/WHO, 1999). With the exception of pH, which was high for the buffer treated samples; other physicochemical properties (SI, BD, WAC etc.) were improved for the treated samples than the control. Buffer treatment is a sure way of guaranteeing cassava food safety and will work well in a mechanized continuous processing; which is yet to be established in gari consuming countries.

The work has revealed that maintaining the temperature condition above the ambient, contributed to volatilization of the residual cyanide. More so, processing at 35°C gave better performance in the physicochemical properties than the control.

On the other hand leaving the mash to ferment for a period up to 72 h further enhanced the reduction of residual cyanide.

REFERENCES

- Abbey, B.W. and C.O. Ibeh, 1988. Functional properties of raw and heat processed cowpea flour. *J. Food Sci.*, 53: 1775-1791.

- Achinewhu, S.C., 1994. Indigenous fermented foods of Nigeria. Public Lecture delivered at the Rivers State University of Science and Technology Port Harcourt, Nigeria, pp: 17.
- Achinewhu, S.C., L.I. Barber and I.O. Ijeoma, 1998. Physicochemical properties and garification of selected cassava cultivars in Rivers State cassava cultivars in Rivers State. *Plant Food Hum. Nutr.*, 52: 133-140.
- Achinewhu, S.C. and C.I. Owuamanam, 2001. Garification of five improved cassava cultivars, physicochemical and sensory properties of gari yield. *Afr. J. Root Tuber Crops*, 4: 18-21.
- Adindu, M.N. and A.B.I. Aprioku, 2006. Cyanogenic content of gari from processing centers in Rivers State, Nigeria.
- Akintonwa, A., O. Tunswashe and A.A. Onifade, 1994. Fatal and non-fatal acute poisoning attributed to cassava based meal. *Acta Hort.*, 375: 285-288.
- Akpapunam, M.A. and P. Markakis, 1981. Physicochemical and nutritional aspects of cowpea flour. *J. Food Sci.*, 46: 972-973.
- AOAC, 1990. Association of Official and Analytical Chemists, 15th Edn., A.O.A.C. Inc. Arlington, V.A.U. S.A., pp: 1945-1962.
- Bokanga, M., 1994. Distribution of cyanogenic potential in cassava germplasm, In Proc. Workshop on Cassava Safety (Bokanga, M., Esser, A.J.A., Poulter, N., Rosling, H. and Tewe, O. eds) 1-4 March, Ibadan, Nigeria, *Acta. Hort.*, 375: 117-123.
- Bradbury, J.H., 2004. Processing of cassava to reduce cyanide content. *Cassava Cyanide Disease Network News (CCDN)*, 3: 3-4.
- Cliff, J., 1994. Cassava safety in times of war and drought in Mozambique. *Acta Hort.*, 375: 372-378.
- Collard, P. and S.A. Levi, 1959. A two stage fermentation of cassava. *Nature*, 183: 620- 621.
- Ernesto, M., A.P. Cardoso, J. Cliff and J.H. Bradbury, 2000. Cyanogens in cassava flour and roots and urinary thiocyanate concentration in Mozambique. *J. Food Composition Anal.*, 13: 1-12.
- Esser, A.J.A, M. Bosveld, A.G.J. Vander Cruft, 1993. Studies on the quantification of specific cyanogens in cassava products and introduction of new chromogen. *J. Sci. Food and Agric.*, 63: 288-290.
- FAO, 1970. Food and Agriculture Organization Year Book, FAO. Rome, pp: 13-17.
- FAO, 2000. Food and Agriculture Organization of the United Nations. Championing the cause of cassava. File /A./Championing cause of cassava.Htm.
- FAO/WHO, 1999. Joint FAO/WHO Food Standards Programme, Codex Alimentarius Commission, XII supplement 4 FAO. Rome, pp: 12-45.
- Hahn, S.K., 1989. A overview of African Traditional cassava processing and utilization, *Out of Agriculture*, 18: 110-118.
- Koch, B.M., O. Sibbeses, E. Swain, R.A. Kahn, D. Liangcheng, S. Bak, B.A. Halkier and B.K. Moller, 1994. Possible use of a biotechnological approach to optimize and regulate the content and distribution of cyanogenic glucosides in cassava to increase food safety. In: proc. of intern. Workshop on cassava safety. (Bokanga, M.; Esser, A.J.A.; Poulter, N; Rosling, H. and Tewe, O. eds) March 1-4 Ibadan Nigeria. *Acta. Hort.*, 375: 45-60.
- Lambien, F., B. Defoort and Y. Kuo, 2004. Konso or Neurolathyris: Is there a difference? *Cassava Cyanide Disease Network News*, 3: 2-3.
- Nweke, F.I., D.S.C. Spencer and J.K. Lynam, 2002. The cassava transformation Africa's best kept secret. Michigan state University Press East Lansing USA, pp: 7-206.
- Oluwole, O.B., O.O. Olatunji and S.A. Odunfa, 2004. A process technology for conversion of dried cassava chips into garri. *Nig. Food J.*, 22: 65-73.
- Onabolu, A., 2001. Cassava processing, consumption and dietary cyanide exposure. IHCAR, Karohnska Institutet, Sweden, pp: 6-7.
- Onwueme, I.C., 1978. The Tropical Tuber Crops, yam, cassava, sweet potato and cocoyam. John Wiley and Sons. New york and Brisbane Toronto, pp: 199-227.
- Oshuntokun, B.O., J.E. Orowojo, H. Mcfarlane and J. Wilson, 1968. Plasma amino acids in the Nigeria nutritional ataxic neuropathy. *Br. Med. J.*, 2: 647-649.
- Roessler, E.E., 1984. Statistical evaluation of experimental data, multiple comparison, In: *Food Analysis, Principles and Techniques* (Gruenwedal, D.W. and Whitaker, J.R. eds.). Marcel Dekker, New York, pp: 12-13.
- Rosling, H., 1988. Cassava toxicity and food security. A report for UNICEF, African household food security programme, 2nd Edn., Tryck Kontakt Uppsala Sweden.
- Sokari, T.G. and P.S. Karibo, 1992. Changes in Cassava Toxicity During Processing into Gari and Ijapu Two Fermented Food Products. *Food Additive Contam.*, 9: 379-384.
- Sosulski, F.W., 1962. The centrifuge methods for determing flour absorption in hard red spring wheat. *Cereal Chem.*, 39: 344.
- Steel and J.H. Torrie, 1980. Analysis of variance II Factorial experiment, In: *Principals and procedures of statistics. A biometrical approach 2nd edn.* McGraw-Hill Int'l. Coy. London, pp: 336-376.
- Ukpabi, U.J. and Ndimele, 1990. Evaluation of gari production in Imo State Nigeria. *Nig. Food J.*, 8: 105-108.
- Vasconcelos, A.T., D.R. Twiddy, A. Westby and P.J.A. Reilly, 1990. Detoxification of cassava during preparation. *Int. J. Food Sci. Technol.*, 25: 199.
- Watt, B.M., G.L. Ylimaki, L.E. Jeffery and L.G. Elias, 1985. Basic sensory methods for food evaluation. *IDRC-277e*: 66-67.