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Effects of oven drying, boiling and fermentation on vitamins, amino acids and mineral nutrient profile of tuber flours of *Icacina senegalensis* A. Juss (Icacinaceae)

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Abstract
Objective: The effects of oven drying, boiling and fermentation on vitamins, selected amino acids and mineral nutrient profile of tuber flours of *Icacina senegalensis* A. Juss (Icacinaceae) were investigated.
Method: The tubers were processed by four different methods: a) oven drying; b) boiling; c) fermenting; and d) fermenting plus boiling. Samples b-d were further oven-dried and all samples pulverized into respective flours RD, BD, FD, and FBD (from treatment methods a, b, c, and d). Vitamins, amino acids and mineral nutrient profiles of tuber flours were determined using standard methods.
Results: The B group of vitamins and Vitamin C suffered drastic losses through boiling and fermentation. There was a significant improvement in Folate in FD over RD, BD and FBD. Boiling stabilized Beta carotene in BD and FBD compared to RD, while fermentation caused a significant reduction in FD. Vitamin A was significantly improved in FB over RD while the boiled samples (BD and FBD) suffered 11 and 24% losses, respectively. Vitamins E and K were similarly improved by fermentation but reduced though boiling. Boiling caused significant improvement in all 8 selected amino acids evaluated. Fermented samples FD and BD had higher contents of Calcium, Potassium and Copper while boiling and fermentation improved Magnesium.
Conclusion: Processing *Icacina senegalensis* tuber by boiling preserved Beta carotene and improved amino acids while fermentation improved fat soluble vitamins (Vitamins A, E and K) and mineral nutrients. Processed flours must be enriched with water soluble vitamins and other essential nutrients for nutritional balance.

Keywords: Oven drying, boiling, fermentation, *Icacina senegalensis* tuber, vitamins, mineral nutrients

Introduction

False yam *Icacina senegalensis* is a drought-resistant, shrubby perennial root crop that is indigenous to central and West Africa and is found in the wild on light sandy soils in the savanna regions of Guinea, Nigeria, Senegal, Gambia, northern Ghana, and parts of Sudan. The plant is commonly referred to as false yam. Other countries and tribes attribute different names to it e.g. in Nigeria the Efik's call it *efikisong*; [1] the Igbo's call it *Utoto ogiri/Akwukwo ogiri* while the Hausas call it *Tankwara* ; the Ashantes in western Ghana call it *Abubu ntope,* meaning break hoe; while the Badyaras in Senegal call it *Manassa* [2].

All the parts of are useful: leaves and roots for medicine [1], fruit and tubers for food [2]. The tubers are reduced in size by cutting, soaked in water to eliminate toxins and expedite maceration. The reduced and soaked pieces are dried thereafter, pounded and then sieved to rid off the chaff. It is equally softened just as in the case of "garri" into an edible paste by adding hot water. The starch produced from the tubers of *Icacina* is used for commercial purposes that include tapioca [3]. Incorporating *Icacina senegalensis* in poultry feed did not give significant improvement in meat quality [4], and the presence of anti-nutrients or toxins was suggested to be responsible. In another study, we investigated the proximate and anti-nutrient profile changes in differently processed tuber flours of *Icacina senegalensis* with the view of finding the treatment that can best eliminate the antinutrients [5]. In this study, we evaluated the effects of those processing methods on vitamins, selected amino acids and mineral nutrients profile of of *Icacina senegalensis* tuber flours.

Materials and Methods

Collection and identification of plant materials

Icacina senegalensis tuber used for this study was harvested from the wild in Akpabuyo Local Government of Cross River State; identified by a taxonomist in the Department of Botany, University of Calabar; and deposited with herbarium voucher number 0620.

Preparation of *Icacina senegalensis* tuber flours

The tubers were peeled, washed and cut into tiny pieces. It was thereafter divided into four portions; each portion was subjected to different processing method: a) oven drying; b) boiling before drying; c) fermenting and drying; and d) fermenting followed by boiling, then drying. Washing was with tap water, fermentation was with water (1:3, w/v) at room temperature for 3 days; boiling was also with water (1:3, w/v) at 100 ^{o}C, for 1 hour. Oven drying was done at 40^{o}C for 48 hours. The dried samples were ground into powder using a hammer mill into respective flours RD, BD, FD, and FBD (from treatment methods a, b, c, and d), stored in tightly capped bottles for analyses.

Determination of vitamins

Antioxidant vitamins (Vitamins A, E, and C) were determined using the methods of Rutkowski & Grzegorczyk [6] while vitamins B_1, B_2, B_3, B_5, B_6, K and Folate were determined using standard methods. [7]

Determination of the amino acids

Each sample was hydrolysed and thereafter subjected to HPLC analysis according to the method of Wathelet [8].

Mineral assessment of *Icacina senegalensis* flour sample

Selected mineral elements were determined using atomic absorption spectrophotometery (AAS) [9].

Statistical analysis

The data obtained was expressed as the mean ± SEM using analysis of variance (ANOVA) of statistical package for social sciences (SPSS) software version 17, followed by Least Significant Difference (LSD post hoc test), Differences was considered significant at $p<0.05$.

Results

The results of this study indicated that boiling and fermentation caused significant ($p<0.05$) losses in all the water soluble vitamins when compared to raw- dried (RD) sample (Table 1).

There was a complete elimination of Vitamin C (BD and FBD) and Vitamin B6 (FD and FBD) in some cases. Significant ($p<0.05$) improvement in Folate (mcg/100g) in FD (27.00) over RD (24.00), BD (14.00) and FBD (8.67) was recorded. Beta carotene (mg/100g) in BD and FBD ranged 82.33-84.00 compared to RD (87.00), while its level in FD (48.00) was significantly ($p<0.05$) lower than the other samples. Vitamin A (mcg/100g) was significantly ($p<0.05$) improved in FB (149.00) over RD (139.33) while the boiled samples (BD, 124.33 and FBD, 105.67) suffered 11 and 24% losses, respectively. Vitamins E and K were similarly improved by fermentation but reduced though boiling.

The boiled samples (BD and FBD) had significantly ($p<0.05$) higher levels of all the 8 selected amino acids (Isoleucine, Phenylalanine, Valine, Methionine, Lysine, Threonine, Leucine and Alanine) evaluated while their levels were similar in RD and FD samples (Table 2).

Fermented samples (FD and BD) had higher contents of Calcium, Potassium and Copper while BD, FD, and FBD recorded significant ($p<0.05$) improvement in Magnesium levels (Table 3). Sodium was absent in all samples analyzed.

Table 1: Result of Water and fat soluble vitamins content of processed *Icacina senegalensis* tuber flours

Vitamins (/100g)	**RD**	**BD**	**FD**	**FBD**
Vitamin B1(mg)	0.083±0.047	0.037±0.012^{a,c,d}	0.09±0.008 ^{a,d}	0.01±0.004^{b}
Vitamin B2(mg)	0.037±0.012	0.017±0.009^{a,c,d}	0.01±0.00 ^{a,b,d}	0.003±0.004^{a,b,c}
Vitamin B3(mg)	0.353±0.082	0.02±0.004 ^{c,d}	0.01±0.009 ^{a,b,d}	0.003±0.004^{a,b,c}
Vitamin B5(mg)	0.3±0.02	0.103±0.017^{a,c,d}	0.25±0.051 ^{a,d}	0.01±0.005 ^{a,b,c}
Vitamin B6(mg)	0.42±0.09	0.15±0.042 ^{a,c,d}	0.00±0.00 ^{a,b,d}	0.00±0.00 ^{a,b,c}
Vitamin C(mg)	13.54±0.799	0.00±0.00 ^{a,c,d}	4.04±0.122 ^{a,b,d}	0.00±0.00 ^{a,b,c}
Folate(mcg)	24.00±2.16	14.00±0.816 ^{c,d}	27.00±1.632^{a,b,d}	8.67±1.25 ^{a,b,c}
Beta carotene(mg)	87.00±0.4.082	82.33±0.471 ^{c,d}	48.00±4.967^{a,b,d}	84.00±2.160^{b}
Vitamin A(mcg)	139.33±7.134	124.33±2.054^{a,c,d}	149.00±2.16 ^{a,b,d}	105.67±4.03^{a,b,c}
Vitamin E(mg)	0.34±0.057	0.24±0.244 ^{a,c,d}	0.32±0.016 ^{a,d}	0.04±0.057 ^{a,b,c}
Vitamin K(mcg)	2.33±0.37	2.01±0.012 ^{a,c,d}	2.63±0.285 ^{a,b,d}	1.79±0.094 ^{a,b,c}

Values are expressed as mean ± SD. n=replicate of three (3) samples. a = significantly different from dried ($p<0.05$), b = significantly different from boiled ($p<0.05$), c = significantly different from fermented ($p<0.05$) and d = significantly different from fermented and boiled ($p<0.05$).

Table 2: Selected Amino acid content of processed *Icacina senegalensis* tuber flours

Amino acid (mg/100g)	**RD**	**BD**	**FD**	**FBD**
Isoleucine	2.15±0.325 ^{a}	4.06±0.111 ^{a,c,d}	2.67±0.589 ^{b}	1.97±0.352 ^{b}
Phenyalanine	2.54±0.325 ^{b}	6.07±1.549 ^{a,c,d}	2.54±0.392^{b}	1.97±0.352 ^{b}
Valine	3.56±0.822^{b,d}	4.92±0.324 ^{a,c,d}	3.56±0.822 ^{b,d}	2.15±0.316 ^{a,b,c}
Methionine	2.42±0.521 ^{b,d}	3.77±0.090 ^{a,c,d}	2.43±0.521^{b,d}	1.57±0.146 ^{a,b,c}
Lysine	7.90±2.049 ^{b}	11.46±.239 ^{a,c,d}	7.9±2.049 ^{b}	6.17±1.017 ^{b}
Threonine	1.67±0.323 ^{b}	2.59±0.805 ^{a,c,d}	1.56±0.282 ^{b}	1.087±0.323 ^{b}
Leucine	3.82±0.810 ^{b}	4.51±2.157 ^{a,c,d}	3.82±0.810 ^{b}	2.68±0.317 ^{b}
Alanine	6.40±0.756 ^{b}	11.27±1.104^{a,c,d}	6.40±0.756 ^{b}	5.27±0.576 ^{b}

Values are expressed as mean ±SD. n=replicate of three (3) samples. a = significantly different from dried ($p<0.05$), b = significantly different from boiled ($p<0.05$), c = significantly different from fermented ($p<0.05$) and d = significantly different from fermented and boiled ($p<0.05$)

Table 3: Minerals nutrient profile table of processed *Icacina senegalensis* tuber flours

Mineral Nutrients (mg/100g)	RD	BD	FD	FBD
Calcium	303.33±15.28^{c,d}	280±87.18 ^{c,d}	466.67±41.63 ^{a,b}	410±36.06 ^{a,b}
Potassium	9450±50.00 ^{b,c}	7966.67±749.43^{a,c,d}	10000±0.00 ^{ab,d}	9500±0.00 ^{b,c}
Sodium	0.00±0.00 ^{b,c}	0.00±0.00 ^{a,c}	0.00±0.00 ^{a,c}	0.00±0.00 ^{b,c}
Copper	3.33±0.115^{c}	2.97±0.06 ^{a,c,d}	3.867±0.153 ^{a,b,d}	3.34±0.208 ^{b,c}
Magnesium	300±0.00 ^{a,c,d}	400±0.00 ^{a,d}	400±0.00 ^{a,d}	550±50.00^{a,b,c}

Values are expressed as mean ±SD. n=replicate of three (3) samples. a = significantly different from dried ($p<0.05$), b = significantly different from boiled ($p<0.05$), c = significantly different from fermented ($p<0.05$) and d = significantly different from fermented and boiled ($p<0.05$).

Discussion

Vitamins composition of *Icacina senegalsis* tuber flours

The significant losses of some water soluble vitamins (Vitamins B_1, B_2, B_3, B_5, and B_6) and complete elimination of Vitamin C through the processing methods of boiling and fermentation applied in this study is not surprising. It has been reported that up to 20 – 30 percent of ascorbic acid from unpeeled roots and tubers may be lost if boiled but if peeled before boiling, the loss may be much higher up to 40% [10, 11]. In this study *Icacina senegalsis* tubers were peeled before further processing. This certainly contributed to the huge loss / total elimination of the water soluble vitamins as reported here. Vitamin A content of *Icacina senegalsis* tuber was improved by fermentation but significantly reduced by subsequent boiling of the fermented product; Beta carotene on the other hand was better preserved by a combination of fermentation and boiling. Previous studies have reported 14 to 25 percent loss of vitamin A activity after processing sweet potato [12]. This is probably because of the destruction of the beta-carotene. The main reaction that could take place during the canning of sweet potato is the isomerization of beta-carotene, to neo-beta-carotene leading to a reduction in the vitamin A activity from 95 to 91 percent [13]. The levels of Beta carotene (48.00 – 87.00 mcg/100g) and Vitamin A (105.67 – 139.33 mcg/100g) as reported in this study for *Icacina senegalsis* tuber flours compare favourably with those reported for dark leafy vegetables from Southeastern Nigeria [14]. This suggests that combining well processed *Icacina senegalsis* tuber flour with vegetable soups could improve dietary availability of pro-vitamin A and Vitamin A among the indigenous groups of Southern Nigeria.

Amino acid composition of *Icacina senegalensis* tuber flours

The levels of selected amino acids content of *Icacina senegalensis* tuber flours evaluated and reported in this study indicate that boiling, followed by fermentation are better processing options for optimum amino acids preservation. This is in agreement with earlier reports in which fermentation was found to cause improvement in amino acids content of *tarhana* [15] and *maize* [16]. It is understood that bacterial enzymatic hydrolysis may improve the bioavailability of protein and fat by the release of free amino acids, short chain fatty acids and vitamins [17].

Mineral composition of *Icacina senegalensis* tuber flours

The significant loss of mineral nutrients through boiling observed in this study is attributed to the fact that most of the minerals leeched out during this process. This position is supported by [18] who reported a 30% and 17% loss of potassium and copper respectively, through cooking in water. An increase in the values of all five minerals after the fermentation process may probably lead to increased availability in nutrient quality and quantity. It could also be due to the decrease in the anti-nutrient components in the tuber flours after processing, eliminating their reaction with the available minerals.

Conclusion

In conclusion, the results of this study show that boiling and fermentation improved nutrient levels of some nutrients while decreasing others, suggesting that processed products of *Icacina senegalensis* tubers should be enriched with water soluble vitamins and other essential nutrients for better nutritional balance.

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Conflict of Interest and Source of Funding Statement

The authors declare that there are no conflicts of interest whatsoever. The research was privately funded

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