DETERMINATION OF THE MINERAL CONTENTS OF 'FUFU', 'GARI' AND 'LAFUN' PRODUCED THROUGH MICROBIAL FERMENTATION OF CASSAVA ROOTS OF SIX VARIETIES IN RELATION TO SOIL COMPOSITION

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ABSTRACT

The study reports the effect of microbial fermentation using *Saccharomyces cerevisae* and *Lactobacillus bulgaricus* on the mineral compositions of 'gari', 'lafun' and 'fufu' prepared from six varieties of cassava by the inoculation of the pulps; the physico-chemical analyses of the soils where the cassava were planted was also carried out.The results of the study revealed that microbial fermentation caused significant increase (at $P < 0.05$) in the levels of Zn (53.5%), Mg (55.2%), Ca (21.7%), Na (45.5%), K (54.53%), P (39.3%) and Fe (57.83%) in the fermented products. There was no significant difference between the activities of the two organisms to enhance the nutritional quality of the cassava products. The mean levels of Ca, Cu, Fe, Na, K, Mg and available P contents of the soils of the farmlands were: 2440.22 ± 4.35 mg/kg, 387.29 ± 3.23 mg/kg, 4404.23 ± 4.00 mg/kg, 519.75 ± 3.84 mg/kg, 2433.18 ± 2.48 mg/kg, 2080.45 ± 5.58 mg/kg and 716.43 ± 3.82 mg/kg respectively. The level of copper in the soil was significantly low compared to the values obtained for the other minerals determined. The elemental compositions of the subsoil samples were higher than the topsoil counterpart. However, the concentrations of K, Ca, Mg, and P showed no clear trend between the subsoil and the topsoil. The results of this study suggest that cassava products can be nutritionally improved with *S. cerevisiae* and *Lactobacillus bulgaricus* fermentations.

Keywords: Microbial fermentation, *Lactobacillus bulgaricus, Saccharomyces cerevisae,* inoculation, nutritionally improved

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INTRODUCTION

Cassava (*Manihot esculenta*) is an important staple food crop for millions of people in the tropical areas of Africa, Asia and Latin America, with an estimated total cultivated area greater than 13 million hectares, of which more than 70% is in Africa and Asia [1, 2]. It is estimated by Emmanuel *et al.* [3] that the crop provides about 40% of all the calories consumed in Africa and ranks second only to cereal grains as chief source of energy in Nigerian diet. Cassava roots contain mainly carbohydrates - 80% starch and about 1% fat-, so it yields more energy per hectare than other major crops [4, 5]. By this, cassava plays an important role in alleviating African Food Crisis. While the cassava roots are a good source of energy, the leaves provide protein, vitamins and minerals.

Though, cassava roots and leaves are deficient in sulphur-containing amino acids (methionine and cysteine) and some nutrients are not optimally distributed within the plant. Its roots contain antinutrients that can have either positive or adverse effects on health depending upon the amount ingested [6]. Despite the fact that some of these compounds act as antioxidants and anticarcinogens, they can interfere with nutrient absorption and utilization and may have toxic side effects. Efforts to add nutritional value to cassava (biofortification through microbial fermentation) by increasing the contents of protein, minerals, starch, and β-carotene are in progress [7].

Cassava roots are processed by several traditional methods, which vary widely from region to region into products such as 'gari', 'lafun', 'landang', 'fufu', 'flour', 'chips', starch, 'akara', 'okpokpo gari', 'ighu', dextrins and alcohol [8, 9], high quality cassava flour that can replace wheat and other imported flours in tropical countries has been reported. Production of 'fufu' of acceptable standard from different varieties of cassava through microbial fermentation has not been adequately reported in literature.

Cassava, like any other plant, takes in nutrients (macro and micro elements) directly from the soil through their roots and from the atmosphere through their leaves [10, 11]. These nutrients are known to bio-accumulate in soil [5] and play a vital role in soil fertility, since mineral surfaces serve as potential sites for nutrients storage. However, different types of soil minerals hold and retain differing amounts of nutrients. Therefore, it is helpful to know the types of minerals that make up the soil so that the degree to which the soil can retain and supply nutrients to plants can be predicted [12].

Yeast cells in particular *S. cerevisiae* is used in fermentation are inexpensive to produce [13]. Yeast extract normally consists mainly amino acids and peptides, carbohydrates and salt. The success of a fermentation process chiefly depends on the microorganism strain used [14].

The ideal soil for the growth of most plants is described as being composed of 45% minerals, 25% water, 25% air and 5% organic matter [13]. Organic matter content is usually much lower than 5% in some soils (typically 1% or less). Some wetland soils, however, have considerably more organic matter in them (greater than

50% of the solid portion of the soil in some cases). The benefits of some of the minerals contained in plants are enormous; for example, calcium is the main part of bones and teeth, it promotes bone health, regulates muscle tone, blood clotting and the ability of fluid to pass through cell walls [7]. Potassium regulates waste balance and blood pressure, it is a catalyst in sending oxygen to the brain and aids in the breakdown of carbohydrates and protein in the body, among a host of other useful minerals.

This work reports the innoculaion of cassava mash and the determination of some selected minerals in the cassava products -'lafun', 'gari' and 'fufu', and relates the minerals in the soil where the six cassava varieties were planted to the levels in the cassava products. This is significant in evaluating the use of microorganisms for nutritional and enrichment of cassava products during production.

MATERIALS AND METHODS

Microorganisms

The inoculants used for the study were *S. cerevisiae* and *L. bulgaricus*, these were obtained from the culture bank of the Department of Microbidogy, Federal University of Technology, Minna, Nigeria.

Plant material

Tuberous roots of three improved varieties (TMS92/0376, L30572 and TME419) and three local varieties ('Karimugi', 'Dan Warri' and 'Kpace Dzuru') of cassava were obtained from the sampling farm cultivated at Bida, Niger State, Nigeria (n= 7). The tubers were each processed into three different products- 'fufu', ' gari' and 'lafun' in triplicates (n = 42). These varieties were identified by an agronomist Research Fellow at the Niger State Agricultural Development Projects, Minna, Niger State, Nigeria. All chemicals used were of analytical grade.

Method of processing the 'gari'

The fresh roots were peeled and grated, after which the grated pulp was put in sacks (polypropylene) and the sacks placed under heavy stones for 4 days to expel excess liquid from the pulp, while it was fermenting. The dewatered and fermented lumps of pulp were then crumbled by hand, and most of the fibrous matter were removed. The remaining mass was sieved with traditional sieves of iron mesh. After being sieved, the fine pulp was then roasted in an iron pan over fire.This resulted in a finished white lumpy product called 'gari'[15]. For the microbial treated 'gari', the pulp was seperately inoculated with the microbes (*S. cerevisiea* and *L. bulgaricus*) prior to fermentation.

Method of processing the 'lafun'

Lafun' in Nigeria, 'cossettes' in Zaire and Rwanda, 'kanyanga' and 'mapanga' in Malawi and 'makopa' in Tanzania was processed by peeling the fresh root of cassava, followed by grinding and then draining the extracts of the pulp under heavy weight. Sun-drying of the pulp was done for 5 days until it dried to yield 'lafun', the dried crumbs was then milled into flour [16].

Method of processing the 'fufu'

The freshly peeled roots of cassava were soaked in water for 3 days so as to absorb water and get fermented and soft. After fermentation, the water was drained off, most of the fibre were removed and the roots were pounded in a wooden mortar, until a soft mash was formed. Excess water was extracted from the mash by placing heavy objects such as rocks on top of the sacks containing the 'fufu' [17]. In order to obtain a microbial fermented 'fufu', 1500 cfu each of *S cerevisiae* and *L. bulgaricus* per 1kg of cassava pulp were seperately introduced prior to fermentation.

Chemical analysis of the cassava products and soil samples

Triplicate samples of each cassava product from each of the six varieties cultivated at Suleja area of Niger State, Nigeria, were collected (n = 42) and the amounts of Zn, Mg, Na, K, Ca, Fe and P determined using atomic absorption spectrophotometer (AAS) and flame emission spectrophotometer (FES) after wet digestion of the samples with nitric-perchloric acid mixture in the ratio 650:80 [18]. Phosphorus in the samples was estimated using the Vanado-molybdate method [19] on the acid digested samples. The mean values ± the standard deviation were used for the discussion.

The physico-chemical parameters of the topsoil and subsoil where the cassava were planted in Suleja area of Niger State, Nigeria were collected using randomised sampling (n = 32) [20] following which the pH was determined according to a $CaCl_2$ solution method. The levels of copper, iron, magnesium, sodium, potassium and calcium in the 'fufu', 'lafun' and 'gari' were determined using atomic absorption spectrophotometry (AAS). Available phosphorus the 'fufu', 'lafun' and 'gari' was determined according to micro-vanadate-molybdate method [21]. Statistical analysis was carried out using Duncan test at $P < 0.05$.

RESULTS AND DISCUSSION

The results of the mineral compositions of the cassava products are presented in Tables 1 and 2. Figures 1 - 7 depict the percentage increase in the minerals of the cassava products. Table 3 gives the physico-chemical parameters of the soil samples from Suleja sampling area.

The results of the level of zinc in the microbial fermented products - 'fufu' and 'gari', and in the uninoculated 'lafun' obtained from the cassava samples presented in Tables 1 and 2 indicate that amount obtained for 'gari' ranged from 349.72 ± 3.17 to 494.74 ± 3.93 $mgkg^{-1}$, 'fufu' had its values ranged from 489.82 ± 4.16 to 382.30 ± 5.20 $mgkg^{-1}$ while 'lafun' recorded the range of 326.33 ± 6.22 to 409.36 ± 3.87 $mgkg^{-1}$.

In addition, both 'fufu' and 'gari' products subjected to the same microbial treatment showed significant difference in their efficiency to be enriched with zinc, particularly the *S. cerevisae*-treated 'fufu' product made from L30572 (53.59%) and *L. bulgaricus*-fermented 'fufu' produced from L30572 (48.57%) as shown in Figure 1. Noticeably, the ability of *S. cerevisae* to effectively increase the level of zinc in the products was not significantly different from the ability of *L. bulgaricus* to enrich the same products. Furthermore, there were significant differences between the products subjected to microbial fermentation and the uninoculated ones. These results were similar to the reports of the nutritive contents of some cassava products being subjected to microbial fermentation [22, 23, 24].

Magnesium contents of both the inoculated and uninoculated cassava products of the six varieties revealed that there was an appreciable difference between the cassava-based products that were microbially inoculated and those naturally treated and the unfermented ones. For example, the value recorded for 'gari' made from TME419 through *L. bulgaricus* fermentation (469.56 ± 3.82 mg/kg) was significantly different from the value obtained for 'gari' of the same cassava variety and subjected to the same microbial treatment (405.49 ± 4.22 mg/kg) as well as the value for the unfermented 'lafun' (429.83 ± 3.76 mg/kg) from the same variety. The grated cassava products - 'gari' - was observed to record lower percentage increase of magnesium in'gari' produced from 'Kpace Dzuru' subjected to *S. cerevisae* fermentation (14.24%) than the 'fufu' product from L30572 subjected to the same microbial treatment (20.18%) as shown in Figure 2. There was a slight increase in percantage of magnesium in 'gari' inoculated with *S. cerevisae* produced from TMS92/0326 having the highest amount of magnesium to be 68.64% and the 'fufu' fermented with *L. bulgaricus* obtained from TME419 recorded the lowest amount of magnesium (1.92%). There was no significant difference between the activities of the two organisms to enhance the nutritional quality of the products with respect to magnesium. There is dearth of information regarding the magnesium contents of cassava products in literature, so this result is vital for evaluating the relevance of fermentation in cassava processing.

In all the microbial inoculated materials, sodium contents was in higher values, though these values were not sgnificantly different from one another and from the values obtained for the uninoculated 'lafun'.

In Figure 3, the highest value of 51.67% sodium increase was recorded in 'fufu' produced from 'Karimugi' through *L. bulgaricus* fermentation followed by a 44.79% increase in 'gari' obtained from TMS92/0326 through *S. cerevisae* inoculation while the least value of 0.89% was for 'gari' produced from 'Kpace bokun' subjected to *S. cerevisae* fermentation. 'Fufu' products recorded reasonable higher percentage increase than recorded for 'gari' products. *L. bulgaricus*, showed more efficiency in bringing about increase in sodium contents of both products (Figure 3). The findings comforms with the report of Oboh and Elusiyan [23], Aro [24] and Ayodeji [25], though their values were expressed in part per million (ppm) and percentage compositions.

Following from Tables 1 and 2, potassium content was highest in all the products that were microbial fermented (for example, 3411.13 ± 7.24 mg/kg was recorded for microbial produced 'fufu' from TME419) compared to those only treated naturally (2688.55 ± 6.00 mg/kg for 'fufu' from TME419) and the 'lafun' products (2621.45 ± 7.38 mg/kg for 'lafun' from TME419) that were produced without fermentation.

Percentage increase of potassium in 'fufu' and 'gari' products microbially fermented as presented in Figure 4 indicated that there was no significant difference between the percentage increase in some 'gari' and 'fufu' products subjected to *S. cerevisae* and *L. bulgaricus* fermentation. Also *S. cerevisae* fermentation proved to be more promising in enriching the cassava products with potassium than *L. bulgaricus*. The highest increase in percentage of potassium was recorded in *L. bulgaricus*-fermented 'gari'obtained from TMS92/0326 variety (30.65%) and the lowest was in 'fufu' produced from the same variety and inoculated with *L. bulgaricus* (0.51%).

Calcium content was higher in all the products that were microbially fermented compared to those that were only treated naturally and the 'lafun' products that were produced without fermentation, though these were not significantly different from one another (Tables 1 and 2). The values of calcium contents were highest in 'gari' produced from TME419 fermented with *L. bulgaricus* (3606.40 ± 7.63 mg/kg) and lowest in 'gari' obtained from 'Karimugi' without inoculation but fermented (1894.53 ± 5.39 mg/kg) as presented in Figure 5. The 'fufu' that was naturally treated and made from 'Kpace Dzuru' recorded the lowest value of calcium (1993.01 ± 5.83 mg/kg) while 'fufu' produced from TME419 and microbially fermented with *L. bulgaricus* recorded the highest value of 3591.10 ± 7.21 mg/kg.

Figure 5 indicates that the percentage increase of calcium ranged from 1.16% for 'fufu' made from L30572 and treated with *L. bulgaricus* to 17.58% for 'fufu' produced from SITMS92/0326 through *S. cerevisae* fermentation. Though the increase in percentage was not appreciably much with the use of the two organisms, but the increase was more with the materials treated with *S. cerevisae.* Also of note is the slightly higher values recorded in 'gari' products than 'fufu'; 6.38% for 'gari' obtained from 'Kpace Dzuru' being the highest value of calcium and the least being 0.62% for 'fufu' from 'Karimugi' through *S. cerevisae* fermentation. The results indicate that there is no significant differences in percentage increase amongst all the products determined.

The iron content (Tables 1 and 2) in the microbially fermented products compared to 'lafun' products and naturally produced 'gari' and 'fufu' products was not significantly different using Duncan test ($P < 0.05$). Levels of increase in percentage of iron in 'fufu' and 'gari; products microbially produced from the cassava samples are prensented in Figure 6. The highest percentage increase was observed in 'fufu' from TME419 and inoculated with *L. bulgaricus* (44.12%), while the lowest value was recorded in 'Karimugi's 'gari' produced through *S. cerevisae* fermentation (1.45%) and 'fufu' manufactured from 'Kpace Dzuru' through *L. bulgaricus* fermentation (1.28%).

There were no significant differences ($P < 0.05$) in phosphorus contents of the microbial fermented products compared to the natural fermented products from most of the varieties (Tables 1 and 2). However, the values obtained for microbial treated products obtained from 'Karimugi' and 'Kpace Dzuru' varieties were significantly different ($P < 0.05$) from the values recorded for the natural fermented products of the same varieties.

Figure 7 presents the result of the level of increase in percentage phosphorus in 'fufu' and 'gari' produced through microbial fermentation. There were significant increase in the level of phosphorus in 'fufu' (25.98%) from 'Karimugi' cultivar through *L. bulgaricus* fermentation, 'fufu' (23.99%) from 'Karimugi' through *S. cerevisae* fermentation and 'fufu' from 'Kpace Dzuru through *L. bulgaricus* (21.33%) and fufu' from 'Kpace Dzuru through *S. cerevisae* 25.98%) compared to the uninoculated counterparts ($P < 0.05$). Cultivar of L30572 was observed to be very low in phosphorus content in both 'gari' and 'fufu' products (Figure 7). There was significant differences in the phosphorus content between the microbial fermented products and the natural fermented products from 'Karimugi' (25.98%), 'Wahabi' (15.06%) and 'Kpace Dzuru' (25.98%) varieties.

Mineral contents of soil samples where the cassava samples were planted

The pH values obtained for all the soil samples where the cassava varieties were planted were not significantly different ($P < 0.05$), the values ranged from 6.00 ± 0.15 to 6.30 ± 0.08 (Table 3). This indicated that the soil samples are fairly acidic. The values agreed with the preferred pH level of 6.0 to 6.5 reported by Tom [26] as suitable for most agricultural and horticultural purposes.

Copper concentration in the soils ranged from 30.31±1.15 to 210.43±4.32 $mgkg^{-1}$ and available phosphorus recorded the range of 597.08±8.68 to 698.34±4.82 $mgkg^{-1}$. Considering the iron contents, it was observed that subsoil samples recorded higher values than the values obtained from the topsoil samples. This could be attributed to the leaching action of the minerals into the soil. The range of 86 to 277 $mgkg^{-1}$ for iron in the cassava products reported by Okeyode and Rufai [5] were lower than the range of 894.57 ± 2.30 to 2484.37 ± 2.31 $mgkg^{-1}$) recorded in this study.

The levels of copper from the results were significantly low compared to the values obtained for the other minerals determined (Table 3). The highest value of Cu (105.33 ± 2.43 $mgkg^{-1}$) was obtained for Bunigi subsoil (BNGSS) sample, while the lowest value of 45.36 ± 0.97 $mgkg^{-1}$ was recorded for Kawo topsoil (KWOTS) sample. The recommended value of Cu for soil ranged from 2 mg/kg and 50 mg/kg [27]. The range of the values obtained in this study was similar to the range of 96.4 $mgkg^{-1}$ to 9.1 $mgkg^{-1}$ reported by Bradford *et al.* [27]. Similarly, the copper contents of the subsoil samples were observed to be higher than those recorded in the topsoil samples, this was possibly attributed to leaching of the sub-soil by rainfall.

Sodium contents of the soil samples showed similar trends like iron contents. The subsoil samples contained higher values than the values for the topsoil samples as a result of leaching action advanced earlier for iron and copper contents. For potassium, calcium, magnesium and available phosphorus, there was no clear relationship between the values of the minerals in the subsoil and those in topsoil samples. The range of the values for potassium was 187.17 ± 1.08 to 2433.18 ± 2.48 $mgkg^{-1}$, magnesium 800.09 ± 9.08 to 2080.45 ± 5.58 $mgkg^{-1}$, calcium 1200.56 ± 6.68 to 2000.54 ± 5.58 $mgkg^{-1}$ and available phosphorus 597.08 ± 8.68 to698.34 ± 4.82 $mgkg^{-1}$; these were higher than the range of 187 to 292 $mgkg^{-1}$ recorded for copper as reported by Gediminas and Rasa [10].

By comparing the elemental compositions of the soil samples and the cassava products, it was observed that the values obtained for the cassava products treated microbial were higher than the values recorded for the soil samples on which the cassava samples were planted. This observation was attributed to bioaccumulation of these minerals in the body tissues of the microorganisms as they grow in the cultured medium and even in the substrate (the cassava pulps) during fermentation [13, 28]. Another possible source of minerals getting into the products could be from the metallic knife used for the peeling of the cassava root tubers prior to fermentation, and from the metallic frying pan used for frying the pressed and sieved pulp into 'gari' where some of these metals might have leached into the product.

CONCLUSION

The study inferred that, the inoculation of cassava pulp with *S. cerevisae* and *L. bulgaricus* during fermentation enhanced the nutritional status of the products obtained. The nature of organism used for fermentation significantly affected the quality of the products. For example, most elements analysed in soil samples had higher values, which could have accounted for the corresponding high values of nutritional compositon of the cassava products.

Saccharomyces cerevisae had greater ability to a large extent (about 40%) to nutritionally enrich the cassava products than the *L. bulgaricus*. The two organisms (*S. cerevisae* and *L. bulgaricus*) showed greater potency to improve the quality of 'fufu' products than the quality of 'gari' products. However, cassava products obtained from the cassava tubers grown on such soils recorded higher values than the values obtained for the soil samples. There was no clear trend regarding varietal compositions between the improved and local varieties investgated. The mineral enrichment of the cassava products through microbial fermentation could provide balanced diet to the chunk of the malnourished population who cannot afford nutrionally balanced diet foods.

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Table 1: Mineral composition of microbial fermented cassava products of TME419, KG and TMS92/0326 varieties of cassava (mgkg^{-1} dry matter (DM))

Variety	products	Parameters						
		Zn	Mg	Na	K	Ca	Fe	P
TME419	Gari	405.49±4.22^a	2995.45±7.04^b	2359.10±6.18^b	2754.04±6.11^c	3366.40±7.35^a	1072.87±.3.87^a	55.33±2.00^b
	Fufu	407.24±2.95^a	3041.08±5.67^a	2590.46±5.12^b	2688.55±6.00^c	3421.00±6.05^a	1091.61±4.76^a	61.21±4.13^a
	Lafun	379.83±3.76^a	2885.40±6.95^b	2412.53±4.93^b	2621.45±7.38^c	2986.10±4.68^b	1063.45±2.75^a	49.00±4.83^c
LITME419	Gari	469.56±3.82^a	3075.46±5.87^a	2431.85±5.56^b	2883.53±6.30^c	3606.40±7.63^a	1240.66±4.73^a	58.98±4.10^b
	Fufu	464.04±3.19^a	3099.47±8.12^a	2878.33±5.62^b	3411.13±7.24^b	3591.10±7.21^a	1682.49±3.67^a	67.16±3.84^a
SITME419	Gari	494.07±4.00^a	3105.93±7.26^a	2442.05±5.32^b	3581.83±5.23^b	3530.70±8.53^a	1363.38±5.60^a	66.32±2.19^a
	Fufu	449.43±5.10^a	3141.45±6.59^a	3044.10±6.66^a	2844.13±6.09^c	3560.47±6.46^a	1172.71±6.00^a	65.90±4.13^a
KG	Gari	410.70±5.19^a	1150.92±5.32^c	2152.40±5.09^b	4151.94±8.42^a	1894.53±5.39^c	1211.34±3.22^a	39.51±4.48^d
	Fufu	409.36±3.91^a	1083.12±4.38^c	2103.96±6.49^b	3040.49±8.30^b	2003.93±5.92^b	1304.50±3.33^a	34.68±2.12^d
	Lafun	368.34±2.57^b	1003.80±6.31^c	2044.75±5.87^b	3004.04±9.21^b	1762.49±4.04^c	1003.36±3.61^a	41.82±3.24^c
LIKG	Gari	440.23±3.72^a	1247.42±4.37^c	2222.56±7.39^b	4581.22±6.73^a	2102.35±5.20^b	1243.64±4.78^a	42.92±4.10^c
	Fufu	424.63±3.02^a	1219.75±5.09^c	2341.61±5.02^b	3298.39±5.94^b	2272.10±5.41^b	1439.84±4.21^a	43.69±1.86^c
SIKG	Fufu	454.89±2.71^a	1284.39±6.94^c	2266.49±4.68^b	3490.94±6.74^b	2190.07±5.19^b	1568.48±7.24^a	43.00±3.03^c
	Gari	459.25±3.14^a	1250.04±5.54^c	2364.68±5.54^b	4642.24±6.39^a	2144.24±4.39^b	1230.26±6.90^a	42.08±2.14^c
TMS92/0326	Gari	349.72±3.17^b	1095.45±7.12^c	1906.84±4.39^c	3722.73±7.17^b	2760.62±5.05^b	1075.34±4.62^a	31.26±3.65^d
	Lafun	326.33±6.22^b	1120.39±4.21^c	1779.34±5.27^c	2893.24±5.08^c	2662.21±5.25^b	1228.00±3.18^a	33.87±4.43^d
	Fufu	382.30±5.20^b	1024.50±5.67^c	2411.25±3.34^b	3481.47±5.35^b	2810.55±7.12^b	1099.09±4.23^a	37.62±2.27^d
SITMS92/0326	Gari	374.55±4.02^b	3052.43±6.41^a	1993.48±6.35^c	4231.33±7.76^a	2871.43±5.84^b	1411.68±3.76^a	36.22±3.55^d
	Fufu	392.23±5.50^b	3084.37±4.57^a	2478.23±6.56^b	4004.13±5.34^a	2945.17±5.78^b	591.46±4.83^b	38.02±1.11^d
LITMS92/0326	Gari	402.13±4.30^a	3172.73±5.39^a	2040.56±5.84^b	4863.92±7.40^a	2832.14±6.35^b	613.78±5.31^b	34.77±4.12^d
	Fufu	416.20±3.89^a	3195.29±6.18^a	2521.82±6.82^b	3499.43±3.76^b	2896.61±6.92^b	913.35±4.52^b	38.27±2.86^d

Means with the same superscript within a column are not significantly different ($P < 0.05$)
TME419 = Improved variety, SITME419 = *S. cerevisea* fermented, LITME419 = *L. bulgaricus* fermented TME419 KG = 'Karimugi', LIKG = *L. bulgaricus* fermented, SIKG = *S. cerevisea* fermented, TMS92/0326 = Improved variety, SITMS = *S. cerevisea* fermented, LITMS = *L. bulgaricus* fermented

Table 2: Mineral compositions of microbial fermented cassava products of KD, DW and L30572 varieties of cassava (mgkg^{-1} DM)

Variety	Product	Parameter						
		Zn	Mg	Na	K	Ca	Fe	P
KD	Gari	433.46±5.21^{a}	1195.00±5.33^{c}	2372.10±6.29^{b}	3852.43±8.45^{b}	1904.50±7.00^{c}	972.02±6.98^{b}	39.51±4.48^{d}
	Fufu	407.±072.69^{a}	1220.75±3.90^{c}	3100.40±6.20a	29420.02±7.56^{c}	1993.01±5.83^{c}	891.00±2.13^{b}	34.68±2.12^{d}
	Lafun	399.28±3.18^{b}	1004.50±3.56^{c}	2332.36±5.25^{b}	3531.10±7.38^{b}	1862.58±6.72^{c}	763.10±4.56^{b}	41.82±3.24^{c}
LIKD	Gari	469.08±3.01^{a}	2992.44±2.73^{b}	2443.07±6.98^{b}	4251.35±9.21^{a}	2103.75±5.92^{b}	1000.84±3.65^{b}	42.92±4.10^{c}
	Fufu	464.00±3.19^{a}	3009.29±5.91^{a}	3776.64±5.21^{a}	3116.58±6.21^{b}	2072.36±6.00^{b}	902.41±5.33^{b}	43.69±1.86^{c}
SIKD	Gari	494.74±3.93^{a}	3122.64±5.06^{a}	2541.53±5.32^{b}	4193.36±9.12^{a}	2090.83±4.13^{b}	1043.58±4.29^{a}	43.00±3.03^{c}
	Fufu	489.82±4.16^{a}	3195.55±6.83^{a}	3194.67±6.23^{a}	3189.47±8.70^{b}	2144.24±4.32^{b}	972.16±4,33^{b}	42.08±2.14^{c}
DW	Gari	433.17±5.11^{a}	2895.4±6.74^{b}	2152.49±6.73^{b}	4063.34±6.00^{a}	2660.75±6.50^{b}	801.73±3.68^{b}	31.26±3.65^{d}
	Lafun	409.36±3.87^{a}	3041.2±4,66^{a}	2103.6±8.12^{b}	3049.47±8.43^{b}	2682.10±.5.30^{b}	804.44±4.11^{b}	33.87±4.43^{d}
	Fufu	440.92±4.17^{a}	2885.44±7.39^{b}	2044.78±6.55^{b}	3204.83±6.20^{b}	2910.56±5.77^{b}	913.39±4.51^{b}	37.62±2.27^{d}
LIDW	Gari	440.12±3.62^{a}	3105.43±8.24^{a}	2222.73±7.05^{b}	4681.2±5.17^{a}	2741.24±6.45^{b}	1043.43±4.18^{a}	36.22±3.55^{d}
	Fufu	473.04±4.32^{a}	2969.22±.54^{b}	2341.90±7.16^{b}	3228.34±5.27^{b}	2795.11±5.61^{b}	1119.74±3.39^{a}	38.02±1.11^{d}
SIDW	Gari	454.93±4.05^{a}	3125.16±6.34^{a}	2208.1±4.85^{b}	4170.9±6.19^{a}	2832.28±7.52^{b}	1068.68±4.38^{a}	34.77±4.12^{d}
	Fufu	479.25±4.10^{a}	2991.42±4.28^{b}	2394.53±6.00^{b}	3542.56±5.39^{b}	3056.09±6.19^{a}	1230.76±3.54^{a}	38.00±2.86^{d}
L30572	Gari	433.75±3.54^{a}	1150.9±5.34^{c}	1898.6±5.10^{c}	3722.4±6.34^{b}	3366.49±5.92^{a}	1075.40±3.45^{a}	45.62±3.13^{c}
	Fufu	47.24±4.20i^{a}	1283.2±5.32^{c}	1975.3±4.56^{c}	2893.33±5.37^{c}	34210.16±6.22^{a}	1228.10±4.49^{a}	46.98±2.25^{c}
	Lafun	389.80±4.26^{b}	1123.8±4.12^{c}	1811.2±2.99^{c}	3481.12±5.44^{b}	2986.10±7.17^{b}	1099.29±4.29^{a}	45.40±1.51^{c}
LIL30572	Gari	469.76±4.29^{a}	1247.60±3.87^{c}	1962.84±4.29^{c}	4101.30±7.34^{a}	3566.40±8.44^{a}	1411.86±4.23^{a}	46.03±2.73^{c}
	Fufu	464.17±3.17^{a}	1319.27±7.23^{c}	2478.34±6.12^{b}	3054.21±6.34^{b}	3461.10±8.19^{a}	1591.44±3.76^{a}	47.24±2.46^{c}
SIL30572	Gari	494.08±2.76^{a}	1284.23±5.19^{c}	2000.52±5.38^{b}	4163.00±6.34^{a}	3530.70±6.43^{a}	1613.70±4.12^{a}	46.28±3.17^{c}
	Fufu	489.39±3.84^{a}	1350.71±5.07^{c}	2512.54±6.34^{b}	3049.43±5.20^{b}	3500.40±7.83^{a}	1313.55±3.14^{a}	47.62±2.42^{c}

Means with the different superscripts within a column are significantly different ($p < 0.05$) L30572 = Improved variety, SIL30572 = *S. cerevisea* fermented, LIL30572 = *L. bulgaricus* fermented, KD = Kpace Dzuru, LIKD = *L. bulgaricus* fermented, SIKD = *S. cerevisea* fermented, DW=Dan Warri, LIDW= *L. bulgaricus* fermented, SIDW = *S. cerevisea* fermented

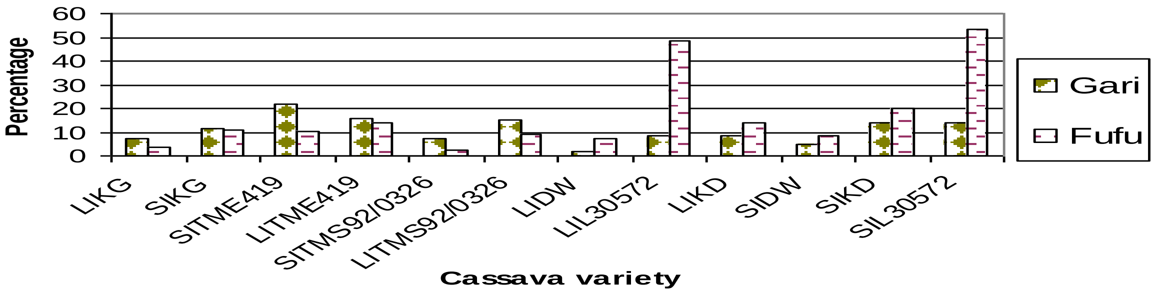

Figure 1: Percentage increase of zinc in 'gari' and 'fufu' of suleja samples due to inoculation

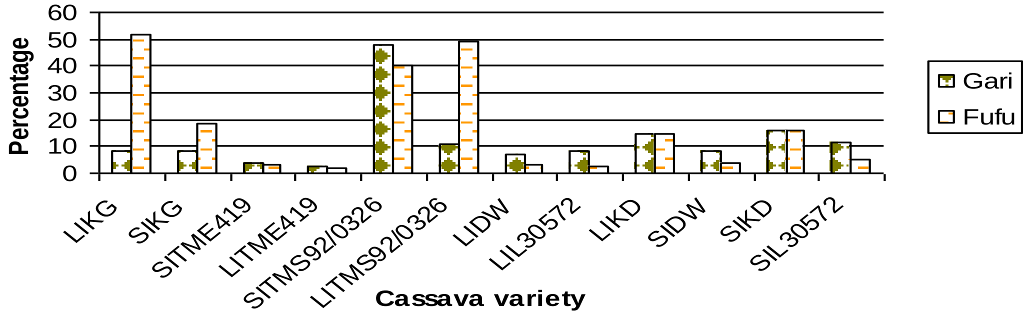

Figure 2: Percentage increase of magnesium in 'gari' and 'fufu' of Suleja samples due to inoculation

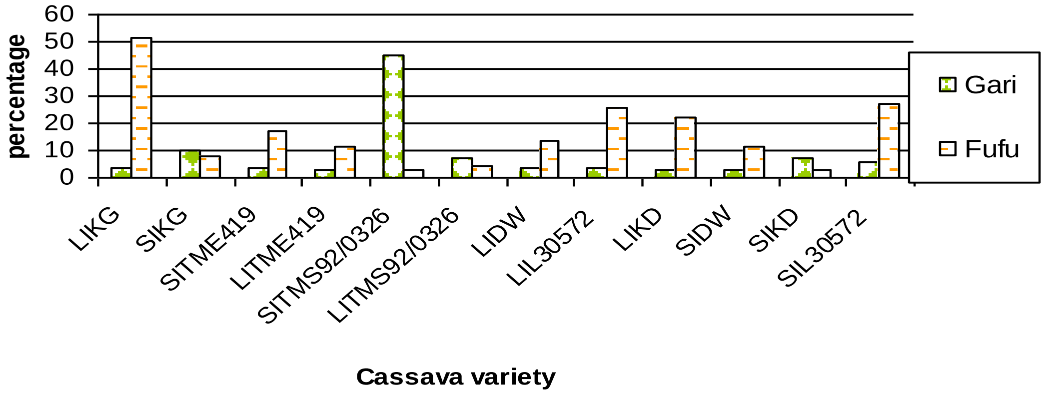

Figure3:Percentage increase of sodium in 'gari' and 'fufu' of Suleja samples due to inoculation

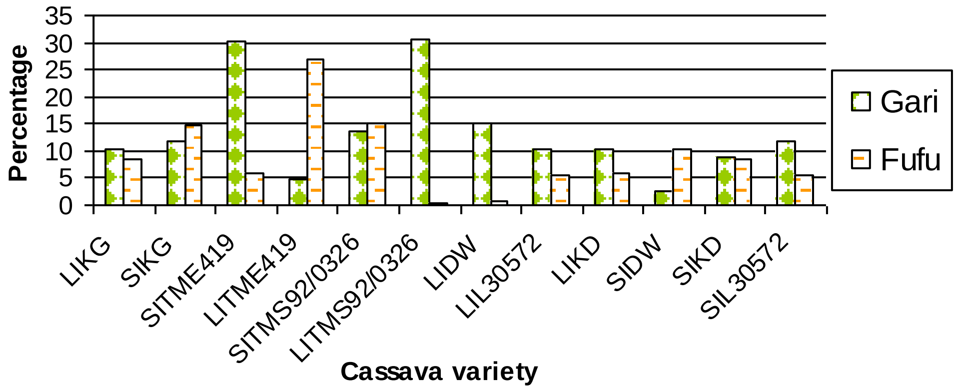

Figure 4: Percentage increase of potassium in 'gari' and 'fufu' of Suleja samples due to inoculation

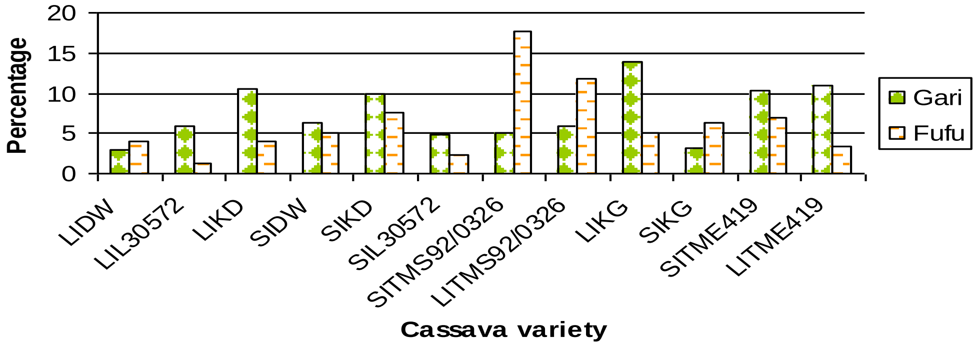

Figure 5: Percentage increase of calcium in 'gari' and 'fufu' of Suleja samples due to inoculation

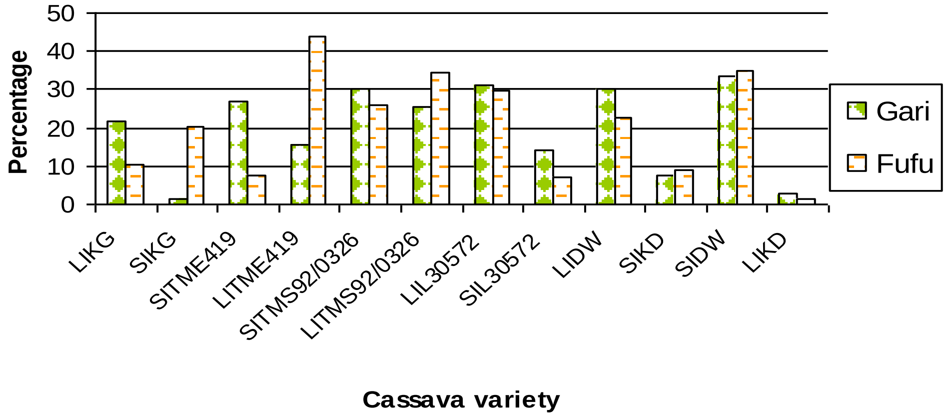

Figure 6:Percentage increase of iron in 'gari' and 'fufu' of Suleja samples due to inoculation

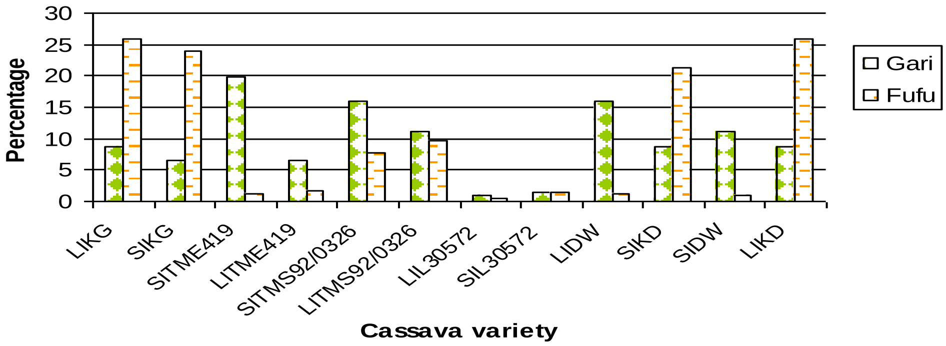

Figure7: Percentage increase of phosphorous in 'gari' and 'fufu' of suleja samples due to inoculation

Table 3: Physico-chemical and elemental composition of the soil from Suleja sampling area

Sample	Parameters (mg/kg)							
	Fe(mg/kg)	Cu(mg/kg)	pH	Na(mg/kg)	K(mg/kg)	Mg(mg/kg)	Ca(mg/kg)	AP(mg/kg)
KWOTS	1370.67±11.54^{h}	45.36±0.97^{c}	6.20±0.11^{a}	176.71±1.83^{d}	1918.47±4.48^{l}	1120.34±8.21^{de}	2080.65±8.48^{hi}	674.55±4.81^{gh}
KWOSS	1674.72±5.34^{j}	68.33±0.89^{de}	6.10±0.01^{a}	467.75±3.07^{i}	2058.85±5.58^{m}	800.57±7.87^{ab}	1680.08±9.48^{e}	581.53±3.38^{b}
WSSTS	1440.17±3.31^{h}	60.33±1.23^{d}	6.30±0.08^{a}	83.16±0.32^{ab}	2246.02±2.28^{p}	1600.56±9.68^{g}	2160.45±6.68^{j}	587.77±7.89^{b}
WSSSS	2484.37±2.31^{m}	45.13±0.65^{e}	6.00±0.41^{a}	176.75±2.23^{d}	1216.59±9.89^{f}	1440.53±5.58^{f}	1760.34±8.78^{fg}	664.45±2.21^{fg}
MATTS	894.57±2.30^{e}	30.19±0.88^{b}	6.00±0.23^{a}	93.56±4.48^{ab}	1965.26±5.51^{l}	710.23±6.68^{a}	1860.67±6.86^{gh}	629.49±3.38^{e}
MATSS	2052.21±9.31^{l}	387.29±3.23^{i}	6.10±0.31^{a}	519.75±3.84^{j}	421.13±3.13^{b}	1120.22±7.84^{de}	1600.40±8.88^{e}	716.43±3.82^{l}
BNGSS	1902.54±7.39^{k}	105.33±2.43^{g}	6.00±0.41^{a}	124.74±5.86^{cd}	2292.80±8.46^{p}	800.09±6.85^{ab}	1040.05±7.86^{a}	654.45±4.45^{f}
BNGTS	1482.67±5.78^{hi}	60.38±0.27^{d}	6.00±0.15^{a}	218.25±7.88^{ef}	1778.096±1.81^{j}	1840.11±10.45^{h}	960.68±6.67^{a}	734.64±4.45^{m}

Key

AP = Available phosphorus, KWOTS = Kawo Topsoil, KWOSS = Kawo Subsoil, WSSSS = Wushishi Subsoil, WSSTS = Wushishi Topsoil, MATTS = Maito Topsoil, MATSS = Maito Subsoil, BNGSS = Bunigi Subsoil, BNGTS = Bunigi Topsoil