Research Article

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Effects of starter cultures and processing unit operations on the physicochemical compositions of odourless 'Fufu'

Abstract

'Fufu' is a starchy staple food usually made from fermented cassava mash, characterized by undesirable odour-producing compounds due to microbial enzymatic activities with inherent objectionable odour during fermentation. This reduces its acceptability to the consumer. The cassava roots biomass have different microorganisms (i.e. bacteria and fungi). Each class of the microorganism (s) identified was separated. Six out of eight 'fufu' (8) samples were fermented with identified microorganisms as starter cultures and coded OBP (Only Bacteria); YBP (Yeasts and Bacteria) OYP (Only Yeasts); MBP (Moulds and Bacteria); YMP (Yeasts and Moulds) and OMP (Only Moulds). Samples WIG (Without Inoculum, but Grated) and WIS (Without Inoculum, but Soaked) were produced without inoculum. The market sample (MTE) served as a control for sensory. The protein content of sample MBP had the highest (3.68 g/100 g) value. The cyanide level of sample WIG and some 'fufu' fermented with starter cultures were drastically reduced. The aroma of the 'fufu' samples fermented with starter cultures was much better than sample MTE.

Keywords: fufu, microorganisms, processing operations, nutrient composition, sensory qualities.

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Abbreviations

OBP, only bacteria; YBP, yeasts and bacteria; OYP, only yeasts; MBP, moulds and bacteria; YMP, yeasts and moulds, OMP, only moulds; WIG, without inoculum, but grated; WIS, without inoculum, but soaked; MTE, market sample to eat.

Introduction

Cassava roots are the parts used from the shrubby perennial plant of the *Euphorbiaceae* (Spurge family) characterized by palmate lobed leaves, inconspicuous flowers, papery brown bark and white-yellow flesh.[1] It has been known to be an acceptable staple food during the era of Spanish victorious combat across the Northern American to the Caribbean.[2] The cassava plantation may need more than 18 months of growth before maturity, especially under hostile or harsh weather and can tolerate soil pH between 4.0 and 8.0, cultivated to a mature stem 7 to 30 cm high.[3] Cassava can create a symbiotic relationship with mycelia of fungi when cultivated in low acidic soils.

The plant has a beneficial role by removing phosphorous from the mycelia to the cassava roots according to Moslehi-Jenabian et al.[4] Fleshly uprooted cassava roots do not withstand long storage and after 3 to 4 days of harvest, they will start to decay due to their high water content, which is around 70%.[5] This is one of the reasons it becomes costly and cumbersome to transport it to urban settings. The quantity of cyanide, a toxin present in varying concentrations in all parts from the leaves to the roots makes uncooked cassava indigestible for both human beings and animals. Thus, cassava roots should be processed to extend the storage life, for easy conveyance and distribution, with less cyanide and better taste, which lowers product loss, and makes stable the otherwise irregular provision of the product.[6]

Cassava roots are classified as the source of an important carbohydrate starch, containing amylose and amylopectin), with 20 to 31% dry/weight. It contains 60 to 65% moisture. The micronutrients present are not different from other plants such as vitamins and minerals, but low. It has 1 to 2% crude protein, as well as high Glutamic acid, but low Methionine sulphur-containing amino acids) of essential amino acids ranging from 0.019 g/100 g to 0.022 g/100 g. The starch is comprised of 70 % amylopectin and 30 % amylose. Processing methods such as cooking, boiling, baking, frying, etc. have effects on the nutritional quality of the food.[7] Cassava roots contain anti-nutritional factors and the hydrogen cyanide level is the most important factor for both human and animal consumption and when hydrolyzed, gives hydrocyanic acid HCN). The amount of anti-nutrient and cyanide differs from species to climatic conditions.

Fermentation is the catalysis by the inherent enzymes present in the food substance and involves among others decomposition of complex substrates polysaccharides) into smaller units.[8] Interaction of microorganisms is usually caused by the breakdown of cassava roots to disintegrate the complex components such as polysaccharides into smaller units during fermentation due to the inherent enzymes. These enhance flavour/aroma; improve nutrition as well as the availability of the micronutrients and anti-nutritional reduction.[9,10]

There are different end-products of cassava roots when processed, which can serve as domestic and industrial products. One such domestic product as food is 'fufu'. Some factors brought about its production and consumption, which are categorized into three factors as explained below.

Geographical factors: The origin of cassava *Manihot esculenta* Crantz) roots are grown in tropical and sub-tropical areas of Asia, Latin and South America before it was introduced and planted

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widely in African continents, especially Eastern and Western parts of Africa.[11] It is a tropical root crop, which provides the staple food for millions of people around the world. It is one of the tuber crops, which can be cultivated in small-scale quantities and can still survive in an environment with a shortfall of rainfall without heavy equipment machineries. It is an advantage to the low-income family can successfully plant it.[12] The yield can be as much as 70 tonnes per hectare under favourable conditions. However, small-scale farmers do improve productivity through cultural practices with a mixture of both organic and inorganic measures to improve both the yield and quality. The topography land scale of the soil is one of the major factors considered for quality and healthy root yield. The harvest can be matured eight months from the time of plantation.

Nigeria's diverse landscape and agricultural abundance influenced the development and plantation of cassava in Nigeria when it was introduced for the production of 'fufu' and other by-products. The region's rich soil and favourable climate allowed for the cultivation of crops like cassava, plantains, and yams, to thrive better as the primary factors for cassava plantation. The availability of these starchy-based roots provided the foundation for the creation of 'fufu' as a staple food in some African continents, especially Nigeria.[13]

Cultural factors: 'Fufu's development is deeply intertwined with Nigerian cultural practices. Traditional methods of food preparation such as pounding and fermentation of cassava have been practiced from one generation to another. This practice shaped by societal norms and culinary preferences, contributed to the evolution of 'fufu' as a central component of Nigerian cuisine. ''Fufu' is a smooth white food often eaten with soups or stews and made by pounding with mortar and pestle with the addition of boiling water to soften, to have a smooth and fine texture from cassava mash peeled cassava roots, soaked for 3-5 days fermentation and pressed out. The soaking and fermentation is to soften the roots and at the same time allow the cyanide poisoning) to be expelled,[14] contributing to the sour taste of good quality acceptance.[15] The 'fufu' processing can also be stirred in boiling water until it turns into a dough meal.[16] It is second to pounded yam pounded boiled yam) swallowed with soups and stew. It is usually served at parties and ceremonies as special delicacies. The starchy nature of 'fufu' makes it a filling and satisfying addition to any meal. It is not only delicious but has adaptive importance in West Africa Nigeria). It is a kind of dish known to bring people from diverse ethnicities together. It is usually served during special occasions and celebrations. The taste of 'fufu' varies depending on the substrate is made from and the colour appearance,[17] but in general, it has a mild, slightly sour taste, and has been compared to pounded yam or sweet potatoes. Its subtle flavour makes it the perfect accompaniment for rich, bold African soups.

Historical factors: The history of Nigeria, including colonialism and trade, played a significant role in the spread and adaptation of 'fufu'. It was believed to come from the Central and Southern Twi spoken language of Ghana and the South Eastern of Côte d'Ivoire. The name is derived from the Akan people, which means to crush a type of food to soft mass or mix, from the way it looks. It has a different way of spelling it: 'foofoo', 'foufou' or 'fufuo'. It spreads across many other West African Nations. Enslaved populations then brought it to the Americas, where it was adapted to use locally available food, becoming a staple food in many Caribbean countries including Haiti, Jamaica, Cuba and Puerto Rico. The African Americans viewed the consumption of fufu as a way to connect with their ancestors who discovered it in the 16th century.[11] Colonialism introduced new agricultural techniques and crops, while trade networks facilitated the exchange of food products and culinary traditions. Over time, 'fufu' integration became more into Nigerian culinary culture increasingly, adapting to local tastes and preferences. This has brought about cassava roots sweet variety of cassava roots TMS 30572) improvement on quality and nutritional values, with the help of research with collaborations from international supports IITA). Overall, the development of 'fufu' in Nigeria became the interplay of geographical factors, cultural practices, and historical influences, all of which defined the evolution of this iconic dish.

'Fufu' also called 'Akpu' in Nigeria, is one of the products from cassava roots processing. It is a starchy fermented food with a high rate of consumption. It is a staple food common in both the West and Central parts of Africa, as a source of cheap calories for rural livelihood.[18] It is processed by traditional methods, where the cassava roots are peeled, washed, cut into smaller pieces and soaked in water for 4-5 days of softening and fermentation. The fermented slurries stirred in boiling water or pounded with the addition of hot water form gelatinized smooth dough consumed with favoured sauces, soups or stews.[19] The 'fufu' produced always has an undesirable odour generally forms of low molecular aldehydes and ketones), which limits its acceptability by consumers. The focus of the study is to know the processing unit operations that can be engaged to enhance the fermentation and production of odourless 'fufu' and its effects on nutrition, anti-nutrition, mineral elements and sensory qualities.

Materials and methods

Materials collection: The cassava roots sweet variety TMS 30572) is a specially bred variety with less hydrogen cyanide and high resistance to diseases. The roots were distributed by the International Institute for Tropical Agriculture IITA) Ibadan to farmers through the Federal government of Nigeria in food cassava processing value chain scheme. The roots were given to cassava farmers, cultivated by Teaching and Research Farm, Federal University of Technology Akure, Ondo State, Nigeria. The roots were distributed by the International Institute for Tropical Agriculture IITA) Ibadan to farmers through the Federal government of Nigeria in food cassava processing value chain scheme.

Reagents and chemicals: All reagents and chemicals used were of analytical grade obtained from SIGMA-ALDRICH, Germany and USA. Microbiological media used [Nutrient Agar NA),deMan Rogosa Sharpe Agar MRS) and Potato Dextrose Agar PDA)] were from L:S- Biotech label, USA and prepared according to manufacturer's instruction.

Microbial determination: Cassava roots were TMS 320572) fermented by spontaneous wild-type fermentation. The media NA, MRS and PDA) were prepared according to manufacturer's specification for isolation. The dilution factor at 10^3 for saline solution was used as previously described by Babatuyi et al.[20]

Identification of microorganisms: The isolated microorganisms were purified and identified according to Ochei and Kolhatkar[21] and Bergery's manual of identification by Holt et al.,[22] by examining colonies morphology on their cultural properties followed by biochemical tests. The fungal isolates were characterized by their cultural properties stained withcotton-blue lacto phenol solution and morphological observations under low power objective lens according to Barnett and Hunter.[23]

Identity of microorganisms characterized: The microorganisms identified and characterized were used as starter cultures for the 'fufu' fermentation. The microorganisms were as follows: Bacteria *Bacillus subtilis*, *Corynebacterium manihot*, *Lactobacillus plantarum* and *L. fermentum*) and Fungi *Saccharomyces cerevisiae*, *Candida stellata*, *Kloeckera apiculata Hanseniaspora uvarum*), *Aspergillus niger* and *Penicillium notatum* as previously described by Babatuyi et al.[9]

Preparation of cassava roots into 'Fufu'

Preparation of Cassava Roots into Mash: Fifty-two kilograms 52 kg) of cassava roots were sorted, washed, peeled and re-washed before dividing into three 3) portions as previously described by Babatuyi et al.[9] The standardization of each starter culture was carried out using the method of McFarland standard.[24] The turbidity of a McFarland Standard was visually comparable to a bacterial suspension of cultured broth and the approximate concentration of the bacteria in suspension as described below:

Quantification of starter culture used for inoculation

McFarland standard	1% $BaCl_2$ in ml)	1% H_2S0_4 in ml)	Appropriate Cell density the CFU)/ml
0.5	0.05	9.95	1.5×10^8

Therefore, 10-fold dilutions A log dilution is a tenfold dilution, meaning the concentration is decreased by a multiple of ten, where 1ml sample + 9 ml diluent = 10 ml i.e. 10^1 dilution) were prepared serially by performing a plate count of the dilution. The adjustment of each bacterial suspension was measured to have the same turbidity with McFarland Standard to produce a suspension with appropriate 1.5×10^8. The accuracy was verified by McFarland Standard to ensure that the suspension gives a representative colony count.

Eqn. 1

$$0.5 \text{ McF} = 1.5 \times 10^8 \text{ cells to be equal to } 0.06 (\text{OD } 600\text{nm})$$

Production of 'Fufu': The portion of the cassava mash to be fermented with starter cultures was weighed 200 g of the mash, 300 mL of water and 30 ml broth of inocula for each group i.e. six groups) and the remaining two portions WIG and WIS) without the addition of starter cultures/broth inocula. These three portions were fermented in different sterilized covered plastic containers. The fermentation was carried out in 3 days at 27 ± 2°C. The fermenting water of those in the first portion was changed every 24 h for 3 consecutive days with 300 mL of sterilized water and re-inoculated with 30 mL broth of inocula for each group using McFarland as reference as previously described by Babatuyi et al.[9] The grated 'fufu' samples were labelled as follows:

Chemical analyses

Analysis of proximate constituents of the 'Fufu'

Proximate constituents of the 'fufu' moisture contents, total ash, crude fat, crude fiber, and crude protein) of odourless 'fufu' samples were determined as described by the method of AOAC.[25] The composition of carbohydrates was determined from the result of subtraction as stated below:

Eqn. 2

$$100 - (\text{Moisture} + \text{ Total ash} + \text{Crude fat} + \text{ Crude fiber} + \text{ Crude protein})$$

The energy value was calculated as:

Eqn. 3

$$(\text{Crude fat} \times 9) + (\text{Carbohydrate} \times 4) + (\text{Crude protein} \times 4) = \text{Energy value}$$

Determination of anti-nutritional composition

Determination of tannin concentration from odourless 'fufu' samples was by the method of Jaffe.[19,26] The method of Munro[27] was employed for the determination of Oxalate. Hydrogen cyanide and phytate were determined by the method of AOAC.[25]

Analysis of some selected mineral elements

Some selected mineral elements such as calcium Ca), manganese Mn), iron Fe), and zinc Zn) were determined in odourless 'fufu' samples using the standard method of AOAC.[25]

Assessment of sensory qualities

The sensory qualities of the 'fufu' were determined using 9 point-Hedonic scale.[28] Semi-trained panelists 20) within the university community included both males and females and were cut across social and economic groups who are regular consumers of 'fufu'. The rating was "9" "like extremely" and "1" "dislike extremely". The sensory attributes accessed were appearance colour), texture, aroma and overall acceptability. The sensory evaluation was carried out according to the guidelines for human studies approved by the Ethical Committee of the School of Agriculture and Agricultural Technology, Federal University of Technology, Akure, Ondo State, Nigeria FUTA/SAAT/2019/001).

Statistical analysis

Data obtained were subjected to a one-way analysis of variance ANOVA) and the means were separated using New Duncan's Multiple Range Tests NDMRT). Statistical Package for Social Science SPSS) version 21.0 IBM Inc., New York, NY, USA) was used. The results are shown as Mean ± SEM (n=3).

Results and discussion

Effect of processing operations on proximate composition

The 'fufu' samples produced from the processing operations were significantly different in the proximate composition of the 'fufu' samples fermented for three 3) days as shown in Table 1. The 'fufu' sample SWI had the highest moisture 10.50 g/100 g) of the 'fufu' samples, above the FAO/WHO[29] recommendation 10.00 g/100 g). This implies that the sample may not have good storage quality, is porous and has a shorter shelf life as microorganism grows faster in high moisture content. Hence, results in quick deterioration[30] compared to other samples within the required value. 'Fufu' samples prepared with a combination of yeasts and moulds had higher protein contents, which were not significantly different from each other and statistically ranged between 3.66 g/100g and. 3.68 g/100g.

When compared with sample WIG 2.09 g/100g), had a higher value than sample WIS 1.59 g/100g). The biomass of the starters Moulds and yeasts) used enhanced the protein content in those 'fufu' samples. The ability of the hyphae to penetrate the cassava roots enabled high water absorption capacity causing the 'fufu' products to swell.[31] This thereby increased the hydrophilic path carboxyl of amino acid) of the protein content.

'Fufu' samples OBP 2.49 g/100g) and MBP 1.49 g/100g) had higher crude fat contents and the other 'fufu' samples were not significantly $p<0.05$) different 0.52 g/100g to 0.69 g/100g) from each other. This explains the principle of fat absorption, which enhances the protein concentration because of microbial activities present in the fermentation to break down the fat in the body. This will make protein content hydrophobic path absorb fat and protein emulsion) readily available to the body liver) and convert the simple sugar to supply energy during metabolic activities.[32] Some of the 'fufu' samples made with starter cultures OMP, YMP and MBP) had higher crude fibre content 3.58 g/100 g, 3.79 g/100 g and 3.84 g/100 g) respectively when compared with those fermented without inoculation WIG) 1.87 g/100 g) and WIS) 1.46 g/100 g). The lower amount of fiber content in sample WIG might be due to the decomposition of the cassava roots by the enzymatic activity of inherent microorganisms during the opening up of the roots. This could lead to leaching out of the molecules during processing to cause fiber reduction.[33] The total ash contents of 'fufu' samples were similar in their values, close to the standard ash value for cassava flour recommended by SON[34] 3% m/m, max). This implies that the samples may be a potential source of mineral elements.

Table 1 Proximate composition (g/100 g) of an odourless 'fufu' samples

Starter culture	Moisture	Protein	Crude fat	Crude fiber	Total ash	Carbohydrate	Energy (Kcal)
OBP	6.35±0.02^{b}	2.90±0.04^{b}	2.49±0.18^{a}	2.68±0.01^{b}	3.98±0.08^{c}	89.96±0.09^{c}	393.85±0.09^{a}
YBP	4.52±0.05^{d}	3.66±0.49^{a}	0.53±0.01^{c}	1.66±0.18^{c}	4.83±0.06^{a}	89.33±0.19^{b}	376.73±0.06^{b}
OYP	4.50±0.01^{de}	3.67±0.00^{a}	0.52±0.01^{c}	1.74±0.17^{c}	4.64±0.17^{ab}	89.43±0.34^{b}	377.08±0.02^{b}
WIG	3.34±0.01^{f}	2.07±0.00^{c}	0.55±0.07^{c}	1.46±0.09^{c}	4.73±0.06^{ab}	91.19±0.14^{a}	377.99±0.09^{b}
WIS	10.50±0.08^{a}	1.59±0.09^{d}	0.56±0.01^{c}	1.87±0.01^{c}	4.69±0.05^{ab}	91.31±0.14^{a}	377.34±0.04^{b}
MBP	4.84±0.02^{c}	3.68±0.01^{a}	1.49±0.09^{b}	3.84±0.32^{a}	4.82±0.08^{a}	86.35±0.04^{d}	373.53±0.02^{b}
YMP	3.25±0.04^{fg}	3.62±0.01^{a}	0.62±0.06^{c}	3.79±0.09^{a}	4.42±0.01^{ab}	87.55±0.04^{c}	370.26±0.03^{c}
OMP	4.50±0.01^{de}	3.67±0.01^{a}	0.69±0.09^{c}	3.58±0.18^{a}	4.66±0.11^{ab}	87.42±0.03^{c}	370.57±0.09^{c}

Mean ± SEMs with the same subscripts in the same column are not significantly p ≤ 0.05 different

Legend: OBP, only bacteria; YBP, yeasts and bacteria; OYP, only yeasts; WIG, without inoculum but grated; WIS, without inoculum but soaked; MBP, moulds and bacteria; YMP, yeasts and moulds; OMP, only moulds.

The carbohydrate content of sample WIS 91.31 %) and WIG were not significantly different p ≤0.05) from each other. Starch hydrolysis and conversion of sugar are responsible for some special microbes that produce amylase during the breakdown of complex carbohydrates into simpler ones[35] for their development and function. This could be responsible for low carbohydrate content in fermentation products. The energy level of sample OBP had the highest energy (393.85 g/100g) calorie intake, which is an added advantage over others sample in term of nutrition.

Effect of processing operations on anti-nutritional composition

Starter cultures used on the processing operations showed significant p ≤0.05) reduction of anti-nutrients of the 'fufu' during fermentation as presented in Figures 1a-1d.

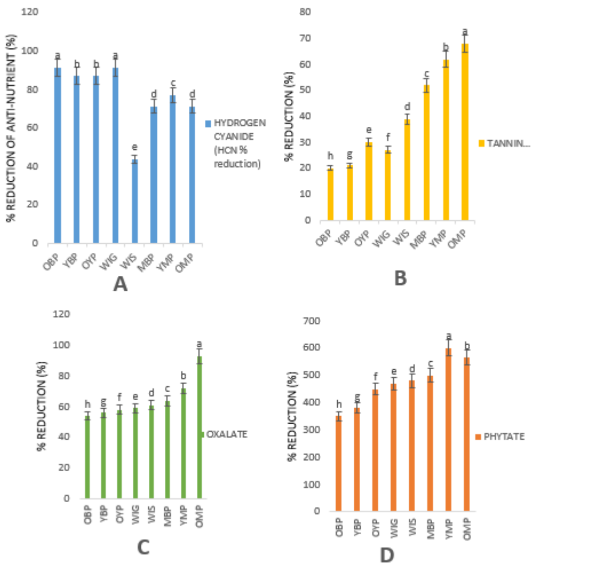

Figure 1a-1d Percentage (%) reduction of anti-nutritional composition of 'fufu' samples.

The cyanide contents of samples WIG and OBP 91.37%) had the highest reduction, while sample WIS had the least 43.76%) value respectively. This could be due to loss of inherent adhesion due to shredding during breakdown of cell wall, thereby allowing the enzyme to act onthe cyanogenic glycoside to release HCN.[36] Grating enhances contact between endogenous enzymes linamarase) to hydrolyze linamarin rapidly to hydrocyanic acid.[37] This could be due to large opening up of the cassava roots, making the nutrients more readily available to the fermentative microorganisms.

All the 'fufu' samples had low cyanide contents 0.5-1.80 mg HCN/kg) after fermentation, and were within the recommended standard 10 mg/kg) according to SON.[34] The reduction of the cyanide could be opening of cell structure of the cassava roots, which volatilizes during grating and fermentation to cause autolytic conversion of non-volatile cyanohydrin to hydrogen cyanide.[9] The contents of other anti-nutrients followed the same trend of reduction during fermentation. The reduction in the anti-nutrients levels indicates significant effect on the consumers of 'fufu' as phytate has the ability to combine with divalent elements like phosphorus and prevent their absorption into the body system. In addition, oxalate can combine with polyvalent elements like calcium or magnesium to make the element unavailable to the body and can cause kidney stone, resulting to cardiovascular disease when calcium oxalate is formed.[38]

Effect of processing operations on mineral elements

The treatments given to the cassava mash during the processing operations affected the mineral elements content of the odourless 'fufu' samples fermented for three 3) days as shown in Table 2.

'Fufu' sample WIS had the least amounts of calcium 31.37 mg/100 g) due to leaching out of the elements during fermentation.[33] Its potassium content was highest 533.92 mg/100 g) to give 10 % of the 4,700 mg for healthy adults[39] compared to the other samples, and manganese was 1.10 mg/100g) tending towards recommendable value of 1.2 %. High zinc content in all the samples could be due to a lower amount of phytate as reported by.[40,41] Zinc is required for the body's growth and as well as synthesis of both protein and nucleic acid.[35,42] Likewise, the sodium contribute to the significant function in movement of body metabolites, while potassium for ionic equilibrium and stimulation of tissue. The ratio of sodium and potassium Na:K) signified less than one <1) in most case except for samples OBP and OYP. This implies that samples less than one may be suitable for hypertensive patient, as less than one value of Na/K ratio has been recommended for management of high bloodpressure.[43]

Table 2 Mineral composition (mg/100 g) of an odourless 'fufu' samples

Starter culture	K	Ca	Na	Fe	Mn	Zn	Na/K
OBP	65.91±0.22^{h}	50.90±0.38^{b}	138.30±0.76^{b}	337.77±3.20^{b}	0.47±0.15^{c}	16.93±0.09^{c}	2.09^{a}
YBP	117.29±1.21^{f}	37.90±0.10^{e}	37.57±0.58^{h}	90.07±2.53^{g}	0.33±0.03^{cd}	9.00±0.06^{h}	0.32^{e}
OYP	149.34±1.34^{e}	34.47±0.19^{f}	164.60±0.55^{a}	117.67±2.38^{f}	0.73±0.12^{b}	18.20±0.26^{b}	1.10^{b}
WIG	98.67±1.04^{g}	39.77±0.13^{d}	82.63±0.13^{e}	93.10±4.20^{g}	0.20±0.06^{d}	11.13±0.12^{e}	0.84^{c}
WIS	533.92±6.45^{a}	31.37±0.13^{g}	126.01±0.66^{c}	162.10±2.96^{e}	1.10±0.06^{a}	33.53±0.15^{a}	0.24^{f}
MBP	221.21±1.92^{d}	70.37±0.33^{a}	88.27±0.45^{d}	276.07±3.80^{c}	1.00±0.06^{a}	16.33±0.07^{d}	0.40^{d}
YMP	276.38±1.38^{b}	51.60±0.36^{b}	58.77±0.27^{f}	829.93±4.17^{a}	0.87±0.03^{ab}	9.77±0.19^{g}	0.21^{g}
OMP	237.92±6.83^{c}	49.97±0.27^{c}	41.30±0.06^{g}	179.57±3.33^{d}	1.00±0.06^{a}	10.23±0.07^{f}	0.17^{h}

Mean ± SEMs with same subscripts in the same column are not significantly p ≤ 0.05 different

Legend: OBP, only bacteria; YBP, yeasts and bacteria; OYP, only yeasts; WIG, without inoculum but grated; WIS, without inoculum but soaked; MBP, moulds and bacteria; YMP, yeasts and moulds; OMP, only moulds.

Effect of processing operations on sensory qualities

The use of the starter cultures on the different processing operations had significant p≤0.05) different effect on the sensory quality of 'fufu' samples fermented for three 3) days as shown in Table 3.

Table 3 Effect of processing operations on the sensory properties of 'fufu' samples

Properties	FUFU Samples								
	OBP	YBP	OYP	WIG	WIS	MBP	YMP	OMP	MTE
Texture	6.60±0.58^{ab}	6.40±0.52^{ab}	6.61±0.7^{ab}	7.50±0.52^{a}	7.20±0.47^{a}	6.00±0.58^{ab}	4.80±0.79^{bc}	4.00±0.65^{c}	7.70±0.60^{a}
Appearance	7.61±0.50^{a}	7.11±0.58^{a}	6.00±0.48^{c}	7.70±0.56^{a}	6.91±0.60^{b}	6.49±0.53b^{c}	3.00±0.35^{e}	3.58±0.60^{d}	6.91±0.60^{b}
Aroma (Odour)	7.70±0.56^{a}	6.70±0.68^{a}	5.90±0.6^{a}	7.10±0.57^{a}	6.40±0.67^{a}	6.30±0.58^{a}	6.90±0.53^{a}	6.40±0.62^{a}	1.60±0.34^{b}
Overall acceptability	7.17±0.54^{a}	6.50±0.56^{b}	5.90±0.59^{c}	7.37±0.53^{a}	6.87±0.51^{b}	6.30±0.49^{b}	4.80±0.54^{d}	4.67±0.51^{d}	5.65±0.47^{c}

Mean ± SEMs with same subscripts in the same row are not significantly p ≤ 0.05 different

Legend: OBP, only bacteria; YBP, yeasts and bacteria; OYP, only yeasts; WIG, without inoculum but grated; WIS, without inoculum but soaked; MBP, moulds and bacteria; YMP, yeasts and moulds; OMP, only moulds; MTE, Market sample to eat.

The texture of each of the 'fufu' samples was considered acceptable except samples YMP (4.80±0.79) and OMP (4.00±0.60). The texture of 'fufu' sample of MTE (7.70±0.60) was not significantly better than that of samples WIG (7.50±0.52) and WIS (7.20±0.45) respectively. The appearance of 'fufu' sample WIG (7.70±0.56) had the highest value; it was not significantly different from samples OBP (7.61±0.50) and OYP (7.11±0.58). The processing operation unit of samples WIS (6.91±0.60) and MTE (6.91±0.60) served, as controls were the traditional processing operation produced from the laboratory and commercial ready to consume market type not significantly different from each other in appearance because they undergone the same process. This could be due to similarity in combination of battery of fermenting microorganisms present in the substrate. The aroma of the 'fufu' samples fermented with starter cultures were much better, ranged from 5.90±0.6 to 7.70±0.56 than sample MTE (1.60±0.34). 'Fufu' samples fermented with starter cultures did not give objectionable odour as it was perceived in sample MTE; contributing to the factors that discourage majority of people from consumption.

Samples OBP (7.17±0.54) and WIG (7.37±0.53) were rated overall acceptable. Samples YBP (6.50±0.50) and MBP (6.30±0.49) were not significantly different from each other, while sample WIS (6.87±0.51) was better than the two due to different microbial colonization [44]. There was a drastic reduction of the objectionable odour during the fermentation. This could be as a result of fermenting water being changed at every 24h and replacing with fresh and new fermenting water in addition of inocula broth as stated in the methodology. The yeast population flora increased with increase in period of fermentation and this significantly contributed to the objectionable odour of fermented cassava.[10]

Effect of processing operational units on the 'fufu' quality

The grated and soaking processing operational units of cassava roots into 'fufu' is presented in Figures 2 a-2b below. The effects of the processing on the overall acceptability in the pictorial Figures 2a-2b below showed the summary of the effects of the processing operations.

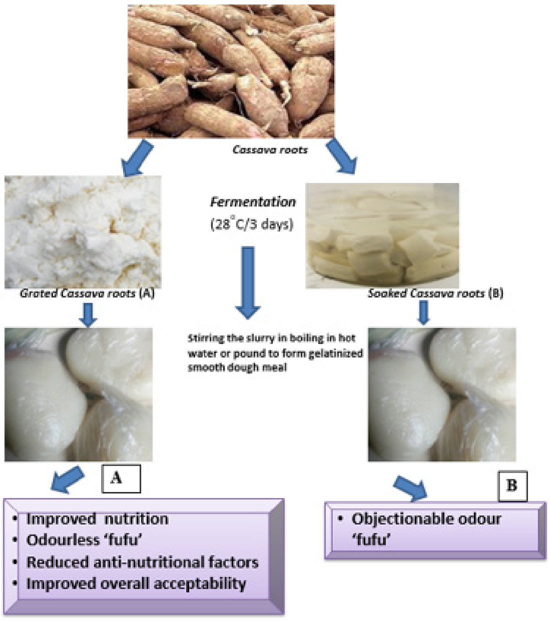

Figure 2a-2b Operation units of cassava roots into 'fufu' ready for consumption.

Conclusion

The processing operation engaged in production of odourless 'fufu' flour made with starter cultures improved the nutritional quality, reduced cyanide level to the lowest minimum tolerable level and as well as the days of fermentation to three 3) days. However, samples OBP, YBP and WIG had better results better than other samples even though all the samples were without known associated odour with 'fufu' except control sample (MTE), to monitor the sensory qualities.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and material

The datasets during and/or analyzed during the current study available from the corresponding author on reasonable request.

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Authors' contributions

CY conceived, designed the work, acquired, analyzed, interpreted the data and drafted the work. BE interpreted the data and substantively revised it. TN also interpreted the data and substantively revised it. All authors read and approved the final manuscript.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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