International Journal of Modern Science and Technology, 2019;4(8):196-203.
ISSN: 2456-0235.
www.ijmst.co

Research Article

Effect of fermentation using *Mucor strictus, Rhizomucor michei* and *Saccharomyces cerevisiae* on the nutritional composition and physicochemical properties of cassava by-products

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Abstract

Microbial fermentation has been reported to affect the nutritional composition of samples at different levels. The research was aimed at comparing the effect of three species of *Mucor strictus, Rhizomucor michei* and *Saccharomyces cerevisae* on the nutritional content and physico-chemical properties of cassava after solid state fermentation. The results of the study depict the following; Temperature shows a level of significance (P>0.05) with an increase from 27.12±0.25 to 30.17±1.02, 32.02±0.05 and 35.12±0.15 on the first, second, third and fourth day of fermentation respectively. There was a significant (P>0.05) difference in the Total soluble sugar and Total titrable acid. The proximate composition shows that there is a significant (P>0.05) difference before fermentation. The study revealed that there is a decrease in the percentage content of carbohydrate and moisture content during fermentation with *S. cerevisiae, R. Mucor* and *M. strictus* respectively, with a corresponding increase in the protein content of the cassava products.

Keywords: *Mucor strictus; Rhizormucor michei; Saccharomyces cerevisiae;* Detoxification; Cassava; Fermentation; Nutritional content; Physicochemical properties.

Introduction

Cassava is grown in Tropical Africa, South and Central America and consumed by most people in these countries (R). Over the years, fermentation has been carried on cassava to produce similar or different products which are mostly associated with residue products [1], [2]. Cassava peels; leaves and starch residues constitute 25 % of the cassava plant which are usually discarded as wastes after harvesting and processing, with limited utilization due to low protein, high crude fibre and cyanide contents [3, 4]. Among these, cassava peel is noted to be the highest and is heaped in production areas with accompanying smelly odours [3].

The utilization of cassava by products for livestock feeding is highly limited because apart from the low protein and high crude fibre levels of the products, they also contain cyanide [4]. Traditional processing techniques help to reduce the cyanogen levels in these products [5]. Nevertheless, residual amount of cyanide is present in many processed products and according to [6], [7] toxicity from processed cassava depends on the residual content of cyanohydrins and bound glucosides. Ingestion of cassava product of high cyanogen levels often results in withdrawal of the animal's reserve of sulphur amino acids for detoxification of the cyanide to thiocyanate [8]. The removal of the cyanogen from the product prior to feeding them to livestock is therefore essential.

Processing cassava into different ready-to-eat products usually through fermentation has been shown to affect the nutritive value of cassava roots through modification and losses in nutrients of high value, such as proteins, carbohydrates, Minerals and Vitamins [4]. A combination of strategies may be needed to ensure a positive effect on micronutrient adequacy [9]. Raw and boiled cassava root retains the majority of high-value nutrients except riboflavin and iron. Garri (shucking + fermentation + drying) and products obtained after retting of cassava root with skin (flours and baton) are less efficient than raw and boiled cassava root in keeping nutrients of high value

Received: 29.07.2019; Received after Revision: 22.08.2019; Accepted: 22.08.2019; Published: 26.08.2019

but are better than products obtained after retting of shucked cassava roots. However, the latter is richer in riboflavin than sun-dried flours obtained after retting of cassava root with skin. In contrast, although its calcium content is high, meduame-mbong, which involves boiling and washing, has the poorest nutritional value compared to other cassava ready-to-eat products because the prolonged washing step removes most of its soluble nutrients and a considerable part of its energy [10]. In contrast with boiled cassava, gari, sun-dried flours after retting of cassava root with skin, smoked-dried flours, meduame-mbong, and more general cassava products obtained after retting of shucked cassava root lose a major part of dry matter, carbohydrates, and calories (26% to 35% of loss). Products of retting of shucked cassava root and medua-me-mbong cause high protein loss of 52% to 68% and 66%, respectively [9].

Similarly, high loss of ash (minerals) occurs during medua-me-mbong preparations, smoked-dried cassava flour preparations, and for products obtained after retting of shucked cassava roots [10]. Comparing processing techniques, boiling, gari, and retting cassava roots with skin appear to be the most beneficial techniques on a nutritional basis [16]. Although peeling and soaking cassava roots are efficient at removing fiber and cyanogenic-glucosides, respectively, they cause considerable nutrient losses because of solubility of the nutrients in water. Furthermore, fermentation during soaking improves riboflavin status but fails to improve digestibility [9]. Although pounding cassava roots removes much of the cyanogenic-glucosides, it causes loss of raw material. Sun-dried and smoke-dried cassava flours have significant losses of vitamins [16]. In addition to vitamin depletion, smoke-dried cassava flours experience important losses in protein and minerals, while sun-dried cassava flours result in an increase in ash probably due to the dust it contains [9]. Biodegradation of waste materials through fermentation process involving different microorganisms could help in improving the shelf life, texture, aroma, nutritional quality digestibility and reduction in antinutrient content under different conditions [16]. The research was aimed at comparing the effects of fermentation using *Mucor strictus, Rhizomucor Michei* and *Saccaharomyces cerevisiae* on the nutritional composition and physicochemical properties of cassava by-products.

Materials and methods

Microbial inoculation and fermentation

Slants of *M. strictus, R. miehei* and *S. cerevisiae* were cultured from local burukutu joint. The *M. strictus* was sub-cultured on corameal agar, the *R. miehei* on malt extract agar and the S. cerevisiae was on agar medium of yeast extract (1%), peptone (2%) and glucose (2%) in 250 ml Erlenmyer flasks after sterilization at 121°Cfor 15 min. A spore suspension was prepared using distilled water. About 30 g of the milled cassava leaves and peels was added to each of 3 sets of flasks and the moisture content adjusted to about 25%. After autoclaving, the set of flasks was aseptically inoculated with each of the organisms and properly labeled. The *M. strictus* flasks was incubated at 15°C, *R. miehei* at 40°C and *S. cerevisiae* at 25°C, corresponding to the optimum temperature growth of the respective organism. The Samples was withdrawn at day 4, 8 and 12 from the substrates inoculated with the fast growing *R. miehei* and at day 7, 14 and 21 from those with the moderately growing *M. strictus* and *S. cerevisiae*. The cassava tubers were sorted, peeled, washed with potable water and drained. 10 kg of the washed tubers were cut into slices of 3 to 4cm length and soaked in the bowl containing the microbial spore. It was wrapped with polythene bag which was then covered with foil paper leaving space for thermometer. During the fermentation, samples of the fermenting tubers and steep water were aseptically taken out and subjected analysis. After fermentation, the pulp was removed, water squeezed out and spread on a tray and sun-dried [17].

Proximate composition

Determination of moisture content

About Five gram (5 g) of the powdered samples will be weighed (W1) in to pre-weighed empty crucible (W0) and placed into a hot drying oven at 105°C for 3 h. The crucible was removed, cooled into desiccators and weighed. The process of drying, cooling and weighing will be repeated until a constant weight (W2) is obtained [12].

Determination of total ash

About 2 g of the dried powdered samples was weighed (W1) into pre-weighed empty crucible (W0) and placed into a lepton muffle furnace at 550°C at 5 h. The ash was cooled into

desiccators and weighed (W2). The weight of the ash was determined by the difference between the powdered samples, pre-weighed and the ash in the crucible [12].

Determination of fat content (lipids)

The fat (lipid) content in the sample was extracted using soxhlet extraction [11]. The powered samples (g) was weighed (W0) into a porous thimble and covered with a clean white cotton wool. Petroleum ether (200 cm^3) was poured into a 250 cm^3 extraction flask, which was previously dried in the oven at 105°C and weighed (W2). The porous thimbles were placed into the Soxhlet and the rest of the apparatus will be assembled. Extraction was done for 5hr. The thimble was removed carefully and the extraction flask placed in a water bath so as to evaporate the petroleum ether and then dried in the oven at a temperature of 105^oC to completely free the solvent and moisture. It was cooled in desiccators and reweighed (W1).

Determination of crude fibre

About 2 g of powered samples were weighed (W0) into a 1 dm^3 conical flask. Water (100 cm^3) and (20 cm^3) of 20% H_2SO_4 were added and boiled gently for 30min. The content was filtered through Whateman No.1 filter paper. The residue was scrapped back into the flask with a spatula. Water (100 cm^3) and 20 cm^3 of 10% NaOH was added and allowed to boil gently for 30min. The content was filtered and the residue was washed thoroughly with hot distilled water, and then rinsed once with 10% HCl and twice with ethanol and finally three times with petroleum ether. It was allowed to dry and scrapped into the crucible and dried overnight at 105°C in an air oven. It was then removed and cooled in desiccators. The sample will be weighed (W1) and ashed at 550^oC for 90 min in a lepton muffle furnace. It was finally cooled in desiccators and weighed again (W2) [12].

Determination of protein

About 2 g of the sample and 5 g of anhydrous sodium sulphate or 4 tables of kjedahl catalysts were weighed into the kjedahl flasks. The mixture was followed up with addition of 1g copper sulphate and a speck of selenium or 1 tablet of kjeldahl catalyst (each tablet contains 1 g Na_2SO_4 + 0.05 g selenium) into the mixture, 25 ml concentrated sulphuric acid was added and 5 glass beads (glass beads prevents bumping during heating). The samples were heated in the fume very gently at first and then increase heat with occasional shacking till solution assumes a green colour (temperature of digester is above 420°C for about 30 min. The mixture was then cooled and washed down any black particle showing at the mouth and neck of the flask with distilled water. It was re-heated gently at first until the green colour disappears. It was later allowed to cool. After cooling, the digested mixture was mixed with several washing into 250 ml volumetric flask and make up to the mark with distilled water. Distillation was done using Markham distillation apparatus [13].

Protein distillation

The sample was steamed through the markham distillation apparatus for about 15 min before use. 5ml of the digest was pipetted into the body of the apparatus via the small funnel aperture, it was washed down with distilled water followed by 5 ml 60% NaOH solution. The sample was steamed for about 5-7 min to collect enough ammonium sulphate. The receiving flask was removed and washed down the tip of the condenser into the flask. The solution was titrated in the receiving flask using 0.01N hydrochloric or sulphuric acid and the nitrogen content was calculated and hence the protein content of the food.

Crude protein is a measure of nitrogen in the sample. It was calculated by multiplying the total nitrogen content by a constant, 6.60. This is based on the assumption that, protein contain about 16%N which includes both true protein and non-protein N and does not make a distinction between available or unavailable [11].

Determination of carbohydrate

Nitrogen free extract content was calculated as the carbohydrate content of the sample [11].

The total proportion of carbohydrate in the samples was obtained by calculation using the percentage dry method. That is by subtracting the % sum of food nutrients which include: %protein, %crude lipids, %crude fibre, % moisture and % ash from 100%. This will be done by using the equation below:

CHO (%) =100% - (%crude protein + %crude lipid + %crude fibre + %ash + % moisture)

Statistical analysis

Results were subjected to one-way ANOVA and

means separated by least significant difference (LSD) using Duncan multiple range test, also the proximate, cyanide composition and physico-chemical properties were analyzed to test the effect of fermentation on these properties.

Result and discussion

Physicochemical properties of cassava byproducts

Table 1 shows the effects of fermentation using *S. cerevisiae* on cassava products. There was no significant (P>0.05) difference in the Total soluble sugar and Total titrable acid of the tubers. There was a significant reduction (P>0.05) in the total soluble sugar of the peels and the total titrable acid reducing from 4.7±0.3 and 3.3±0.5 to 4.2±0.3 and 3.4±0.7 respectively. The Total soluble sugar of the Leaves increased significantly (P>0.05) from 6.8±0.3 to 7.1±0.4. Total titrable acid of the leaves reduced significantly (P>0.05) from 7.6±0.5 to 2.4±0.1.

Table 2 shows the effects of fermentation using *M. strictus* on cassava products. There is a significant (P>0.05) difference in the Total soluble sugar and Total titrable acid of the tubers where the total soluble sugar reduced from 4.6±0.5 to 3.7±0.5 and 4.2±0.2 to 3.4±0.3 respectively. There was also a significant increase (P>0.05) in the total soluble sugar of the sample and the total titrable acid of the peels reducing from 3.9±0.3 and 4.2±0.2 to 4.2±0.2 and 4.8±0.9 respectively. The Total soluble sugar of the Leaves increased significantly (P>0.05) from 6.6±0.2 to 7.3±0.5. Total titrable acid of the leaves reduced significantly (P>0.05) from 7.8±0.1 to 5.9±0.8.

Table 3 shows effects of fermentation using *R. mucor* on cassava products. There is a significant (P>0.05) difference in the Total soluble sugar and Total titrable acid of the tubers where the total soluble sugar reduced from 5.0±0.2 to 3.7±0.5 and 3.9±0.8 to 4.4±0.1 respectively. There was also a significant (P>0.05) difference in the total soluble sugar of the peels and the total titrable acid of the peels increasing from 4.9±0.2 to 4.2±0.2 and increasing from 3.9±0.5 and 3.1±0.1 respectively. The Total soluble sugar of the leaves increased significantly (P>0.05) from 6.8±0.3 to 7.0±0.7. Total titrable acid of the leaves reduced significantly (P>0.05) from 7.6±0.4 to 2.5±0.5.

Table 1. Physico-chemical properties of cassava leaves, tubers and peels during fermentation with *S. cerevisiae*

Sample	Total Soluble Sugar (TSS)			Total Titrable Acid (TTA)		
	48 h	72 h	96 h	48 h	72 h	96 h
Tuber	4.5 ± 0.2^{a}	4.7 ± 0.4^{a}	4.2 ± 0.3^{a}	4.1 ± 0.4^{a}	3.9 ± 0.3^{a}	3.8 ± 0.4^{a}
Peel	4.7 ± 0.3^{c}	4.4 ± 0.4^{b}	4.2 ± 0.3^{b}	3.3 ± 0.5^{a}	4.6 ± 0.6^{c}	3.4 ± 0.7^{a}
Leaves	6.8 ± 0.3^{c}	6.9 ± 0.3^{c}	7.1 ± 0.4^{c}	7.6 ± 0.5^{c}	6.0 ± 0.8^{b}	2.4 ± 0.1^{a}

Values indicated by superscripts are statistically significant (P>0.05) across the groups.

Table 2. Physico-chemical properties of cassava leaves, tubers and peels during fermentation with *M. strictus*

Sample	Total soluble sugar (TSS)			Total titrable acid (TTA)		
	48 h	72 h	96 h	48 h	72 h	96 h
Tuber	4.6 ± 0.5^{b}	6.3 ± 0.1^{c}	3.7 ± 0.5^{a}	4.2 ± 0.1^{b}	4.6 ± 0.2^{b}	3.4 ± 0.3^{a}
Peel	3.9 ± 0.4^{a}	3.9 ± 0.2^{a}	4.2 ± 0.2^{b}	4.2 ± 0.2^{b}	3.8 ± 0.9^{a}	4.8 ± 0.9^{b}
Leaves	6.6 ± 0.2^{c}	6.9 ± 0.3^{c}	7.3 ± 0.5^{c}	7.8 ± 0.1^{c}	3.5 ± 0.8^{a}	5.9 ± 0.8^{b}

Values indicated by superscripts are statistically significant (P>0.05) across the groups.

Table 3. Physico-chemical properties of cassava leaves, tubers and peels during fermentation with *R. mucor*

Sample	Total soluble sugar (TSS)			Total titrable acid (TTA)		
	48 h	72 h	96 h	48 h	72 h	96 h
Tuber	5.0 ± 0.2^{b}	4.4 ± 0.3^{a}	3.8 ± 0.5^{a}	3.9 ± 0.8^{a}	4.0 ± 0.3^{b}	4.4 ± 0.1^{c}
Peel	4.9 ± 0.2^{a}	3.9 ± 0.3^{a}	5.1 ± 0.4^{b}	3.9 ± 0.5^{a}	3.4 ± 0.3^{a}	3.1 ± 0.1^{b}
Leaves	6.8 ± 0.3^{c}	6.8 ± 0.4^{b}	7.0 ± 0.7^{c}	7.6 ± 0.4^{b}	3.0 ± 0.4^{a}	2.5 ± 0.5^{a}

Values indicated by superscripts are statistically significant (P>0.05) down the group.

Table 1, 2 and 3 shows the effects of the organisms on the total titrable acid and total soluble sugar, the tables shows that *M. strictus* had the highest effect on the cassava leaves on total soluble sugar and Total titrable acid while *R. mucor* had the highest effect on the peels and *S. cerevisiae* on the tubers. Total soluble sugar (TSS) content is not only the main photosynthate in higher plants, but also the main form of carbohydrate metabolism and temporary storage. The soluble sugar content plays a very important role in carbohydrate metabolism and has a close relationship with photosynthesis and production. The level of soluble sugar content is a sign of the supply ability of leaves and reflected transformation and ability of grains to use assimilates [18].

Table 4 shows the temperature changes of the samples during fermentation. During the period of fermentation, there is a significant increase in the temperature (P>0.05) with an increase from 27.12±0.25 to 30.17±1.02, 32.02±0.05 and 35.12±0.15 on the first, second, third and fourth day of fermentation respectively. The changes in the physicochemical activity (Temperature) in Table 4 shows that fermentation is accompanied by an increase in temperature, as the microorganisms make use of the substrate, the metabolic activity leads to an increase in the temperature [10].

Table 4. Changes in temperature during fermentation process

Days	Temperature, ºC
1	27.12 ± 0.25^{a}
2	30.17 ± 1.02^{b}
3	32.02 ± 0.05^{b}
4	35.12 ± 0.15^{c}

Values indicated by superscripts are significantly different (P>0.05) down the group.

Proximate composition of the cassava leaves, tubers and peels

Table 5 shows the proximate composition of the cassava products before fermentation. There is a significant (P>0.05) difference in the moisture, fat, ash, fibre, protein and carbohydrate content of the samples. Cassava peels had the highest moisture content of 60.0±0.2 while the leaves had the highest ash (9.5±0.6), fibre (13.5±0.4) and protein content (11.8±0.3). The tubers had the highest carbohydrate content (75.4±0.4). Considering the importance of carbohydrate, moisture and protein as essential nutrients for energy production, transport of metabolic product, and for repair of lost cells and tissues and the nutrient composition is shown in Table 5. Table 6, 7 and 8 reveals that there was a decrease in the percentage content of carbohydrate and moisture content (dw) during fermentation with *S. cerevisiae, R. Mucor* and *M. strictus* respectively, with a corresponding increase in the protein content of the cassava products.

Table 6 shows the proximate composition of cassava Tuber after fermentation (96 hours). There is no significant (P>0.05) difference in the moisture, fat and ash content of the cassava tuber. The protein content increased significantly (P>0.05) from 2.8±0.1 to 7.2±0.3, 7.8±0.4 and 7.1±0.4 after fermentation with *S. cerevisiae, R. mucor and M. strictus* respectively. The carbohydrate content decreased significantly (P>0.05) from 75.4±0.4 to 68.1±0.6, 68.1±0.4 and 13.3±0.4 after fermentation with *S. cerevisiae, R. mucor and M. strictus* respectively. The high residual starch of cassava residue from the composition analysis could partly be attributed to the peeling process of cassava tuber which normally leaves some amount of the flesh which contains starch as well as the trimmings which are also starchy [19].

Table 5. Proximate composition of cassava leaves, tubers and peels before fermentation

	Moisture %	Fat %	Ash %	Fibre %	Protein %	Cho %
Cassava Tuber	14.0 ± 1.3^{b}	1.5 ± 0.3^{a}	4.6 ± 0.1^{b}	1.7 ± 0.7^{a}	2.8 ± 0.1^{a}	75.4 ± 0.4^{c}
Cassava Peel	60.0 ± 0.2^{c}	1.6 ± 0.4^{a}	0.7 ± 0.1^{a}	10.3 ± 0.4^{b}	6.2 ± 0.2^{b}	18.2 ± 0.3^{a}
Cassava Leaves	8.9 ± 0.1^{a}	3.1 ± 0.1^{b}	9.5 ± 0.6^{c}	13.5 ± 0.4^{c}	11.8 ± 0.3^{c}	43.8 ± 0.4^{b}

Values indicated by superscripts are statistically significant (P>0.05) down the group.

Table 6. Proximate composition of cassava tuber after fermentation (96 h)

	Moisture %	Fat %	Ash %	Fibre %	Protein %	Cho %
Cassava Tuber (Control)	14.0±1.3[a]	1.5±0.3[b]	4.6±0.1[a]	1.7±0.7[a]	2.8±0.1[a]	75.4±0.4[c]
S. cerevasae	15.2±0.8[b]	1.5±0.1[b]	4.5±0.8[a]	1.7±0.1[a]	7.2±0.3[b]	68.1±0.6[a]
Rhizor m.	16.1±0.6[c]	1.4±0.2[a]	4.5±0.2[a]	1.6±0.2[a]	7.8±0.4[b]	68.1±0.4[a]
Mucor s.	15.2±0.5[b]	1.4±0.2[a]	4.6±0.4[a]	1.7±0.2[a]	7.1±0.4[b]	70.2±0.9[b]

Values indicated by superscripts are statistically significant (P>0.05) down the group.

Table 7 shows the proximate composition of cassava Peels after fermentation (96 hours). There is no significant (P>0.05) difference in the moisture, fat and ash content of the cassava peels. The protein content increased significantly (P>0.05) from 6.2±0.2 to 9.3±0.5, 8.4±0.7 and 9.2±0.5 after fermentation with *S. cerevisiae, R. mucor and M. strictus* respectively. The carbohydrate content decreased significantly (P>0.05) from 18.2±0.3 to 16.3±0.5, 13.3±0.4 and 15.0±0.1 after fermentation with *S. cerevisiae, R. mucor and M. strictus* respectively. Table 8 shows the proximate composition of cassava leaves after fermentation (96 hours). There is no significant (P>0.05) difference in the fiber content of the cassava leaves. The protein content increased significantly (P>0.05) from 11.8±0.3 to 17.4±0.1, 15.2±0.2 and 16.3±0.2 after fermentation with *S. cerevisiae, R. mucor and M. strictus* respectively. The carbohydrate content decreased significantly (P>0.05) only with *S. cerevisiae* fermentation while the values for the other organism remained the same.

Table 7. Proximate composition of cassava peels after fermentation

	Moisture %	Fat %	Ash %	Fibre %	Protein %	Cho %
Cassava Peel (Control)	60.0±0.2[a]	1.6±0.4[a]	0.7±0.1[a]	13.3±0.4[a]	6.2±0.2[a]	18.2±0.3[c]
Saccharomyces c.	59.0±0.3[a]	1.6±0.4[a]	0.6±0.2[a]	13.2±0.4[a]	9.3±0.5[b]	16.3±0.5[b]
Rhizor m	62.0±0.4[a]	1.5±0.5[a]	0.6±0.3[a]	14.2±0.7[a]	8.4±0.7[b]	13.3±0.4[a]
Mucor s.	59.2±0.5[a]	1.5±0.2[a]	0.7±0.4[a]	14.4±0.9[a]	9.2±0.5[b]	15.0±0.1[b]

Values indicated by superscripts are statistically significant (P>0.05) down the group.

Table 8. Proximate composition of cassava leaves after fermentation

	Moisture %	Fat %	Ash %	Fibre %	Protein %	Cho %
Cassava Leaves (Control)	8.9±0.1[b]	3.1±0.1[b]	9.5±0.6[b]	10.5±0.4[a]	11.8±0.3[a]	53.8±0.4[b]
S. cerevisiae	9.1±0.2[b]	2.9±0.2[a]	9.2±0.3[b]	10.1±0.1[a]	17.4±0.1[c]	51.3±0.1[a]
R. mucor	8.2±0.3[a]	2.7±0.3[a]	8.6±0.3[a]	10.8±0.5[a]	15.2±0.2[b]	54.5±0.2[b]
M. strictus	8.3±0.6[a]	2.6±0.4[a]	8.2±0.5[a]	10.2±0.6[a]	16.3±0.2[c]	54.4±0.1[b]

Values indicated by superscripts are statistically significant (P>0.05) down the group.

The high protein content observed could be attributed to the ability of the *S. cerevisiae* to secrete some extracellular enzymes such as amylases, linamarase and cellulase into the cassava mash during their metabolic activities, which would lead to yeast growth [14,15]. Table 6, 7 and 8 reveals that there was a decrease in the percentage content of carbohydrate and moisture content (dw) during fermentation with S. cerevisiae, R. Mucor and M. strictus respectively, with a corresponding increase in the protein content of the cassava products. The

high protein content observed could be attributed to the ability of the S. cerevisiae to secrete some extracellular enzymes such as amylases, linamarase and cellulase into the cassava mash during their metabolic activities, which would lead to yeast growth [15]. It was revealed by [16] that the improvement in the nutritional component and reduction in cyanide content of cassava peels is as a result of certain endogenous enzymes by the microorganisms which might enhance the degradation of recalcitrant substances in nature.

Conclusions

Fermentation of cassava could facilitate the decontamination of waste disposed into the environment for a desirable products formation in food processing industry under normal conditions. The results obtained from this have revealed the improvement in the nutritional component of cassava tubers, peels and leaves. This secretion of certain endogenous enzymes by the microorganisms might enhance the degradation of recalcitrant substances in nature. Therefore, fungi fermentation, especially in cassava tuber, peel and cassava leaves could potentially increase the protein content of the products. The differences in nutrient values observed across the products by the different organisms could be due to availability of substrate and metabolic interaction between the organisms and the available substrates.

Conflict of interest

The authors declare that there is no competing interest.

Acknowledgement

The authors wish to acknowledge the Management of Biochemistry Department, Federal University of Agriculture Makurdi, Benue State, Nigeria, for granting the authors permission to embark on the project. The authors also appreciate Mr. Charles Amos for his contribution towards the research.

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