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RESEARCH ARTICLE

Nutrient enrichment of cassava peels using a mixed culture of *Saccharomyces cerevisae* and *Lactobacillus spp* solid media fermentation techniques

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Cassava pulp was fermented with pure strains of *Saccharomyces cerevisae* and two bacteria namely *Lactobacillus delbruckii* and *Lactobacillus coryneformis* for 3 days. The squeezed liquid from the fermented pulp was used to ferment cassava peels for 7 days. Analysis of the dried fermented peels revealed that there was a significant ($P < 0.05$) increase in the protein content of the cassava peels fermented with squeezed liquid from the inoculated cassava pulp (21.5%) when compared with the unfermented cassava peel (8.2%). Moreover, the treatment equally brought about a significant ($P < 0.05$) decrease in the cyanide (6.2 mg/kg) and phytate content (789.7 mg/100g) when compared with the unfermented cassava peels, which had 44.6 mg/kg cyanide and 1043.6 mg/100g phytate. The fermented cassava peels could be a good protein source in livestock feeds.

Fermentation is one of the oldest applied biotechnologies, having been used in food processing and preservation as well as beverages production for over 6,000 years (Motarjemi, 2002). The fermentation process of staples serves as a means of providing a major source of nourishment for large rural populations, and contributes significantly to food security by increasing the range of raw materials which can be used in the production of edible products (Adewusi et al. 1999). Fermentation enhances the nutrient content of foods through the biosynthesis of vitamins, essential amino acids and proteins, by improving protein quality and fibre digestibility. It also enhances micronutrient bioavailability and aids in degrading antinutritional factors (Achinewhu et al. 1998).

Two important biological wastes, that may cause damage to environment, are generated during the traditional processing of cassava starchy storage roots for gari production in Africa, namely, the cassava peels and the liquid squeezed out of the fermented parenchyma mash. Cassava peels derived from gari processing are normally discarded as wastes and allowed to rot in the open, thus resulting in health hazards. As a rough estimate, about 10 million tonnes of cassava are processed into gari annually in Nigeria alone. Since these peels could make up to 10% of the wet weight of the roots, they constitute an important potential resource for animal feeds if properly processed by a bio-system (Antai and Mbongo, 1994). The peels contain toxic levels of cyanogenic glucosides, while the liquid

Table 1. Proximate composition of fermented cassava peel (% dry weight). Protein content of the waste water from inoculated fermented cassava pulp was 3.8 mg/ml.

Sample	Ash	Moisture	Protein	Fat	Crude fibre	Carbohydrate
Inoculated fermented	$7.2^{a} \pm 0.2$	$6.4^{a} \pm 0.4$	$21.5^{a} \pm 1.2$	$2.1^{b} \pm 0.1$	$11.7^{a} \pm 0.5$	$51.1^{b} \pm 0.4$
Naturally fermented	$6.0^{b} \pm 0.2$	$5.7^{b} \pm 0.2$	$11.1^{b} \pm 0.3$	$3.5^{a} \pm 0.2$	$6.5^{b} \pm 0.5$	$67.3^{a} \pm 0.4$
Unfermented	$6.4^{b} \pm 0.4$	$5.1^{c} \pm 0.3$	$8.2^{c} \pm 0.1$	$3.1^{a} \pm 0.4$	$12.5^{a} \pm 0.2$	$64.6^{a} \pm 0.2$

Values with the same alphabet along the same column are not significantly different ($P > 0.05$).
Values are mean ± S.E (n = 3).

contains a heavy load of microorganisms capable of hydrolyzing the glucosides. The resulting products of fermentation of cassava peels with squeezed out water can be dried and used as animal feeds (Tweyongyere and Katongole, 2002). This study therefore sought to investigate the effect of the fermentation of cassava peel on the nutritional quality of the fermented product.

MATERIALS AND METHODS

Materials

Sweet variety of Cassava tubers (less than 50 mg/kg cyanide content) was freshly harvested from the Research farm of the Federal University of Technology, Akure, Nigeria. The chemicals used were of analytical grade, and glass distilled water was used. The microorganisms were collected from Federal Institute of Industrial Research Oshodi (FIIRO), Lagos, Nigeria.

Methods

Sample preparation. There were two treatments carried out in three replicates each. In the first treatment, whole roots were peeled, washed, grated, after which 1 kg of the processed pulp was spread in a tray (about 50 cm diameter) to an average layer thickness of 2 cm, a 10 g mixture of freshly sub-cultured pure strains of *Lactobacillus delbruckii, Lactobacillus coryneformis* and *Saccharomyces cerevisae*(2:1:1) was carefully added to the solid matrix in order to obtain a well homogenized mixture. The mash was allowed to ferment for three days; the incubation temperature and the relative humidity of the air were 30ºC and 90-93%. After the fermentation the waste-water was pressed out, while the second treatment was fermented naturally without any inoculum. 150 ml of the wastewater was carefully mixed with 200 g of washed, dried and ground cassava peels, the mash was subsequently spread in a tray to an average thickness of about 2 cm and allowed to ferment for seven days, the incubation temperature and the relative humidity of the air were 30ºC and 90-93%. The fermented peels were subsequently analyzed. Unfermented peels served as control.

Sample analysis. The nutritional composition (ash, fat and crude fibre) of the fungi/bacterial fermented cassava product was evaluated using the methods reported by Cordenunsi et al. 2004 and the protein content was determined using the micro-Kjeldhal method (N x 6.25). The phytate content was determined, based on the ability of standard ferric chloride to precipitate phytate in dilute HCl extracts of the sample (Preet and Punia, 2000). The cyanide content of the fermented cassava peels was determined by silver nitrate titration (Oboh et al. 2002). The Zn, Na, Ca, and K contents were determined on aliquots of the solutions of the ash by established flame atomic absorption spectrophotometry procedures using a Perkin-Elmer atomic absorption spectrophotometer (Model 372).

Analysis of data. The results are presented as the mean standard values of three replicates each. A one-way analysis of variance (ANOVA) and the Least Significance Difference (LSD) were carried out. Significance was accepted at $P \leq 0.05$.

RESULTS AND DISCUSSION

There was a significant increase ($P < 0.05$) in the protein content of the cassava peels fermented with waste-water from fermented cassava pulp (Table 1). This increase was highest in the peel fermented with waste-water from the inoculated cassava pulp (21.1%). The increase in the protein content of the cassava peels fermented with waste water from the inoculated fermented cassava pulp could be attributed to the possible secretion of some extracellular enzymes (proteins) such as amylases, linamarase and cellulase (Oboh and Akindahunsi, 2003) into the cassava mash by the fermenting organisms in an attempt to make use of the cassava starch as a source of carbon (Raimbault, 1998). Apart from this, the increase in the growth and proliferation of the fungi/bacterial complex in the form of single cell proteins may possibly account for the apparent increase in the protein content of the peels fermented with waste water from the inoculated fermented cassava pulp (Antai and Mbongo, 1994; Obohet al. 2002). In view of this significantly enhanced protein content in the fermented cassava peels, the cassava peels, regarded as having no economic value, could be integrated into animal nutrition provided the cassava peel is acceptable and highly digestible in farm animals.

There was a significant decrease ($P < 0.05$) in the carbohydrate content of the cassava peels fermented with waste water from the inoculated cassava pulp, when compared to the unfermented (Table 1). The decrease could be attributed to the ability of the fungi/bacterial complex to hydrolyze starch into glucose and ultimately the glucose will be used by the same organisms as a carbon source to

Table 2. Mineral composition of fermented cassava peel (ppm dry weight).

Sample	Ca	Na	K	Zn
Inoculated fermented	0.03[a] ± 0.00	0.04 [a] ± 0.00	0.05 [a]± 0.00	0.01 [a] ± 0.00
Naturally fermented	0.03[a] ± 0.00	0.04 [a] ± 0.00	0.06 [a]± 0.00	0.01 [a]± 0.00
Unfermented	0.03 [a]± 0.00	0.04 [a]± 0.00	0.05 [a]± 0.00	0.01 [a]± 0.00

Values with the same alphabet along the same column are not significantly different ($P > 0.05$).
Values are mean ± S.E (n = 3).

synthesize fungi/bacterial biomass rich in protein. The proportionate increase in the protein content in peels fermented with waste water from the inoculated cassava pulp could also account for the decrease in the carbohydrate content (Obohet al. 2002). There was no discernable trend in the fat, crude fibre, ash (Table 1) and the mineral content of the cassava peels (Table 2).

Cassava peels usually have higher concentration of cyanogenic glucosides than the parenchyma (pulp); this makes the peel unsuitable as animal feed. Fermentation of the cassava peels with waste water from the fermented cassava pulp significantly reduced ($P < 0.05$) the cyanide content of the cassava peels (6.2 - 23.5 mg/kg), when compared with the unfermented cassava peels which had 44.6 mg/kg cyanide content. However, the cassava peels fermented with waste water from cassava pulp fermented with a mixture of *Saccharomyces cerevisee, Lactobacillus delbruckii* and *Lactobacillus coryneformis* had a significantly lower ($P < 0.05$) cyanide content (6.2 mg/kg) than those cassava peels fermented with waste water from the naturally fermented cassava pulp that had 23.5 mg/kg cyanide content.

The cyanide concentration in the cassava peels fermented with waste-water from fermented cassava pulp was low, when compared with the usual cyanide content of cassava products in Nigeria [19.0 mg/kg (gari), 25 mg/kg (fufu)], and that of the cyanide content of some micro-fungi fermented cassava products (9.1 - 17.2 mg/kg) (Oboh et al. 2002; Oboh and Akindahunsi, 2003). This shows that the microorganisms in the waste water were capable of partially degrading cyanogenic glucosides and the breakdown products (Tweyongyere and Katongole, 2002).

It is also evident from the results that waste-water from the inoculated cassava pulpwas very efficient in cyanide detoxification than that of naturally fermented cassava. The cassava peels fermented with waste-water from the inoculated cassava products could be considered safe in terms of cyanide poisoning in view of the fact that the cyanide was below the deleterious level of 30 mg/kg (Tweyongyere and Katongole, 2002).

There was a significant decrease ($P < 0.05$) in the phytate content of the fermented cassava peels (705.1 - 789.7 mg/100g). This decrease was more significant in cassava peels fermented with waste water from naturally fermented cassava pulp (705.13 mg/100g). The unfermented cassava peels had 1043.56 mg/100g phytate content (Table 3). The decrease in the phytate content of the fermented cassava peel could be attributed to possible secretion of the enzyme phytase by the microorganisms in the waste-water. This enzyme is capable of hydrolysing phytate thereby decreasing the phytate content of the fermented cassava peels. The variation in the level of decrease in the phytate content of the products by each waste water indicated that the enzyme activity varies with organism (Oboh et al. 2003). It would appear from the result that the phytase in wastewater from the naturally fermented cassava productshad the highest activity.

Table 3. Antinutrient composition of fermented cassava peel (dry weight).

Sample	Cyanide (mg/kg)	Phytate (mg/100g)
Inoculated fermented	$6.2^{a} \pm 0.3$	$789.7^{b} \pm 0.2$
Naturally fermented	$23.3^{b} \pm 0.2$	$705.1^{c} \pm 0.2$
Unfermented	$44.6^{a} \pm 0.2$	$1043.6^{a} \pm 0.1$

Values with the same alphabet along the same column are not significantly different ($P > 0.05$). Values are mean ± S.E (n = 3).

In view of the increase in protein content of the cassava peels fermented with waste-water from fermented cassava products (inoculated and natural) and the significant decrease ($P < 0.05$) in the antinutrients (residual cyanide and phytate), this by-product could be a good supplement in compounding animal feed provided that it is acceptable and highly digestible.

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