Journal of Microbiology, Biotechnology and Food Sciences

Bandna et al. 2012/13 : 2 (3) 947-958

REGULAR ARTICLE

EFFECT OF PROCESSING ON THE CYANIDE CONTENT OF CASSAVA PRODUCTS IN FIJI

Chand Bandna

Address: Ms (s) Bandna Chand, Fiji National University or University, College of Engineering, Science and Technology, Department of Food Sciences, 1 Ono Street, Samabula, Fiji.

Corresponding author: bandna.chand1@fnu.ac.fj

ABSTRACT

In Fiji cassava *(Manihot esculenta* Crantz, Euphorbiaceae) is one of the most important root crops. According to the 2004 National Nutrition Survey, 59.2% of the Fijian population consumes cassava on a daily basis while 31% of the Indian population consumes cassava on a weekly basis. Substantial quantity of anti-nutrient factor cyanogenic glucoside, linamarine and a small amount of lotaustralin is also present in cassava that interferes with digestion and uptake of nutrients. This study was aimed at finding out the cyanide content of cassava products available and consumed in Fiji

Cyanide content of twelve cassava based food items with cassava as the main ingredient was tested for the cyanide content using the pictrate method. The absorbance was measured in a spectrophotometer at 510 nm and the total cyanide content in mg HCN equivalents/kg fresh weight = ppm calculated by multiplying the absorbance by 396. The results were analyzed by SPSS by one way ANOVA and pair-wise comparison was made post hoc using Tukey t-tests.

The results showed that the cyanide content ranged from 2.21 to 44.14 mg HCN equivalent/kg. Grated cassava products exhibited lower cyanide content as compared with minimally processed cassava products and fried cassava products. Since cyanogenic glycosides are water soluble, a higher percentage of cyanides are removed when cassava products are processed in water. Fried cassava products had higher levels of cyanide as it is not soluble in lipids/oil, hence less cyanide is lost during frying.

Keywords: Cassava, *Manihot esculenta* Crantz, Fiji, cyanogenic glucoside, linamarine, pictrate method, processing

INTRODUCTION

In Fiji cassava *(Manihot esculenta* Crantz, Euphorbiaceae) is one of the most important root crops. 59.2% of the Fijian population consumes cassava on a daily basis while 31% of the Indian population consumes cassava on a weekly basis **(NFNC, 2007)**. It is relatively cheaper than other root crops such as taro and is especially utilized in urban households; it has a shorter period of maturity and it is easily available. Cassava roots are consumed in many forms. The most common method of preparation in Fiji is boiling, however, baked cassava is also consumed and is readily available at markets. Grated cassava products are also consumed and are readily available at markets. Recently, processed (fried) cassava chips and crisps manufactured locally were also introduced in our market and are widely consumed especially by children as a snack.

The roots contains 20-25% starch but has limited amounts of proteins, fats, vitamins and minerals. However, they have a huge deficit of essential amino acids namely methionine and cystine **(Heuberger, 2005)**. Substantial quantity of anti-nutrient factor cyanogenic glucoside, linamarine and a small amount of lotaustralin **(Burns *et al*., 2012; Kalenga Saka *et al*., 2012)** is also present in cassava that interferes with digestion and uptake of nutrients. Both compounds are hydrolyzed by plant's endogenous linamarase to release free cyanide **(Yeoh and Sun, 2001)**. Any process that ruptures the cell walls will bring the enzymes into contact with the glycosides and will thus release free cyanide and reduce the glycosides' content of the final product **(Heuberger, 2005)**.

Some of these processes used to reduce cyanide content in cassava products are the fermentation method **(Kobawila *et al*., 2005; Oboh *et al*., 2007)**; wetting method **(Cumbana *et al*., 2007; Bradbury *et al*., 2011).** These compounds are toxic to humans and can cause serious health problems. Cyanide content ranges from 10 to 500 mg HCN equivalents/kg DW **(Dufour, 1988)** in root parenchyma. Bitter varieties of cassava have a cyanide level exceeding the Food and Agriculture Organization/World Health Organization (1991) recommendation of 10 mg/kg DW, which makes cassava acutely toxic for humans **(Montagnac *et al*., 2008)**.

Consumption of 50 to 100 mg of cyanide has been associated with acute poisoning which is lethal to humans. Long term consumption of small amounts of cyanide can cause severe health problems such as tropical neuropathy, konzo **(Cardoso *et al*., 2005)**, and

fibrocalculous pancreatic diabetes (FCPD), also known as tropical calcific pancreatitis **(Mathangi *et al*., 2000)**, glucose intolerance and coupled with iodine deficiency goiter and cretinism also results. Cyanide toxicity is aggravated by low protein content of cassava and a deficiency of sulfur containing amino acids in the diet.

Apart from cyanide, cassava also contains other anti-nutrients such as phytates, oxalates, nitrate, fibre, saponins and polyphenols that can reduce nutrient bio-availability. However, some of these compounds can act as antioxidants and anti-carcinogens depending on the amounts consumed.

The objective of this study was to determine the cyanide content of cassava products available and consumed in Fiji and to find out if the products available in Fiji meet the standards set by Codex Alimentarius of 10mg cyanide per kg of cassava product.

MATERIAL AND METHODS

Materials

Food products containing cassava were purchased from supermarkets and markets in Suva, Fiji. The samples were divided into three groups based on the method of preparation: fried cassava products, grated cassava products and minimally processed cassava products. The fried cassava products consisted of chips and crisps; grated cassava products consisted of pie, cake, bread and porridge and minimally processed cassava products consisted of cassava flour, frozen cassava, boiled cassava and baked cassava. All samples were purchased in three different batches and each sample was analyzed in triplicates. All samples were blended using a blender and the blended samples were used. Frozen cassava roots were blotted dry with paper towel before weighing.

Methods

Cassava product samples were analyzed for total cyanogens using the picrate kit method (Bradbury *et al*., 1999; Bakayoko, et al., 2009).100mg of cassava products were taken in triplicates and added to small plastic bottles.A linamarase-impregnated paper and 0.5ml of water was added before the bottles were closed with a screw cap. The bottles were allowed to stand for 16-24 h at 30^{o}C, the picrate papers were removed from the plastic support and 5.0 mL of water added to elute the colour. The absorbance was measured using a

spectrophotometer at 510 nm and the total cyanide content in mg HCN equivalents/kg fresh weight = ppm. This was calculated by multiplying the absorbance by 396 (Bradbury *et al*., 1999); thus giveing an accurate total cyanide analysis down to a minimum of 1 ppm total cyanide (Haque & Bradbury, 2002; Bradbury, 2009). The cyanide present is primarily linamarin (Jorgensen *et al*., 2005). The assay used here measures both linamarin and acetone cyanohydrin, but the concentration of the latter is extremely small compared to linamarin. Any HCN released from acetone cyanohydrin is of relevance to human health, as it breaks down completely in the alkaline condition in the gut to give CN (Bradbury, 2009). The amount of lotaustralin and free cyanide (HCN and CN) is negligible (Jorgensen *et al*., 2005). Food was tested in the form that it is normally consumed, with cyanide expressed on a fresh weight (or 'as consumed') basis and free cyanide (HCN and CN) is negligible (Jorgensen *et al*. 2005).

Statistical Analysis

The data are given as means ± SD. The results were analyzed by multiple tests to identify significant differences among groups. P values <0.05 were considered significant. All analysis was performed using SPSS by one way ANOVA and pair-wise comparison was made *post hoc* using Tukey t-tests.

RESULTS AND DISCUSSION

The total cyanide content of traditionally prepared foods available in Fiji is shown in Table 1. These products are most commonly consumed on a regular basis especially by people of iTaukei origin. They are lower in cyanide content than the other products analyzed mainly due to the cooking method used as most products are cooked by boiling or steaming and some of the products have grated cassava as the main ingredient which further lowers the cyanide content.

Table 1 Total cyanide content (mg HCN equivalents/kg fresh wt = ppm) of traditional cassava products available in Fiji (2011)

Product	Processing method and the cyanide content of the products			
	Local Name	Processing method	Total Cyanide content ppm (average ± S.D)	Amount of cyanide per 100g serve (mg)
Cassava pie	*Tavioka yaca*	Grated, baked	6.73±4.23	0.67
Cassava cake	*Bila*	Grated, steamed	5.02±0.93	0.50
Cassava bread	*Madrai*	Grated, steamed	12.80±1.78	1.3
Cassava porridge	*Lote*	Grated, boiled	5.28±1.78	0.5
Boiled cassava	*Tavioka saqa*	Boiled	10.43±1.98	1.0
Baked cassava	*Tavioka vavi*	Baked	10.95±4.17	1.1
Cassava chips (Homemade)	-	Boiled, fried	8.13±4.30	0.8

Legend : *Data are mean values ± standard deviation (SD) of duplicate results; ppm = parts per million (1mg/kg = 1ppm).

The cyanide content of commercially prepared foods is shown in Table 2. These products have been introduced into the market in Fiji recently and are consumed as snacks. Most of these products contain more than the legal limit of 10mg HCN per kg of the cassava product.

Table 2 Total cyanide content (mg HCN equivalents/kg fresh wt = ppm) of processed cassava products available in Fiji (2011)

Product	Processing method and the cyanide content of the products			
	Local Name	Processing method	Total Cyanide content ppm (average ± S.D)	Amount of cyanide per 100g serve (mg)
Cassava chips 1	-	Fried	25.08±3.78	2.5
Cassava chips 2	-	Fried	17.16±10.45	1.7
Cassava crisps	-	Fried	37.02±5.59	3.7
Frozen cassava	-	Frozen	20.06±16.23	2.0
Cassava flour	*Yabia*	Dried	6.61±5.71	0.6

Legend : *Data are mean values ± standard deviation (SD) of duplicate results; ppm = parts per million (1mg/kg = 1ppm).

Grated Cassava Products

This group consists of products made with grated cassava such as cassava pie, cake, bread and porridge. Cassava pie and cake are products that are readily available from markets throughout Fiji and are normally consumed by people of iTaukei origin. Bread is normally prepared at home and is consumed by people of all age groups. Cassava porridge is prepared by people of iTaukei origin normally for infants and small children as a weaning food.

The cyanide content of these products ranged from 5.02±0.93 to 12.80±1.78ppm Total cyanide as shown in Figure 1.0. These products are normally consumed for breakfast in iTaukei households and in a meal a person would consume 100-200g of the cooked product. This shows that the amount of cyanide consumed per meal would range from 0.5mg to 2.6mg. Thus lethal dose of cyanide will not be consumed by consuming grated cassava products in a meal.

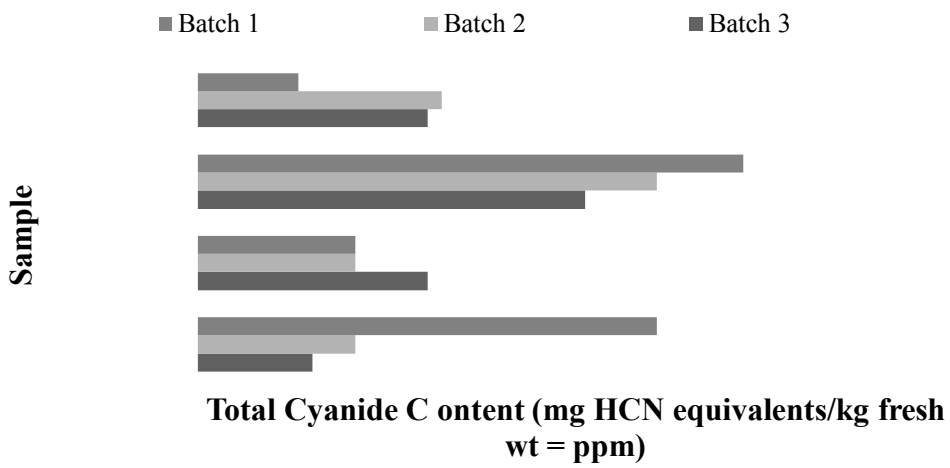

Figure 1 Total cyanide (mg HCN equivalents/kg fresh wt=ppm) content of grated cassava products

Grated cassava products contained the lowest amount of cyanide. A reason for this low cyanide content may be due to high loss of cyanide glucoside when tissue is crushed. Pounding, crushing or grating ruptures cell compartments, which allows direct contact between linamarin and the enzyme linamarase ultimately catalyzing the hydrolytic breakdown. Acetone cyanohydrin decomposes into cyanide and acetone spontaneously above pH 4 and temperatures above 30°C (Montagnac *et al*., 2008) as the average temperature at daytime during the warm months is 31°C (Fiji Meteorological Service). Thus free cyanide is removed from damaged cassava tissue due to extraction with water or volatilization into the atmosphere (Montagnac *et al*., 2008) as most of these grated cassava products are then either boiled or steamed.

Fried Cassava Products

This group consists of chips and crisps made from cassava and available in packaged form. This was compared with cassava chips sold from fast food outlets. These products are normally consumed as a snack by people of all age groups. The cyanide content of these products ranged from 8.13±4.30 to 37.02±5.59ppm Total Cyanide as shown in Figure 2.0. This is not alarming even for children who are within the 10-20kg range as these products are only available in smaller packet sizes (25g, 45g and 150g). This means that a 25g cassava crisps will have less than 1mg of cyanide while a 150g packet of chips will contain 1.7mg to

5.55mg cyanide. Thus lethal dose of cyanide will not be consumed by consuming fried cassava products in Fiji (Burns *et al*., 2012).

One way ANOVA revealed that there was significant differences in the cyanide content in samples with this group as the $P<0.05$. Turkeys test further revealed that there was significant difference in cyanide content of homemade chips and crisps while the differences in cyanide content between the chips and crisps samples were not significant. This difference may be attributed to the boiling of homemade chips prior to frying which leads to the leaching of cyanide in the cooking water (Cereda *et al*., 1996). Other fried products contained more cyanide as cyanide is not soluble in oil/fats hence no leaching of cyanide takes place from fried products.

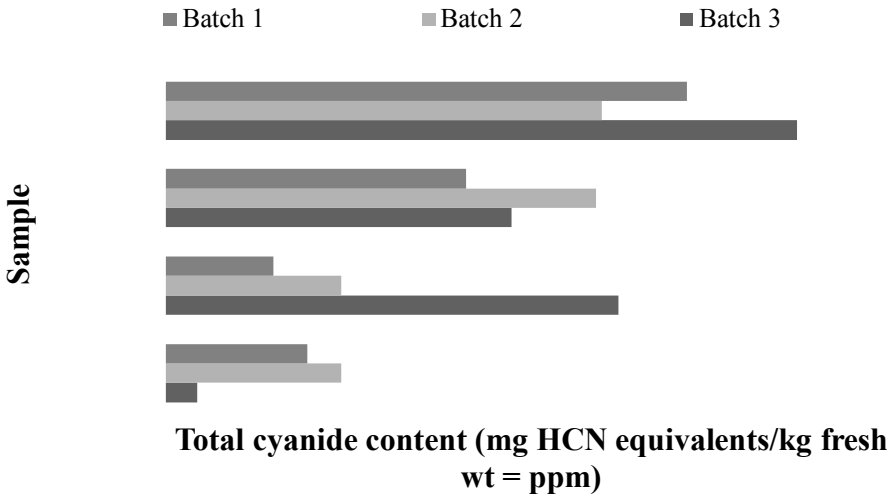

Figure 2 Total cyanide (mg HCN equivalents/kg fresh wt=ppm) content of fried cassava products

Generally, there is minimal loss of cyanide from fried cassava products as they are processed at higher temperatures of more than 100°C. Linamarin is also stable at neutral or weakly acidic conditions (Montagnac *et al*., 2008). However, due to the availability of sweet varieties of cassava in Fiji that normally have up to 50mg HCN per kg of cassava (FSANZ, 2004), the amount of cyanide in fried cassava products is low especially when the amount of cyanide is calculated per serve of the product.

Minimally Processed Cassava Product

This group of products consists of boiled cassava which is the most common method of cooking cassava; baked in an earth oven or '*lovo*' cassava which is normally prepared during feasts and is available for sale from markets. Also included in this group were frozen cassava which is now available in some supermarkets and cassava flour that is normally used for the preparation of desserts.

The cyanide content of these products ranged from 6.61±5.71 to 20.06±16.23ppm Total cyanide as shown in Figure 3.0. Boiled and baked cassava is consumed as a staple food item in iTaukei households. This may be consumed in all three meals in a day depending on the availability of other staple food items. In a typical meal an adult would consume 100-200g of the cooked product. This shows that the amount of cyanide consumed per meal would range from 1.04g to 2.18mg. Thus lethal dose of cyanide will not be consumed by consuming grated cassava products in a meal.

The amount of cyanide in cassava flour ranged from 2.37 to 14.69mg. According to the benchmark set in this study, all the flour samples were not below the limit. This indicates that there is efficiency in the method that is used for drying of cassava into flour rendering it safe for consumption. Since the cassava flours are not manufactured in Fiji, there is a possibility that it is made from only the pulp and not the peels of cassava as the amount of cyanide in low (Kalenga Saka *et al*., 2012). Only one batch had cyanide levels above the FAO/WHO limit of 10mg HCN/kg of DW. Study by Charles *et al.*, (2005) showed that the different genotypes of cassava flours had cyanide content ranging from 8.88 to 28.8mg per kg dry weight.

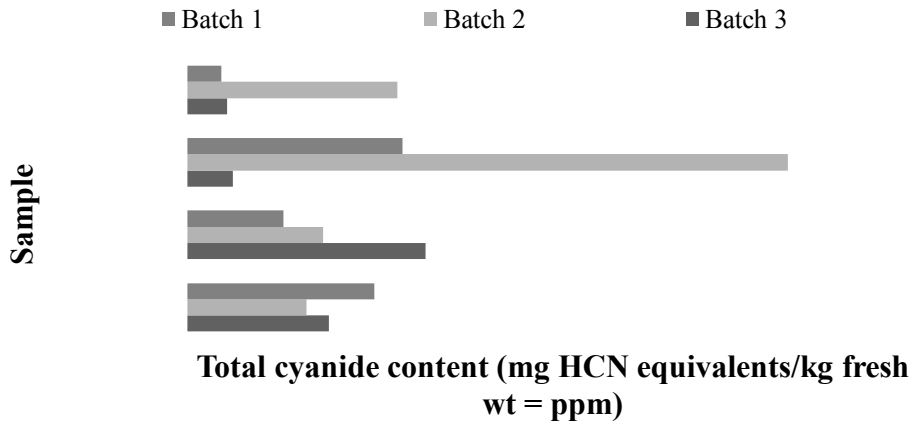

Figure 3 Total cyanide (mg HCN equivalents/kg fresh wt=ppm) content of minimally processed cassava products

CONCLUSION

This study revealed that fried cassava products have higher levels of cyanide (>10mg of cyanide per kg of product) in them than grated cassava products or boiled/ baked cassava flour. This is related to the high solubility of cyanide in water as there is higher loss of cyanide in products cooked in water. 58% of the samples had higher cyanide levels than the levels accepted by Codex Alimentarious. However, the levels in the products are not high enough when compared with the amount of cassava product consumed in a meal. Hence, the processed cassava products available in Fiji are safe for consumption in regards to cyanide toxicity.

Acknowledgments: I gratefully acknowledge Dr. J. H. Bradbury for his support of my work on cassava products. I would also like to thank Fiji National University for funding this research.

REFERENCES

BAKAYOKO, S. - SORO, D. - NINDJIN, C. - DAO, D. - TSCHANNEN, A. - GIRARDIN, O. - ASSA, A. 2009. Evaluation of cyanogenic potential and organoleptic properties in cassava *(Manihot esculenta* Crantz. roots of improved varieties in Côte d'Ivoire. In *African Journal of Food Science*, vol.3, 2009, p. 328-333.

BRADBURY, J. H. - CLIFF, J. - DENTON, I. C. 2011. Uptake of wetting method in Africa to reduce cyanide poisoning and konzo from cassava. In *Food and Chemical Toxicology,* vol.49, 2011, p.539-542.

BRADBURY, J. H. 2009. Development of a sensitive picrate method to determine total cyanide and acetone cyanohydrin contents of gari from cassava. In *Food Chemistry*, vol. 113, 2009, p. 1329-1333.

BRADBURY, M. G. - EGAN, S. V. - BRADBURY, J. H. 1999. Picrate paper kits for determination of total cyanogens in cassava roots and all forms of cyanogens in cassava products. In *Journal of the Science of Food and Agriculture*, vol. 79, 1999, p. 593-601.

BURNS, A. E. - BRADBURY, J. H. - CAVAGNARO, T. R. - GLEADOW, R. M. 2012. Total cyanide content of cassava food products in Australia. In *Journal of Food Composition and Analysis,* vol. 25, 2012, p. 79-82.

CARDOSO, P. - MIRIONE, E. - ERNESTO, M. - MASSAZA, F. - CLIFF, J. - HAQUE, M.R. - BRADBURY, J. H. 2005. Processing of cassava roots to remove cyanogens. In *Journal of Food Composition and Analysis*, vol. 18, 2005, p. 451–460.

CEREDA, M. P. – MATTOS. M.C.Y. 1996. Linamarin - the toxic compound of cassava. *In Journal of Venomous Animals and Toxins*, vol. 2, 2005, p. 6-12.

CHARLES, A. L. - SRIROTH, K. - HUANG, T. 2005. Proximate composition, mineral contents, hydrogen cyanide and phytic acid of 5 cassava genotypes. In *Food Chemistry*, vol. 92, 2005, p. 615-620.

CUMBANA, A. - MIRIONE, E. - CLIFF, J. - BRADBURY, J. H. 2007. Reduction of cyanide content of cassava flour in Mozambique by the wetting method. In *Food Chemistry*, vol. 101, 2007, p. 894–897.

DUFOUR, D. L. 1988. Cyanide content of cassava (Manihot esculenta Euphorbiaceae) cultivars used by Tukanoan indians in northwest Amazonia. In *Economic Botany*, vol. 42, 1988, p. 255-266.

Fiji Meterology Service. 2012. The climate of Fiji. [cit. 2012-11-22]. Available on internet: http://www.met.gov.fj/climate_fiji.html

FSANZ. 2004. cyanogenic glycosides in cassava and bamboo shoots: A Human Health Risk Assessment, http://bambusy.pl/bambusy/28_Cyanogenic_glycosides_bamboo.pdf

HAQUE, M. R. - BRADBURY, J. H. 2002. Total cyanide determination of plants and foods using the picrate and acid hydrolysis methods. In *Food Chemistry*, vol. 77, 2002, p. 107–114.

HEUBERGER, C. 2005. Cyanide Content of Cassava and Fermented Products with Focus on Attiéké and Attiéké Garba. (A dissertation submitted to the Swiss Federal Institute Of Technology Zurich).

HIDAYAT, A. - ZUARAIDA, N. - HANARIDA, I. - DAMARDJATI, D. S. 2000. Cyanogenic Content of Cassava Root of 179 Cultivars Grown in Indonesia. In *Journal Of Food Composition And Analysis*, vol. 13, 2000, p.71-82.

JORGENSEN, K. - BAK, S. - BUSK, P. K. - SORENSEN, C. - OLSEN, C. E. -PUONTI-KAERLAS, J. – MOLLER, B. L. 2005. Cassava Plants with a Depleted Cyanogenic Glucoside Content in Leaves and Tubers. Distribution of Cyanogenic Glucosides, Their Site of Synthesis and Transport, and Blockage of the Biosynthesis by RNA Interference Technology. In *Plant Physiology*, vol. 139, 2005, p. 363-374.

KALENGA SAKA, J. D. - NYIRENDA, K. K. 2012. Effect of two Ethnic Processing Technologies on Reduction and Composition of total and non-glucosidic Cyanogens in Cassava. In *Food Chemistry*, vol. 130, 2012, p 605-609.

KOBAWILA, S. C. - LOUEMBE, D. - KELEKE, S. - HOUNHOUIGAN, J. - GAMBA , C. 2005. Reduction of the cyanide content during fermentation of cassava roots and leaves to produce bikedi and ntoba mbodi, two food products from Congo. In *African Journal of Biotechnology*, vol. 4, 2005, p. 689-696.

MATHANGI, D. C. - DEEPA, R. - MOHAN, V. - GOVINDARAJAN, M. - NAMASIVAYAM, A. 2000. Long term ingestion of cassava (tapioca) does not produce diabetes or pancreatitis in rat model. In *International Journal of Pancreatology*, vol. 27, 2000, p. 203-208.

MONTAGNAC, J. A. - DAVIS, C. R. - TANUMIHARDJO, S. A. 2008. Processing Techniques to Reduce Toxicity and Antinutrients of Cassava for Use as a Staple Food. In *Comprehensive Reviews in Food Science and Food Safety*, vol. 8, 2008, p. 17-27.

NFNC – National Food and Nutrition Science. 2007. 2004 Fiji National Nutrition Survey Main Report, p. 130-134. [cit. 2012-11-22]. Available on internet: http://www.nutrition.gov.fj/pdf/reports/2004%20NATIONAL%20NUTRITION%20SURVEY.pdf

OBOH, G. - ELUSIYAN, C. A. 2007. Changes in the nutrient and anti-nutrient content of micro-fungi fermented cassava flour produced from low- and medium-cyanide variety of cassava tubers. In *African Journal of Biotechnology*, vol. 6, 2007, p. 2150-2157.

YEOH, H. H. - SUN. F. 2001. Assessing cyanogens content in cassava based food using the enzyme-dipstick method. In *Food and Chemical Toxicology*, vol. 39, 2001, p 649-653.