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Cyanide content and sensory quality of Cassava (*Manihot esculenta* Crantz) root tuber flour as affected by processing

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The effects of processing schemes (boiling–chipping–steeping, CFC; mashing–steeping–dewatering, CFM; sun-drying; oven-drying) on the cyanide content and sensory quality of cassava root tuber flour were studied. Hot-water reconstitutes of CFC, CFM and semolina (SLN) were sensorily assessed for preference or acceptance. Cyanide reduction was 81.5% for CFC and 84.2% for CFM. Even at the predrying stages, CFM effected relatively more cyanide reduction. However, consumers preferred CFC, which was statistically of equivalent general acceptability to SLN ($P \leqslant 0.01$). Significant differences were found in texture ($P \leqslant 0.10$), colour, aroma and taste ($P \geq 0.005$) of the samples. Sun-drying effected higher reduction in cyanide and retention of a stable whitish colour compared with oven-drying, which imparted a yellower coloration.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) root tubers constitute a cheap food carbohydrate source. Up to 60% of all cassava tubers produced are used as a basic food. The root is consumed in all tropical countries (Cooke & Cock, 1989).

The problems of inherent nutritional hazard (fresh roots contain 50–400 mg cyanide kg^{-1} root) and high perishability of the roots call for elaborate processing prior to consumption (Akinrele, 1964; Ketiku *et al.*, 1978; Hahn & Keyser, 1985; Hahn, 1989; Cooke & Cock, 1989), thereby improving storability, handling convenience, palatability and nutritional safety.

Dry cassava flour is one of the forms in which processed tubers can have guaranteed longevity. Reconstituted cassava flour products, *fufu* (stiff paste or sticky dough-like mass), undergo colour, odour and storage changes, and several attempts have been made to produce cassava flour products with a pleasant aroma, longer shelf-life and acceptable texture (Numfor, 1983; Okpokiri *et al.*, 1984; Kanu, 1986).

Traditional fermentation employs varying fermentation periods and additives to eliminate odour. However, there is little information on flour production with simultaneous assessment of prussic acid or on the extent of consumer acceptance.

This paper summarizes the effects of processing schemes on cyanide content and sensory quality of cassava tuber flour.

MATERIALS AND METHODS

Fresh cassava (*Manihot esculenta* Crantz) root tubers, obtained from the Agricultural Research Farm, Federal University of Technology Owerri (FUTO), Nigeria, were processed within 3 h of harvest. Semolina (reference sample, SLN) was procured from a local retail shop. All chemicals used for proximate and cyanide analyses were AnalaR (BDH Chemicals, Poole, UK) and ACS Reagent (Sigma Chemicals, St. Louis, MO, USA) grades.

CFC: a batch (50.0 kg) of peeled cassava chunks was boiled (30–100°C, 35 min), sliced into chips (0.25 cm average thickness) and steeped in water (29 ± 2°C, 48 h with a 12-hourly change of steep liquor); the spent liquor was decanted, the chips dried (sun-drying, 72 h; or oven-drying, 50°C, $\leqslant 24$ h), sieved ($\leqslant 425$ μm) and packed for further use and analyses.

CFM: a second batch of peeled cassava chunks was steeped in water (29 ± 2°C, 24 h), grated and the mash left to stand/ferment for 48 h (29 ± 2°C); it was then dewatered, wet-sieved while suspended in fresh water, separated, dried and finished off as for CFC.

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Moisture, ash, crude fat, crude fibre and total nitrogen contents were analysed (Association of Official Analytical Chemists, 1975). Protein content was determined for cassava flour (total N×6.25) and semolina (total N×5.70). Cyanide determination was carried out according to the iodine titration procedure (Knowles & Watkin, 1950).

An acceptance/preference test of CFC and CFM, as compared with SLN, was conducted by a panel of 20 judges drawn randomly from the FUTO community, on a nine-point hedonic scale (Watts *et al.*, 1989), for colour, texture, aroma, taste and general acceptance. Univariate analysis (Hayslett, 1974) was carried out on the overall mean scores of the samples (SOMs). Fisher's multiple comparison tests (Roessler, 1984) were used to determine which SOMs differed significantly from others. A two-way analysis of variance (ANOVA) procedure (Miller & Freund, 1977) was used to determine the extent of significance in the mean hedonic scores for each sensory attribute.

RESULTS AND DISCUSSION

The processing method adopted for the CFM showed slight deviation from conventional/traditional straight fermentation, and was a modification of the procedure for instant cassava *fufu* flour as described by Okpokiri *et al.* (1984). This was a deliberate attempt to deviate from the pattern which experience has shown reduces prussic acid (Akinrele, 1964; Oyakhilome, 1982) but frequently imparts a bland taste and sticky texture to the reconstituted products.

The approaches adopted in the two processes resulted in varied conversion/extraction rates: CFC gave 957.0 g flour kg^{-1} root, while CFM gave 651.5 g flour kg^{-1} root (dry matter basis). The lower conversion rate for CFM could be due to the multiple hydroimmersion operations coupled with lengthy residence times at these stages, causing leaching of solutes (native starch, etc.) and resulting in reduction of the overall dry matter since most cassava starch granules are < 20 μm in diameter (Meuser *et al.*, 1978).

Table 1. Proximate composition[a] of cassava products and reference sample

Parameter (% DM)	Test sample		Reference
	CFC	CFM	SLN
Moisture	11.36	14.29	15.74
Ash	0.18	0.16	0.83
Crude fibre	3.12	2.74	0.38
Crude protein	1.00	1.26	11.4
Crude fat	0.71	0.80	1.74
Carbohydrate[a]	84.8	82.6	70.6

[a] Values are means of duplicate determinations (dry matter, DM, basis).
[b] By difference.

Proximate analyses (Table 1) indicate that drying the chips gave reduced moisture, more fibre and relatively higher carbohydrate content. This could be a result of hydrothermal fixing of the tuber constituents prior to drying and milling. The relative increase in protein of CFM was possibly due to an increase in total nitrogen effected by the fermentation process during the second steeping in the CFM process. Semolina (SLN) had the highest protein and fat contents (in comparison to CFC and CFM). This was expected, as cereal grains are better sources for such nutrients than cassava root.

Table 2 shows the effect of processing on cyanide content of cassava. Total percentage cyanide reduction was 81.5% in CFC and 84.2% in CFM. Prior to drying, grating/mashing–steeping–dewatering for CFM effected 80.3% cyanide reduction, while drying resulted in an additional 3.94% reduction. On the other hand, boiling–chipping–steeping for CFC caused 71.0% cyanide reduction prior to drying; drying alone increased the reduction by 10.4%. The greater reduction of cyanide in the mash (CFM) must be due to grating of the tubers, which increased the surface area, thus favouring the detoxification activity of linamarase which would

Table 2. Effect of processing on colour, cyanide and moisture contents of cassava products

Parameter	Processing conditions/stages					
	Predrying[a]		Sun-drying[b]		Oven-drying[b]	
	Chips[c]	Mash[d]	Chips[e]	Mash[f]	Chips[e]	Mash[f]
Moisture (% DM)[g]	—	—	11.36	14.29	9.77	11.73
Cyanide (ppm)	25.0	17.0	16.0	13.6	20.2	15.6
Colour (visual)	White	White	Cream white	White	Light yellow	Light yellow

[a] Fresh (raw) tubers/chunks contained 86.3 ppm cyanide and 72.60% moisture (wet basis).
[b] Sun-drying was done for up to 72 h (31–40°C), oven-drying was done for ≤24 h (50–80°C), prevailing relative humidity = 70–76%.
[c] Chips—boiled for 35 min (≥100°C), steeped for 48 h.
[d] Mash—steeped for 24 h (28°C), grated, steeped for 48 h and dewatered.
[e] Cassava flour from chips production (CFC).
[f] Cassava flour from mash production (CFM).
[g] Equivalent to g H_20 per 100 g dry matter (DM).
Values are means of two determinations.

Table 3. Product means and two-factor ANOVA for taste panel sensory attributes of two cassava flours and semolina products

Attributes	Products[a]			Sources of variation[b]		
	CFC	CFM	SLN	Panellist (19)	Product (2)	Error (38)
Colour***	7.10 ± 1.45^{a}	5.50 ± 1.16^{b}	6.45 ± 0.97^{ab}	2.59^{y}	12.12^{z}	1.06
Texture*	6.60 ± 0.92^{a}	7.35 ± 1.07^{bc}	7.05 ± 1.20^{ac}	1.17^{NS}	3.22^{w}	1.22
Aroma***	6.10 ± 0.91^{ac}	5.75 ± 1.18^{bc}	6.85 ± 0.88^{a}	1.48^{x}	6.32^{z}	0.79
Taste***	5.40 ± 0.92^{a}	5.65 ± 0.85^{c}	6.70 ± 1.10^{a}	0.70^{NS}	9.52^{z}	1.01
General acceptance**	6.45 ± 0.92^{a}	5.60 ± 1.11^{b}	6.55 ± 1.07^{a}	1.56^{w}	5.45^{y}	0.92

[a] CFC, CFM, cassava flours from chips and mash, respectively; SLN, semolina. ^{abc}Means within a row with different superscripts differ significantly: $^{*}P = 0.1$, $^{**}P = 0.01$, $^{***}P = 0.005$.

[b] Values are mean squares of the variables. (Figures in parentheses are degrees of freedom.) F-value (2,38) = 6.07 (at 0.5%), 5.18 (at 1%), 2.44 (at 10%); F-value (19,38) = 2.37 (at 1%), 1.84 (at 5%), 1.61 (at 10%). ^{wxyz}Significant at 10, 5, 1 and 0.5% levels of confidence, respectively; ^{NS}not significant.

otherwise be localized in intact cells, and dewatering which expels hydrolysed toxic moieties. This inference accords with the reports by Numfor (1983) and Vasconcelos *et al.* (1990) that grating enhances contact between linamarin, lotaustralin and linamarase. Elsewhere, it was reported that 70–85% cyanide reductions were obtained when cassava roots were soaked for 3 days (Hahn, 1989). Oke (1984) had earlier reported that soaking cassava is an efficient method for reducing the cyanide content.

Paper chromatographic analysis of freshly produced 'gari' (toasted cassava mash) showed that it contained 25 ppm HCN (Wood, 1966). In a later study using a thin-layer chromatographic procedure (Bisset *et al.*, 1969) as modified (i.e. coupling colorimetry) by Izokun-Etiobhio *et al.* (1987), extracts of 'gari' and 'akpu' (steeped/fermented cassava flour) were found to contain 3.60 and 2.46 ppm HCN, respectively. These results indicate a marked reduction in cyanide content of the cassava product (more than in the present study). Differences, however, exist in both the processing of root tubers with preprocessing history, and the analytical procedure for cyanide.

Results in Table 2 also show that residual cyanide was greater in oven-dried products than in the sun-dried products. The relatively higher temperature involved in oven-drying (50–80°C) was reported to be responsible for the consequent increased cyanide retention (Nambisan & Sundaresan, 1985). Lower cyanide was observed in the mash, especially with the sun-dried material. The reasons are that larger surface areas were created for reactivity and a longer period was involved at the temperature that favours the activity of endogenous linamarase. These findings are consistent with the report by Cooke & Maduagwu (1978).

Oven-drying imparted a slight yellowish colour to the products, in contrast to sun-drying, which did not effectively alter the whiteness. The colour change during oven-drying is believed to be a result of caramelization of sugar produced during the predrying processes.

Two-factor ANOVA for taste panel evaluation of the cassava flour and semolina products is shown in Table 3. The CFC product attributes scored consistently higher than those of CFM, except on taste in which the two were significantly equal but different from SLN. The texture score for CFM (7.35) was significantly higher than that for CFC (6.60). This was due to the smoothness and uniformity of the products: 68.6% of the CFM consisted of 180 μm particles, followed by SLN (7.05) with 81.9% of the flour being 300 μm in size, while 45.8% of CFC was 300 μm and 36.2% was 180 μm. The results showed significant differences among the products for texture ($P \leqslant 0.10$), general acceptance ($P \leqslant 0.01$), colour, aroma and taste ($P \geq 0.005$), indicating various sensitivities to quality attributes of the products. However, the overall mean hedonic scores showed that consumers accepted CFC (6.33) more than CFM (5.97), but the difference was not significant (Table 3).

This study has shown that, as an alternative to the traditional cassava root fermentation process, the roots can be processed into flour via boiling, chipping, steeping, sun-drying and milling to give flour which is (1) safe from cyanide intoxication (< 50 mg HCN kg^{-1} root is quite safe), and (2) organoleptically satisfying, equivalent to semolina (wheat flour product).

REFERENCES

Akinrele, I. A. (1964). Fermentation of cassava. *J. Sci. Food Agric.*, **1510**, 589–594.

Association of Official Analytical Chemists (1975). *Official Methods of Analysis*, 12th edn. Association of Official Analytical Chemists (AOAC), Washington, DC.

Bisset, F. H., Clapp, R. G., Coburn, R. A., Ettlinger, M. G. & Long, L. (1969). Cyanogenesis in manioc: concerning lotaustralin. *Phytochemistry*, **8**, 2235–2247.

Cooke, R. & Cock, J. (1989). Cassava crops up again. *New Sci.*, 17 June, 63–68.

Cooke, R. & Maduagwu, E. N. (1978). The effect of simple processing on the cyanide content of cassava chips. *J. Food Technol.*, **13**, 299–306.

Hahn, S. K. (1989). An overview of African traditional cassava processing and utilization. *Outlook Agric.*, **183**, 110–118.

Hahn, S. K. & Keyser, J. (1985). Cassava: a basic food for Africa. *Outlook Agric.*, **142**, 95–99.

Hayslett, H. T. (1974). One-way analysis of variance. In *Statistics Made Simple*. W. H. Allen, London, pp. 196–212.

Izokun-Etiobhio, B. O., Oraedu, A. C. I. & Ugochukwu, E. N. (1987). A simple procedure for the qualification of intact linamarin in cassava and its products. *J. Sci. Food Agric.*, **41**, 81–86.

Kanu, C. M. (1986). Production of instant cassava *fufu* flour with acceptable odour. Unpublished B.Sc. Tech. report, Federal University of Technology, Owerri, Nigeria.

Ketiku, A. O., Akinyele, O. I., Keshinro, O. O. & Aninawo, O. O. (1978). Changes in hydrocyanic acid concentration during traditional processing of cassava into *gari* and *lafun*. *Food Chem.*, **3**, 221–228.

Knowles, F. & Watkin, J. (1950). *A Practical Agricultural Chemistry*. Longman, London, p. 109.

Meuser, F., Smolnik, H. D., Rajani, C. H. & Giesemann, H. G. (1978). Comparison of starch extraction from tapioca chips, pellets and roots. *Starch/Starke*, **309**, 299–306.

Miller, I. & Freund, J. E. (1977). Analysis of variance. In *Probability and Statistics for Engineers*, 2nd edn. Prentice-Hall, Englewood Cliffs, NJ, pp. 331–374.

Nambisan, B. & Sundaresan, S. (1985). Effect of processing on the cyanoglucoside content of cassava. *J. Food Technol.*, **201**, 45–48.

Numfor, F. A. (1983). An improved technique of processing cassava *fufu*. In *Proceedings 2nd Triennial Symposium of the International Society for Tropical Root Crops on Tropical Root Crops Production and Uses*, Douala, Cameroon, pp. 111–113.

Oke, O. L. (1984). Processing and detoxification of cassava. In *Proceedings 6th Symposium of the International Society for Tropical Root Crops*, International Potato Center (CIP), Lima, Peru, 21–26 February 1983, pp. 329–336.

Okpokiri, A. O., Ijoma, B. C., Alozie, S. O. & Ejifor, A. N. (1984). Production of improved cassava *fufu*. *Niger. Food J.*, **2**, 145–148.

Oyakhilome, A. S. O. (1982). Cassava processing in Nigeria. Paper presented at the 12th Annual Seminar of Bendel College of Agriculture, Asaba, Nigeria.

Roessler, E. B. (1984). Statistical evaluation of experimental data: multiple comparison. In *Food Analysis: Principles and Techniques*, eds D. W. Gruenwedel & J. R. Whitaker. Marcel Dekker, New York, pp. 12–13.

Vasconcelos, A. T., Twiddy, D. R., Westby, A. & Reilly, P. J. A. (1990). Detoxification of cassava during *gari* preparation. *Int. J. Food Sci. Technol.*, **25**, 198–203.

Watts, B. M., Ylimaki, G. L., Jeffery, L. E. & Elias, L. G. (1989). Hedonic tests. In *Basic Sensory Methods for Food Evaluation*. International Development Research Center (IDRC), Ottawa, Canada, pp. 66–71.

Wood, T. (1966). The isolation, properties, and enzymic breakdown of linamarin from cassava. *J. Sci. Food Agric.*, **17**, 85–90.