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cassava toxicity and thyroid: research and public health issues

proceedings of a workshop held in Ottawa, Canada, 31 May – 2 June 1982

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Proceedings of a workshop held in Ottawa, Canada, 31 May - 2 June 1982

Editors: F. Delange[1] and R. Ahluwalia[2]

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Résumé

Cette publication est un résumé des actes d'un atelier qui a porté sur les relations entre la consommation de manioc et les troubles thyroïdiens chez l'homme. L'atelier a rassemblé des spécialistes de la médecine, de l'agriculture et de l'hygiène publique pour (1) examiner les résultats des études subventionnées par le CRDI sur le rôle du manioc dans l'étiologie du goitre endémique et du crétinisme ; (2) passer en revue les travaux de recherche sur les aspects du manioc intéressant l'agriculture ; (3) échanger des informations sur la méthodologie et les résultats d'études dans des domaines connexes ; et (4) définir les priorités de recherche et faire des recommandations touchant les programmes d'hygiène publique. La poursuite des travaux de recherche dans ces domaines contribuera grandement à prévenir et à contrôler le goitre endémique qui, par les anomalies de développement dont il est la cause constitue toujours un grand danger pour les populations des pays en développement.

Resumen

Esta publicación informa sobre las exposiciones presentadas en un seminario dedicado a la relación entre el consumo de yuca y el problema de la tiroides en los humanos. El seminario reunió científicos de los sectores médico, agrícola y de salud pública con el objeto de (1) reseñar los resultados de los estudios financiados por el CIID sobre el papel de la yuca en la etiología del bocio endémico y el cretinismo, (2) reseñar las actividades investigativas sobre aspectos agrícolas de la yuca, (3) intercambiar información sobre metodologías y hallazgos de otros estudios relacionados, y (4) identificar prioridades específicas para la investigación y hacer recomendaciones para los programas de salud pública. Los esfuerzos continuos en estas áreas de la investigación se dezicarán en buena parte a prevenir y controlar el bocio endémico y sus anormalidades acompañantes en el desarrollo, las cuales siguen constituyendo un problema serio de salud pública entre las poblaciones del mundo en desarrollo.

Contents

Cassava, Cyanide, and Animal Nutrition

Guillermo Gomez[1]

Cassava is the principal root crop and a major calorie staple in the rural lowland tropics. Cassava roots are peeled and used for human consumption either as a fresh vegetable or in the form of processed products. In some tropical regions, cassava leaves are also consumed as human food or animal feed. Whole cassava roots are often used in either fresh or processed form (dried, ensiled) as animal feed (Gomez 1979).

Cassava varieties, or cultivars, are classified as "sweet" or "bitter" according to the low- or high-cyanide content of their roots; however, the cyanide concentrations in the roots exhibit a wide range of values among the different varieties studied (Joachim and Pandittesekere 1944; de Bruijn 1973; Muthuswamy et al. 1973; Cooke et al. 1978b; Gomez et al. 1980). In addition to varietal differences, the cyanide content in cassava tissues appears to be affected by several factors such as the age of the plant and the part of the plant, as well as by environmental factors such as soil and temperature conditions (Bolhuis 1954; de Bruijn 1973).

The cyanide in cassava roots and tissues is mainly found in a bound form as a cyanogenic glucoside (linamarin), which accounts for approximately 90% of the total cyanide content (Nartey 1978); the remainder being present as free cyanide. Processing of cassava roots leads to the rapid conversion of bound cyanide to free cyanide, which is then released. The cyanide content of the processed products, therefore, is considerably lower than that of the fresh roots.

The purpose of this paper is to briefly review some of the factors, such as variety and age of plants, that affect the cyanide content in the roots, the effects of drying whole-root chips on cyanide elimination, and the results of animal-feeding trials using cassava meals produced from roots of low- or high-cyanide content varieties.

[1]Centro Internacional de Agricultura Tropical, Cali, Colombia.

Effect of Variety and Age of Plants on the Cyanide Content in Cassava Roots

Cassava varieties grown under practically identical edaphoclimatic conditions differ, at a given age, in the cyanide content of their root tissues (Gomez et al. 1980). One-year-old plants of variety MCol 1684 produced roots with the highest cyanide concentration (825 mg/kg, dry-matter basis) in the parenchymal tissue or pulp; the roots of nine other varieties studied contained cyanide levels ranging from 49–221 mg/kg (Table 1). With the exception of variety CM 305-38, the local varieties exhibited the lowest cyanide concentrations in the root parenchyma.

The root cortex, or peel, contains higher cyanide concentrations than the parenchyma (Table 1). For the 10 varieties studied, the total cyanide levels in the root cortex ranged from 2–48 times the levels found in the root parenchyma. Varieties such as MCol 22, Llanera, and CM 305-38, having relatively low cyanide con-

Table 1. Total cyanide content (mg/kg, dry-matter basis) in root tissues (parenchyma and cortex) of 10 cassava varieties (harvested at 12 months).

Variety	Total cyanide		Total cyanide content ratio (peel/ parenchyma)
	Parenchyma	Peel	
Llanera (local)	73	3210	44
Valluna (local)	52	407	8
MCol 22	88	4229	48
MVen 218	120	2987	25
MCol 1684	825	1450	2
CM 305-38	49	1962	40
CM 321-188	147	3879	26
CM 323-375	221	2876	13
CM 326-407	100	2373	24
CM 342-55	106	1942	18

Source: Gomez et al. (1980).

tents in the parenchyma (49–88 mg/kg), had cyanide levels in the root cortex ranging from 1962–4229 mg/kg. In both the root cortex and parenchymal tissues, the proportion of free cyanide ranged from 5–17% (Gomez et al. 1980) of the total cyanide content, confirming that most of the cyanide occurs as cyanogenic glucoside (Nartey 1978).

Recent studies on the effect of plant age (9–12 months) on the cyanide content of roots indicate that the cyanide concentration in the parenchyma appears to be the most stable parameter and is almost unaffected by plant age. A comparison of results from two varieties, one high- and one low-cyanide content cultivar, showed that the cyanide content of the root parenchyma of variety CMC-84 was approximately three times that of variety CMC-40 (623 ± 25 vs 234 ± 10 mg/kg, dry-matter basis) (CIAT 1981) throughout the period from the 9th to the 12th month of age of the plants. Plant age affected the cyanide concentration in the root cortex of both varieties, decreasing progressively from the 9th to the 12th month of age, with the decline being more pronounced in the roots of variety CMC-40. Variety CMC-40, considered a low-cyanide content cultivar, had very high levels of cyanide in the root cortex (~5000 mg/kg), notably in the roots of 9-month-old plants.

The cyanide levels in fresh chips decreased progressively from the 9th to the 12th month of age of plants in a manner similar to the trend observed with respect to the cyanide content of the root cortex. At 12 months, the total cyanide levels in fresh chips were 61 and 66% of those found at 9 months of age for the varieties CMC-40 and CMC-84 respectively (Table 2) (CIAT 1981).

The aforementioned results indicate that the root parenchymal cyanide level is characteristic of a given variety and that roots from local varieties, normally used for human consumption, are low in cyanide content. Plant age does not appear to affect the cyanide content of the parenchyma but has some effect on the cyanide level of the root cortex.

Effect of Drying Whole-Root Cassava Chips on Cyanide Elimination

Drying whole-root chips is very effective in reducing the cyanide content of cassava roots considerably. Sun-drying on concrete floors (Thanh et al. 1979) is the most practical method of drying cassava; however, on a small scale, wood-framed trays allow for a faster drying process (Best 1979).

The sun-drying process is dependent upon climatic factors such as ambient temperature, intensity of solar radiation, relative humidity, and wind velocity. In addition, the size and form of the chips and the loading rate (amount of fresh chips per surface drying area) also affect the length of the drying period.

A comparison of sun-drying whole-root chips on a concrete floor at two loading rates (10 and 12 kg/m^2) and on inclined trays at three loading rates (10, 15, and 20 kg/m^2) was made (CIAT 1981). Roots of varieties CMC-40 and CMC-84 from 15-month-old plants were used in the experiment. At the loading rates studied, floor-drying was more efficient in reducing cyanide content than tray-drying (Fig. 1). Increasing the loading rate of chips on trays up to 20 kg/m^2 resulted in higher cyanide losses than with lower loading rates, especially with the high-cyanide content variety CMC-84. The proportion of free cyanide in the dried chips appeared to increase progressively as the loading rates on the trays increased. Even with relatively high loading rates, floor- and tray-drying of chips of the low-cyanide content variety CMC-40 produced dried chips containing cyanide levels below 100 mg/kg on a dry-matter basis (standard set at the European market for imported cassava); however, this low cyanide content level could not be reached with the chips of the high-cyanide

Table 2. Effect of plant age on cyanide content of fresh whole-root chips of varieties CM-40 and CMC-84.

	CMC-40		CMC-84	
Age of plant (months)	Total cyanide (mg/kg, dry matter)	Free cyanide (% of total)	Total cyanide (mg/kg, dry matter)	Free cyanide (% of total)
9[a]	584	32	980	18
10	459	24	750	23
11	379	35	723	24
12	355	42	646	20

[a]Mean values of 14 (CMC-40) and 17 (CMC-84) samples; all other values are means of 18 samples.

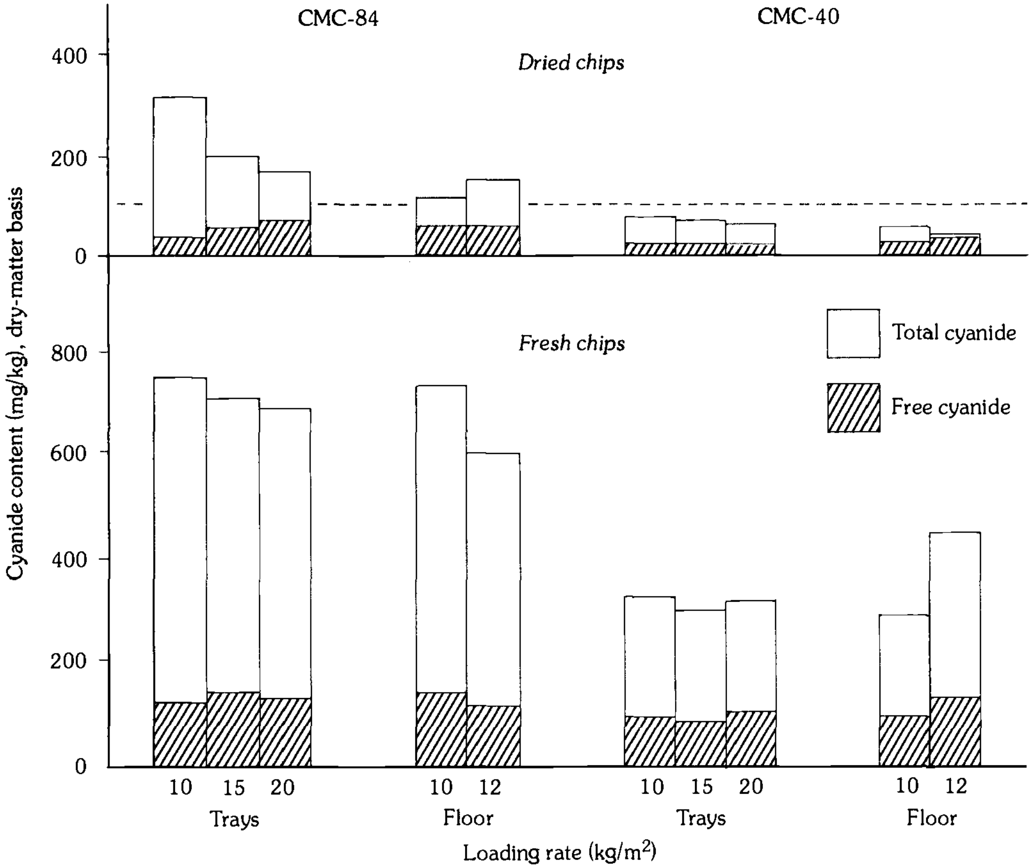

Fig. 1. Effect of loading rate on cyanide reduction in chips dried on trays and on a concrete floor.

content variety.

A sufficient number of 14-month-old plants of each variety was harvested, the roots were processed through a chipping machine, and the cyanide content of the fresh chips was determined. Almost 900 mg/kg of total cyanide were found in the fresh chips of variety MCol 1684, whereas the two local varieties had the lowest cyanide values (137–173 mg/kg) (Table 3). The free cyanide in the fresh chips of all of the varieties was considerably higher than that found within either the parenchyma or the root cortex; free cyanide levels ranged between 24 and 48% of the total cyanide.

The fresh chips of these varieties were either sun-dried on inclined trays or oven-dried in a forced-air oven at 60°C throughout a 24-hour period (Gomez et al., unpublished data). The loading rate for both types of drying was 10 kg/m^2. Oven-drying at 60°C produced dried chips with a final cyanide content lower than that of the corresponding sun-dried chips; the oven-dried chips of variety MCol 1684 were the

Table 3. Dry-matter and cyanide (total and free) contents in fresh whole-root chips of 10 cassava varieties (harvested at 14 months).

Variety	Dry matter (%)	Total cyanide (mg/kg, dry-matter basis)	Free cyanide (%)
Llanera (local)	31.4	173	24
Valluna (local)	23.9	137	28
MCol 22	36.8	267	27
MVen 218	35.8	281	26
MCol 1684	30.2	884	48
CM 305-38	34.1	227	34
CM 321-188	36.1	306	40
CM 323-375	37.3	573	35
CM 326-407	37.4	403	29
CM 342-55	31.7	381	36

Source: Gomez et al., unpublished data.

only ones containing more than 100 mg/kg. Residual cyanide values (total cyanide in dried chips/total cyanide in fresh chips × 100) in oven-dried chips ranged from 13–21%, compared with 20–30% for sun-dried chips of the same varieties. Approximately 60–80% of the total cyanide in the dried chips, obtained by either process, was present as free cyanide.

The available data on cassava drying indicates that sun-drying on a concrete floor; oven-drying at 60°C; and, to a lesser extent, drying on inclined trays led to a reduction in the total cyanide content of the dried chips of the order of 10–30% of the initial cyanide content in the fresh chips. In addition, about 60–80% of the cyanide in the dried chips occurred as free cyanide.

Animal-Feeding Trials Using Cassava Meal from Low- and High-Cyanide Content Varieties

A considerable amount of information has been obtained on the use of cassava in animal feed (Nestel and Graham 1977) and on different aspects of cassava toxicity (Nestel and MacIntyre 1973). Despite this data, very little has been reported on the actual effects of the cyanide content of the cassava products used, although some inferior experimental results have been attributed to the cyanide content of cassava. One of the reasons for this absence of information has been partially due to the lack of an adequate methodology for cyanide analysis; however, the development of an enzymatic method (Cooke 1978; Cooke et al. 1978a) has permitted a more accurate and reproducible cyanide estimation than other methodologies used previously.

In order to ascertain the effect of cassava cyanide on animal performance, several feeding trials using cassava meals, produced from either low- or high-cyanide content varieties, have been carried out on growing rats, pigs, and chickens.

Balanced diets supplying 20% crude protein and consisting of cassava meal (40–42%), soybean meal (37–39%), cellulose (5%), corn oil (10%), and mineral-vitamin premixes (5%) were fed to growing rats throughout a 28-day experimental period. The results are summarized in Table 4. The cassava meals used were based on MCol 1684 and Valluna (MCol 113) varieties. Data on body growth and feed consumption were similar for both varieties tested, as well as for the two drying systems (solar and artificial)

Table 4. Effect of sun-drying and oven-drying whole-root chips of low- and high-cyanide content varieties on the nutritive value of cassava meal for growing rats.

	Cassava meal		Rat results[a]		
Cassava variety	Total cyanide (mg/kg, dry matter)	Free cyanide (%)	Total weight gain (g)	Total feed consumed (g)	Feed/gain
MCol 113					
SD[b]	30	60	156	446	2.86
OD[c]	16	72	144	404	2.81
MCol 1684					
SD	182	77	148	403	2.72
OD	122	72	158	415	2.63

Source: Gomez et al., in preparation.
[a]Means of 8 rats/group; average initial body weight = 43.7 g; duration of experimental period = 28 days.
[b]SD = sun-drying process.
[b]OD = oven-drying process.

Table 5. Effect of cassava meal, obtained from varieties with low- and high-cyanide content, in broiler diets.[a]

	MCol 113			MCol 1684		
Percentage of cassava meal in diet	Final weight gain (g)	Feed intake (g)	Feed/gain	Final weight gain (g)	Feed intake (g)	Feed/gain
0[b]	1977	4346	2.2	—	—	—
10	1714	3982	2.3	1655	4018	2.4
20	1804	4264	2.4	1796	4213	2.3

Source: Santos, J. et al., unpublished data.
[a]Each value is the mean of 140 chickens/group, throughout an 8-week period.
[b]Commercial diet without cassava meal.

used. The difference in the cyanide levels observed did not significantly affect rat performance during the 28-day experimental period.

Results of feeding trials with broilers have clearly shown that least-cost diets, with levels of 10 and 20% cassava meal from either low- or high-cyanide content varieties, produced similar results (Table 5). Actually, the diets with 20% cassava meal produced better results than those with 10% cassava meal, suggesting that there is no apparent toxic effect at these levels (Santos, J. et al., unpublished data).

Experimental results with growing pigs (17–50 kg) have shown that a diet based on cassava meal (74%) produced from a high-cyanide content variety was consumed less than a diet based on cassava meal produced from a low-cyanide content variety (Job 1975); the difference in feed intake was reflected in a significant difference in average daily weight gain. Recent experimental evidence suggests that the consumption patterns of pigs for diets containing 30% cassava meal from either high- or low-cyanide content varieties differ according to the initial body weight of the animals; heavier pigs (~21 kg) consumed more of the high-cyanide content cassava meal diet than the low-cyanide content diet, whereas the reverse was observed for the groups of lighter pigs (~17 kg) (Gomez et al., unpublished data). Further studies are required to elucidate the effect of residual cyanide in cassava meal on feed palatability for pigs.

Available information on cassava as animal feed suggests that the normal drying processes considerably reduce the cyanide content of the roots to a relatively low level in cassava meal, which is apparently not toxic when incorporated into balanced diets for growing animals.

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