Cyanogenic potential of cassava flour: field trial in Mozambique of a simple kit

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The cyanogenic potential (ppm HCN equivalents) of 80 samples of cassava flour (obtained from the Majocojo and Terreiro-A areas of Nampula Province and the markets of Nampula City in Mozambique) were determined using a new simple kit, based on the use of picric acid paper (Egan et al., 1997). The kit is compact, requires only a small amount of water and is very simple to use in the field. Comparison with the results of a semi-quantitative method shows a mean deviation between the two methods of 20% (SD 12%). All samples fitted a single population distribution with a mean value of 45 ppm HCN equivalents (SD 37). Two maxima were observed in the distribution curve at 11–20 and 41–50 ppm. Five samples exceeded 100 ppm with two values of 200 ppm. The WHO safe level for cyanogens in cassava flour is 10 ppm. The lowest levels (2 and 6 ppm) were obtained from cassava flour prepared from sweet cassava. Over 76 samples the mean value of the cyanogenic potential of cassava flour produced by heap fermentation is only one half as large as that produced by sun-drying (*< 0.005). Interventions needed to reduce cyanogen levels are (1) improvements in processing methods, such as replacement of sun-drying by heap fermentation, (2) introduction of additional vegetables, pulses and fruit to alleviate the monotonous cassava diet of the people and (3) introduction of high-yielding, disease-resistant, low-cyanide cultivars.

Introduction

Cassava flour is a very important product in sub-Saharan Africa, particularly in Mozambique, Tanzania and Zaire, as well as in Indonesia and Brazil. High levels of total cyanogens amounting to 131 ± 71 ppm (mg HCN equivalents/kg flour) have been reported in flour from Tanzania (Milingi et al., 1992) but much lower amounts (9.3 ± 2.1 ppm) from the markets of its capital city Dar es Salaam (Milingi, 1995). Tylleskar et al. (1992) found that flour consumed by households in konzo-affected villages in Zaire had a mean value of 32 ppm. The safe level recommended by WHO is 10 ppm.

From 1981 onwards, several epidemics of konzo have occurred during agricultural crises in Nampula Province, northern Mozambique (Ministry of Health, Mozambique 1984; Cliff 1994). Konzo is a spastic paraparesis associated with a monotonous diet of bitter cassava and a
low intake of essential amino acids (Howlett et al., 1990). Populations affected by konzo have high levels of urinary thiocyanate reflecting a high cyanide intake (Casadeci et al., 1990).

The Mogincual District of Nampula Province was chosen for this study because cassava is the staple food of the people, who had recently suffered the depredations of war and as a result had also suffered epidemics of konzo (Cliff et al., 1997). Other food crops include maize, sorghum, pulses and peanuts. During the war that had affected the district for 10 years up to 1992, agricultural production was severely disrupted and the cassava production increased relative to other crops. Since the war ended, agriculture has slowly recuperated; after a slow start, seeds and tools have been distributed. The 1995–96 rainy season was good, resulting in surplus production for selling in some households. Cassava in this area is normally harvested from August to October and is processed by a variety of methods, the two most common ones are sun-drying and heap fermentation. The final stage in each case involves pounding into flour and sieving.

A simple method for the determination of the cyanogenic potential of cassava flour has recently been developed (Egan et al., 1997). One aim of the work was to field-test the new kit in a rural area of Nampula Province previously affected by konzo and in the provincial capital, Nampula City. A second aim was to determine the cyanogenic potential of cassava flour at the time of the cassava harvest and to relate the cyanogen content to the cassava cultivars and processing methods used.

Materials and methods

In two chiefdoms (Mujocojo and Terrene-A) in Mogincual District we went to a central point, divided into two or three teams and visited each house in randomly selected directions. At each house, we obtained a sample of the flour that was being consumed on that day. Relevant information with regard to the name of the cassava variety, whether it is bitter or sweet, and the method of preparation of the flour was obtained by questioning the lady processors. During the collection of flour samples in Mujocojo two persons were found with cyanide intoxication. Samples of flour were also obtained from seven different markets of Nampula City and suburbs. In some cases detailed information was available from women sellers who were also processors of flour, but in other cases the dark-coloured flour was classified as fermented and the white flour as sun-dried.

The simple kit used one per analysis of (1) 21 mm diam. Whatman 3 MM filter paper discs loaded with linalarase and pH 8 phosphate buffer and (2) a plastic strip (10 mm × 50 mm) to which was glued a yellow Whatman 3 MM picrote paper (10 mm × 30 mm). Also included in the kit were 40 small plastic bottles with lids, a small portable plastic balance for weighing 100 mg samples of flour, a small plastic pipette to deliver 0.5 ml water, a colour chart and a graph of absorbance at 510 nm vs cyanogenic potential in ppm.

The samples of flour were assayed for cyanogenic potential within about 2 h of collection. Those collected at Mujocojo in October 1996 were analysed by the simple method (Egan et al., 1997) in a small health centre laboratory at Liwpo. The coloured picrote papers were separately wrapped in tissue, numbered, kept in the dark and transported the next day to Nampula, where they were analysed by semi-quantitative method, using a Bausch & Lomb Spectronic 20 spectrophotometer to measure the absorbance at 510 nm (Egan et al., 1997). The flour samples collected at Terrene-A and in the Nampula markets were analysed in the laboratory at Nampula using the simple and the semi-quantitative methods. For any particular sample there was satisfactory agreement between the results of the two methods, which were reported as a mean value. Squares of Whatman 3 MM filter paper loaded with linalarase amounting to 5 and 15 μg HCN equivalents (which corresponds to 50 ppm and 150 ppm HCN in 100 mg samples of cassava flour) were routinely used as internal standards to check on the correctness of the methodology (Egan et al., 1997). The internal standards gave the correct results using both methods.

Results and discussion

Evaluation of field trial using the simple kit method

The analysis of 32 samples at Mujocojo required less than 1 h for two persons to set up and about 1 h to score the following day, using the colour chart provided. The kit as described
above is compact, requires only a small amount of water and is very easy to use in the field. By eluting the colour from the picrate paper using 6.0 ml of water and measurement of the absorbance at 510 nm, a more accurate, semi-quantitative estimate was obtained of the cyanogenic potential (Egan et al., 1997). The percentage deviation of the result of the simple method from the corresponding result obtained by the semi-quantitative method was calculated to be 20% (SD 12%), providing one eliminated very low results (< 10 ppm) for which the deviations are often > 50% due to loss of accuracy at low values. This result is very acceptable considering the fact that the colour chart has only 10 shades of colour to cover the full range of 0–800 ppm HCN equivalent.

Cyanogenic potentials of flour from different locations

The means and standard deviations (in brackets) of the cyanogenic potentials (ppm) of 32 cassava flour samples from Mujocejo, 22 cassava flour samples from Terrene-A and 26 cassava flour samples from markets in Nampula City are 49 (29), 43 (30) and 40 (51) respectively. There is no significant difference between the three sets of samples and if they are all analysed as one set of 80 samples the grand mean is 45 ppm (SD 37). This high mean value is unacceptably large, in what is considered to be a good season, averaging 4.5 times the safe level recommended by WHO of 10 ppm.

The distribution of the cyanogenic potentials of the samples of cassava flour from the three different locations were found to be very similar and hence have been bulked together and displayed in Figure 1. Two peaks are evident at 10–20 and 41–50 ppm which are not due to differences between different processing methods (see below). It is noted that multiple peaks occur in frequency distributions of cyanogen content of cassava roots from African and South American sources (Bokanga, 1994).

The occurrence of 5 samples out of 80 (6%) with cyanogenic potentials of >100 ppm including two sun-dried samples from Nampula City markets with 200 ppm (20 times the WHO level), presents a problem for human health. The very high values of the latter may be the result of commercial production, which sometimes involves the use of short-cut methods of processing that are less effective in the removal of cyanogens (Tylleskar et al., 1992).

Flour produced from bitter and sweet cassava

The additional information obtained from the processors of the 54 samples of flour from Mujocejo and Terrene-A showed that 40 were made from one bitter variety (cv. Tonyo), four from a less bitter cv. Bwana, one each from bitter cvs Torito, Guerra and Garue, two from

![Cyanogenic potential in ppm](image)

**Figure 1.** The distribution curve of the cyanogenic potentials (0, 10, 11–20, 21–30, — 191–200 ppm) of all samples of cassava flour from the three different locations. Total number of samples = 80.
Table 1. Cyanogenic potentials of cassava flour produced by different processing methods

<table>
<thead>
<tr>
<th>Local name of method</th>
<th>Description of processing method</th>
<th>Number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makaka</td>
<td>Peeled, whole roots or large pieces (cut longitudinally or transversely) sun-dried for ca. 7 d, pounded and sieved</td>
<td>20</td>
</tr>
<tr>
<td>Kokonholo</td>
<td>Peeled, small pieces cut from end of tuber, sun-dried for ca. 7 d, pounded and sieved</td>
<td>18</td>
</tr>
<tr>
<td>Chumulamu</td>
<td>Peeled, size unspecified, heapd up and fermented for 3–5 d, sun-dried ca. 7 d, pounded and sieved</td>
<td>40</td>
</tr>
<tr>
<td>Pilula or naniotokoliwa(^1)</td>
<td>Peeled, pounded into very small pieces, sun-dried for ca. 1 d, pounded and sieved</td>
<td>2</td>
</tr>
</tbody>
</table>

\(^1\)The two samples of pilula gave cyanogenic potentials of 31 and 45 ppm.

sweet cassava cv. Maria, flour from a mixture of sweet and bitter cassava and one from an unknown source. The great preponderance of Tomo meant that we could only make limited comparisons between different cultivars. The small number (six) of different cultivars found in this survey in Mzimcasu District and the high concentration on one cultivar, (Tomo) is the result of the war, when people switched to the bitter cv. Tomo, as they were unable to guard their fields against the depredations of monkeys. The two samples from sweet cassava (cv. Maria), gave the lowest values (2 and 6 ppm) of cyanogenic potential of all the samples. Four samples of sun-dried flour from Terrene-A were prepared from a mixture of sweet and bitter cassava and this caused a 47% reduction in the mean level of cyanogens compared with the mean of all the Terrene-A sun-dried samples. Thus, cassava flour produced from sweet cassava has a lower cyanogenic potential than the WHO safe level. Furthermore, flour prepared from mixed sweet and bitter cassava is safer than that from bitter cassava.

Processing methods and cyanogenic potential of flour

The information on processing methods is collected in Table 1. The processing methods have been divided into four different classes based on two basically different procedures, viz. (1) sun-drying of (a) whole roots or large pieces (Makaka), (b) smaller pieces cut from the end of tubers (Kokonholo) or (c) short, sun-drying of very small pieces produced by pounding (Pilula) and (2) heap fermentation of cassava of different sizes for 3–5 d, followed by sun-drying. In Table 2 we have analysed the data with respect to the three locations where samples were collected and also with respect to the two major processing methods (sun-drying and heap fermentation). In this analysis we have deliberately excluded the two samples produced

Table 2. Cyanogen contents (ppm, standard deviations in brackets) of cassava flour from different locations classified according to processing method\(^1\)

<table>
<thead>
<tr>
<th></th>
<th>Nampula markets</th>
<th>Mupocojo</th>
<th>Terrene-A</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun-drying(^2)</td>
<td>66(70)</td>
<td>65(22)</td>
<td>51(29)</td>
<td>59(43)</td>
</tr>
<tr>
<td>Number of samples</td>
<td>11</td>
<td>11</td>
<td>16</td>
<td>38</td>
</tr>
<tr>
<td>Heap fermentation(^3)</td>
<td>23(14)</td>
<td>43(29)</td>
<td>14(9)</td>
<td>32(26)</td>
</tr>
<tr>
<td>Number of samples</td>
<td>15</td>
<td>20</td>
<td>3</td>
<td>38</td>
</tr>
</tbody>
</table>

\(^1\)The two samples prepared from sweet cassava (cv. Maria) with low cyanogen content and the two pilula samples (Table 1) were not included in this analysis.

\(^2\)This is the sum of makaka and kokonholo treatments given in Table 1 equalling 38 samples.

\(^3\)These are the chumulamu samples from Table 1, minus the two samples of Maria.
from sweet cassava cv. Maria, because they had the lowest cyanogen contents as a result of the nature of the cultivar, and the two pilada samples. Reading across the table, there is no difference between the sun-drying results from the three locations. With the heap fermentation results, although there are differences between different locations, the only one which is significant, $P < 0.01$ using Student’s $t$-test, is that the cyanogen content of Mujocojo is larger than that of Nampula markets.

Of far more importance is the result that in all three locations the cyanogen content of sun-dried cassava flour is significantly greater ($P < 0.025$) than that of heap-fermented flour. The total cyanogen result for sun-drying 59(45) is highly significantly ($P < 0.005$) greater than the total result for heap fermentation 52(26).

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**Figure 2.** The distribution of cyanogenic potentials (0–10, 11–20, 21–30, 31–40, 41–50, 101–200 ppm) of 38 samples of cassava flour processed by sun-drying, see Table 2.

**Figure 3.** The distribution of cyanogenic potentials (0–10, 11–20, 21–30, 31–40, 41–50, 101–200 ppm) of 38 samples of cassava flour processed by heap fermentation, see Table 2.
The distribution curves of the cyanogenic potentials of sun-dried and heap-fermented cassava flour are given in Figures 2 and 3. This shows clearly that the heap fermentation method (Figure 3) gives a much more compact distribution with a lower cyanogenic potential than the sun-drying results shown in Figure 2. Furthermore, the latter method gives rise to more dangerous outliers of high cyanogenic potential than the heap fermentation results in Figure 3. Since these figures each show double maxima, the double maximum observed in Figure 1 cannot be due to the different processing methods.

These results show that the cyanogen content of cassava flour is consistently lower in every location by use of heap fermentation as compared with sun-drying. On average over 76 samples, the cyanogen content of cassava flour produced by heap fermentation is only about one-half of that produced by sun-drying. Thus, cyanogen content would be substantially lowered by the increased adoption of heap fermentation, see also Essers et al. (1995). However, it would be important to check on the possible production of aflatoxins during the fermentation method.

**Interventions to lower cyanogenic potential of flour**

There are three interventions that could lead to the reduction of cyanogens in cassava flour and the elimination of this public health problem.

1. Improvements in the processing of cassava flour to remove a greater proportion of the cyanogens present may be possible in the short term. Our results show that increased use of heap fermentation followed by sun-drying, gave only one-half the amount of cyanogens compared with flour produced simply by sun-drying (Table 2). The crushing methods already in use (pilala) have been shown in Tanzania to rapidly reduce linamarin levels, but result in high cyanohydrin levels. This is probably only because it is a short-cut method and therefore the pieces are not dried for long enough (Mlingi et al., 1995). The adoption of grating of fresh tubers, followed by adequate drying would lead to much lower cyanogen levels than given by sun-drying or heap fermentation (Nambisan & Sundaresan, 1985) but may be culturally unacceptable because of the changes needed in traditional processing methods, which in some cases would involve additional work, materials and cost.

2. Improvement of the diet of the people by the introduction of other crops (vegetables, pulses and fruits). Better assistance in post-war agricultural rehabilitation including better distribution of seeds and tools would have resulted in quicker recuperation. These areas should be priority zones for agricultural extension workers. There is also a need to supply credit to rural traders to re-establish commerce (Hanlon, 1996). Such interventions would help to relieve the monotony of the present cassava-based diet as well as reduce the intake of cyanogens.

3. The introduction of low cyanide (sweet) cultivars of cassava that are high yielding and disease resistant. This would undoubtedly solve the problem, as shown by the low results found with cassava flour made from sweet cassava (see above) and the fact that there is no problem with cyanogens in the cassava used in the Pacific, because it is virtually all sweet cassava (Bradbury & Holloway, 1988). This is a long-term solution to the problem, since it requires the breeding of high-yielding, disease-resistant sweet cassava varieties that are suited to the climatic conditions of East Africa. However, it should be noted that in parts of Nampula Province where monkeys are a problem, bitter cassava is preferred because it reduces the incidence of loss of tubers by monkeys.

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