Toxicity and Food Security: A review of health effects of cyanide exposure from cassava and of ways to prevent these effects

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For several years I have been on the lookout for something that could provide a perspective on this important question. A million thanks to Dr. Hans Rosling for sending the 31 page booklet with the above title that he wrote for UNICEF. It is just what I had hoped to find. The subject is so important that I have summarized much more of the material than in a normal review. I include the extra detail so you will be able to anticipate when conditions such as dietary limitations, economic changes or social turmoil might cause a problem to suddenly appear.

Dr. Rosling does not like the statement "cassava contains cyanide." A food that contained pure hydrogen cyanide could be easily detoxified (it would be driven off as a gas by cooking). If any free cyanide is present in cassava, it can easily be driven off into the air by temperatures over 28°C (82°F)

The "cyanide" in cassava is actually a complex and very stable molecule called linamarin, one part of which is a cyanide molecule. If that part of the molecule is broken off it will become cyanide. Compounds such as this that produce cyanide when broken down are called "cyanogenic" compounds. Some cyanogenic compounds are broken down by boiling. For example, although chaya leaves (EDN 182) contain a cyanogenic compound, the cyanide is driven off by boiling for 5 minutes.

Unfortunately the cyanogenic compound in cassava is largely unaffected by boiling. Boiling whole pieces of cassava does little to reduce the danger of cyanide poisoning (although boiling fermented or grated cassava will remove most of the cyanide, as we will see later).

Linamarin is not itself toxic. If some of it is absorbed from the gut into the blood it is probably excreted unchanged in the urine. The "cyanide" in linamarin can be liberated in two ways. First, enzymes secreted by microbes in the gut can decompose linamarin, liberating cyanide in the process. Second, certain enzymes in the cassava root itself can liberate cyanide from linamarin. In the intact plant, these enzymes never get a chance to degrade linamarin because they are stored in separate places. But when the root structure is disrupted by grating or fermentation, the two come into contact and cyanide is liberated (and will evaporate at temperatures of 28°C or higher).

I am preparing this review while visiting a major cassava growing area in the Amazon Basin of Brazil. It is interesting to fit observations about farmers' practices into the understanding provided by the book. For example, I am told that the roots are fermented and/or grated (which puts the enzyme and linamarin together), then washed with water and squeezed. Free cyanide is washed out in the water. As the water is left to stand, tapioca settles to the bottom. If a hog or other animal drinks this water, unless it is cooked or considerable time has elapsed, they reportedly can die quickly from the dissolved cyanide. There would be very little cyanide nor linamarin remaining in either the tapioca or the ground, dried cassava, which are consumed in large amounts along with fish.

"Considerable cassava consumption has developed in some areas using processing methods like sun drying, which are very ineffective in removing cyanide. This has probably been possible because initially only the less toxic sweet varieties were used. When these varieties were later replaced by more productive toxic varieties, the established processing practices may suddenly have become insufficient. … this is probably the case in many cassava growing areas of East Africa. … sun drying for long periods is not fully efficient, although levels will be lower than after only a few days of drying."

"From the toxicological aspect, strict adherence to the method is as important as the type of method. Soaking in water … as well as grating and sackfermenting processes … are effective as long as the soaking or fermenting steps are not shortened and fermentation conditions are not changed. Sun drying, if performed according to traditional practices, should be extended over several weeks. Populations using prolonged sun drying probably rely on infestation of insects in the roots to achieve a sufficient removal of cyanide.

What if there is an emergency situation in which the water for soaking or some necessary equipment is lacking? A method emerging in coastal Tanzania and Mozambique and Rwanda which "is probably an appropriate and effective way of reducing the cyanide" is called dry fermentation. "A pile of peeled root pieces is covered with leaves or peels for 34 days, after which each root piece is completely covered by a black mould growth. The root pieces are dried in the sun and as much of the mould is removed as possible. These pieces are finally consumed after pounding. Unfortunately **this method seems to result in a very high exposure to aflatoxins from the mould growth**…aflatoxin exposure must thus also be considered as a possible sideeffect when cassava provides food security in droughtaffected areas." Aflatoxins cause liver damage and are powerful carcinogens.

What happens to cyanide in the body? The body is protected from cyanide in two steps. The blood contains a substance which can, within minutes, bind up to 10 mg. of cyanide. This is then taken to the liver and detoxified in a process that takes a few hours.

If more than 10 mg. of cyanide is consumed, but not enough to be fatal, it is converted to a far less toxic substance called thiocyanate. The thiocyanate is eventually excreted in the urine. This detoxification process requires the element sulfur, which is obtained from protein in the diet. In protein deficient diets the detoxification process ceases to operate. So lack of protein in the diet accentuates

the toxicity of cassava. "It should be noted that considerable amounts of fish are consumed in areas of the Amazon, the Congo basin and southern India where cassava has been established as the dominating staple for centuries."

If other food is not available, "an adult will consume daily about … 0.5 kg dry (1.5 kg wet) weight of cassava." **"The newly developed high-producing varieties with less cyanideyielding capacity still contain 50100 mg of cyanide per kg of fresh weight.** This amount will easily be removed by processing, but if roots are consumed unprocessed, even these varieties may cause intoxication." [I believe "intoxication" is medical terminology for "have a toxic effect." It does not mean "drunk"].

Diseases related to cassava toxicity immediate symptoms. Symptoms usually occur 46 hours after a meal and consist of vertigo (dizziness), vomiting, collapse and, in some cases, death within 12 hours. Antidotes are effective, safe and cheap. Intravenous injection of thiosulfate will increase the sulfur available to convert cyanide to thiocyanate. Nitrite acts more rapidly but must be handled with care as an overdose is itself toxic.

Cyanide intake from cassava is probably a factor in two types of paralysis. In tropical ataxic neuropathy, one of the sensory tracts in the spinal cord is damaged. This results in an uncoordinated gait called ataxia. It occurred in Nigeria, mostly in adult males, with successive occurrences over several years. High cyanide intake with low protein diets were suggested causes.

Epidemic spastic paraparesis occurs mainly among women and children. It permanently cripples the victim "from one day to the next" [in a 24 hour period?] by damaging parts of the spinal cord that transmit signals for movement. Muscles are not flaccid, as in polio, so the legs usually support affected persons sufficiently to let them stand, especially if supported by a stick. Walking is often uncontrolled jerks. Outbreaks have been reported in two locations in Zaire during the dry season and during a drought in one location each in Tanzania and Mozambique.

In each of these four cases cassava was the only food available in quantity and roots were inefficiently processed. This disease has never been reported from a population that did not consume cassava, nor from populations eating balanced diets. In Mozambique 1102 people were stricken. Cassava was the only food due to a drought [hence no protein for the body's own detoxification process]. Once other foods were gone, they did not have enough processed cassava to replace them. Also the people wanted to leave the roots in the ground as long as possible to grow bigger. When they finally harvested, they had no time for the lengthy sundrying process. Studies on this population indicated "that acute intoxication may appear when cyanide intake reaches 30 mg in 24 hours."

Health workers should be aware of the following possible causes of cyanide poisoning:

1. varieties that are normally sweet may produce high levels of linamarin under adverse conditions.
2. a new, but toxic, variety may be introduced to the market and surprise people.
3. hungry, unsupervised children have been known to eat toxic roots in spite of their bitterness.

4. if cassava is just being introduced without adequate training in processing methods.

Diseases related to cassava delayed symptoms. Other diseases develop only after exposure to cyanide over a long period of time. Continuous exposure to insufficiently processed cassava can lead to goiter and cretinism. This problem is especially prevalent in Africa. The thyroid gland, situated in front of the neck, is not normally visible. Its main function is to produce iodine-containing hormones that regulate body metabolism. If the diet contains too little iodine the thyroid gland becomes larger so as to be more efficient in extracting what little iodine is in the blood. Some children born to iodine-deficient mothers suffer from cretinism (mental retardation and stunted growth).

How is inadequately processed cassava responsible? The thiocyanate produced when cyanide is detoxified (see above) interferes with uptake of iodine by the thyroid gland. Fortunately this interference can happen only when iodine intake is already low, below 200 micrograms per day. Populations in northern Zaire with very low iodine in the diet and who regularly ate inadequately processed cassava suffered from severe endemic goiter and a high prevalence of cretinism. When iodine supplements were used the goiter problem decreased considerably even though the cassava was still not adequately processed due to adverse conditions.

Do all varieties of cassava contain cyanide? The hundreds of cassava varieties are grouped according to taste into bitter and sweet. The bitter varieties generally have more linamarin than the sweet, but there is no clear-cut division into the two groups. "Cassava growing peasants plant several varieties. The sweet ones in smaller amounts are eaten as snacks or cooked fresh as vegetables. The bitter varieties are grown in large quantities to serve as staple food after processing."

In most cassava-growing areas the bitter and more toxic varieties have been found to be more productive, probably because of the toxicity. For example, monkeys and wild pigs will not feed on toxic varieties. "Peasants often plant small amounts of sweet varieties in the center of a field of toxic varieties" to keep animals from eating the former.

"Breeding programs should continue to take cyanide levels into consideration, but so far no high yielding variety has been found that makes processing unnecessary." "Even 'high-yielding low-cyanide' varieties developed by IITA in Nigeria have a cyanide-yielding capacity of about 510 mg of cyanide per 100 g of fresh weight. … consumption of these new varieties without any processing may still result in considerable cyanide exposure. … strict adherence to efficient processing methods is still needed if large amounts of roots from these new varieties are consumed."

Dr. Rosling has offered copies of his book Cassava Toxicity and Food Security free of charge as long as they are available. Write him at International Child Health Unit, Dept. of Pediatrics, S751 85 Uppsala, Sweden.

An update from Dr. Rosling. Three recent articles give additional details on the occurrence of spastic paraparesis in the Bandundo region of Zaire (110 live and 24 dead cases). The start of these outbreaks in 1974 coincided with the completion of a new tarmac road to the capital, which facilitated the transport of cassava and made it the main cash crop. "The affected population consumed flour made from

short-soaked (one day) cassava roots and thus had high dietary exposure to cyanide (urinary thiocyanate in 31 children was 757 vs 50 units for a population where cassava had been soaked for the normal three days)."

"The reason for processing shortcuts … [is that cassava is] exclusively produced and processed by women in very poor households. Roots are shortsoaked when women are in a 'hurry' to gain cash."

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