Cyanide Removal from Flour Helps Millions

Howard Bradbury describes a simple method to remove nearly all the cyanide from cassava flour, and its potential to help millions of people in Africa.

Cyanide is a potent poison. It is so effective that spies use it in the form of a suicide pill and more than 2000 plants use it to protect themselves from animals and marauding insects. The plant produces a cyanide compound and also an enzyme that can break it down to produce hydrogen cyanide.

In the case of cassava, the plant stores the cyanide compound and the enzyme in different parts of the plant cell. If the cell is broken by a chewing insect then the enzyme immediately breaks down the cyanide compound, and toxic hydrogen cyanide is produced. The insect very soon goes somewhere else for a feed. A scientist friend of mine once said to me: "Plants can't run away like we can, so they have developed very clever ways of defending themselves from attacks by predators".

Cassava is the most important food plant that uses cyanide as a defence mechanism. Cassava is the staple food of up to one billion people in the tropics.

Cassava likes hot conditions, and loses its leaves in winter in Brisbane. We can grow it in Canberra – in a glasshouse.

The cassava plant is a large bush with pretty leaves and stalks, and is sometimes grown as an ornamental shrub in gardens in tropical Australia (Fig. 1). During drought the leaves drop off, and the plant is kept alive by its large roots, which are very starchy and the main source of food. In Africa the young leaves are also eaten after cooking, and are a good source of protein.

The plant is very easy to grow by simply cutting the stem and planting a short section of it in the ground. Cassava grows well even in poor soils without fertiliser, and the roots can be left in the ground for up to 3 years as a reserve source of food.

Figure 1. The cassava plant is a staple food for up to a billion people.

Because of its agricultural advantages, cassava production is steadily increasing to keep pace with the ever-increasing population in the tropics. Cassava is now the fourth most important food source worldwide.

But there is a catch! There is a large amount of a cyanide compound in the leaves of cassava and the skin of the root (which is peeled off), and usually a smaller amount in the inside of the root (called the parenchyma).

Figure 2. A simple kit that can determine the cyanide content in cassava flour is used by health workers in developing countries.

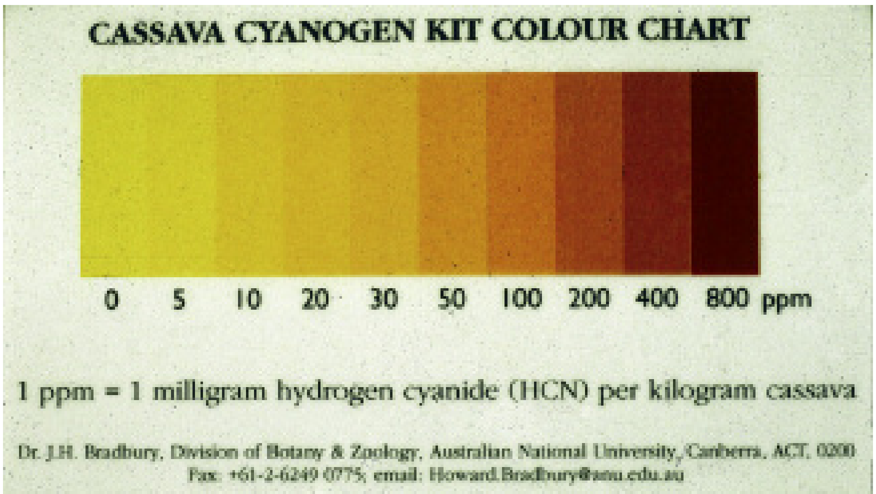

Figure 3. This colour chart indicates how much hydrogen cyanide is produced by the sample.

Processing Cassava

Cassava roots only last for a few days in the air, so they must be used quickly for food or processed into flour or another cassava product. There are many traditional methods of processing cassava roots, but probably the simplest is to peel the root and dry it in the sun for about a week until it is dry and brittle. It is then pounded in a wooden pestle and mortar into a powder and sieved to produce cassava flour. This sun-drying method is used in eastern, southern and central Africa, and leaves about one-quarter to one-third of the cyanide behind in the flour.

Another method called "heap fermentation" is used by rural women when the cyanide level of the roots increases during a drought. This method leaves about one-eighth to one-sixth of the cyanide in the flour.

The cyanide compound retained in the flour in a good season in northern Mozambique amounts to 45 parts of hydrogen cyanide per million parts of flour, but in a drought year is greater than 100 ppm.

Since the World Health Organisation has set a safe level for cassava flour of 10 ppm cyanide, these amounts are far in excess of the safe level and cause considerable health problems.

If the parenchyma contains only a small amount of the cyanide compound, as occurs with the cassava varieties introduced into the South Pacific, then it may be boiled and eaten. However in Brazil and Colombia, where cassava originated, there are many thousands of different varieties. Some have low levels of cyanide in the parenchyma (called sweet cassava), some have medium levels of cyanide and others have high levels of cyanide in the parenchyma (called bitter cassava because the cyanide compound has a bitter taste).

In Africa there is the full range of varieties, including one very high cyanide variety in Nigeria that is called "chop and die". High cyanide cassava roots and all cassava leaves must be processed to reduce the cyanide content before eating.

If the cassava plant is stressed by insect attack or by drought it produces much more of the cyanide compound. In a drought year cassava flour contains a much larger amount of the cyanide compound than in a normal year.

War produces dislocation of the village and the fields where cassava is grown. People flee from their homes, are forced to live off the land and consume cassava roots from the bush without processing them to reduce the cyanide content. The recent 5-year civil war in the Democratic Republic of Congo (DRC; formerly Zaire) killed four million people and caused an estimated 100,000 cases of the paralytic disease konzo.

Effects of Cyanide

The media in countries like Nigeria and East Malaysia occasionally report cases of hospitalisation and death due to cyanide poisoning after a cassava meal. Because the lethal dose of cyanide increases in proportion to bodyweight, children tend to be more susceptible to cyanide poisoning than adults.

Smaller amounts of cyanide cause acute intoxication, the symptoms of which are headache, dizziness, stomach pains, vomiting and diarrhoea.

Iodine deficiency, which is the cause of goitre and cretinism (shortness of stature), occurs in some provinces in the DRC. If these people also eat cassava, the cyanide from the cassava makes the goitre and cretinism much worse.

In West Africa, where cassava is processed into a fermented product called "gari", there is a disease called "tropical ataxic neuropathy" (TAN) that affects older and generally poor people who have eaten cassava for many years. TAN causes elderly people to fall over while walking, produces a loss of sensation in the feet and hands, and blindness and deafness.

Cyanide taken into the body along with cassava is detoxified by a process that uses up essential amino acids, which are the building blocks of proteins. Shortness of stature (stunting) found in children due to cyanide from cassava may result from loss of these essential amino acids

Konzo causes paralysis of the legs, mainly in children and women of child-bearing age in eastern, southern and central Africa. Here the person concerned suddenly loses the ability to move their legs because the upper motor neurons in the brain are affected. Paralysis of the legs is permanent, but rehabilitation can help patients to walk again.

Cases of konzo occur every year in some districts of northern Mozambique, and Julie Cliff has studied larger outbreaks and epidemics due to drought and war.

Cyanide Kits

How is it possible to get information on the amount of cyanide compound present in flour? In 1995 Sylvia Egan, H-H Yeoh, Meredith Bradbury and myself developed a simple method to measure the amount of cyanide in cassava roots and in cassava products.

We use a small plastic bottle with a screw lid, inside of which is placed a small filter paper loaded up with a very small amount of enzyme and phosphate buffer. One hundred milligrams of cassava root or flour is weighed out using a small plastic balance, and this is added to the bottle as well as some water. A yellow picrate paper is placed in the bottle and the lid closed (Fig. 2). The hydrogen cyanide gas produced from the breakdown of the cyanide compound turns the yellow paper a brownish colour. The next day the colour of the picrate paper is matched with a colour chart (Fig. 3), or the colour matching may be done accurately in a laboratory using a spectrophotometer.

The cyanide kit was evaluated in the field in northern Mozambique in 1996 by Julie Cliff, Paula Cardoso, Mario Ernesto and myself.

We make the kits at the Australian National University (ANU), and they are sent free of charge to health workers and agriculturalists in developing countries funded by ACIAR. Each kit allows 100 analyses. They are also sold to workers in first world countries.

Since 1996 about 350 free kits have been sent by courier and nearly 150 kits have been sold. The supply of free cyanide kits to workers in Africa and elsewhere has allowed them for the first time to measure the amount of cyanide present in cassava roots and products.

But what is the use of them knowing how much cyanide is present in their staple food? They still have to eat it anyway because they have nothing else to eat. If they eat it they may get sick with cyanide, but if they don't eat it they will go hungry and could starve.

This double jeopardy is inflicted on the poorest of the poor people in more marginal agricultural areas of many countries like Mozambique, Tanzania and the DRC. A solution to this perplexing dilemma is now at hand.

Solution to the Dilemma

A literature survey revealed that the methods used to get rid of cyanide from cassava were much more effective in South America and West Africa than in eastern, southern and central Africa, so we clearly needed a new or improved method to remove the cyanide compound from cassava flour.

At the time Julie Cliff and I had been discussing whether the cyanide compound remained in the flour for a long time or whether it broke down. I tested this at ANU with six samples of flour left standing in the laboratory. Even after 6 months there was still no decrease in their cyanide level.

Realising that the air during Mozambique's wet season could be nearly saturated with moisture, I tried the flour samples under these conditions and found a 20% decrease in cyanide content per week.

Then I wondered what would happen if I mixed the flour with water into a thick paste. In 5 hours some flour samples lost up to 90% of their cyanide, whereas others lost less than 10%.

I found that the flour samples that did not lose cyanide had very little enzyme present. When I added enzyme there was a much more rapid breakdown of the cyanide compound.

Clearly the key to the removal of the cyanide compound from flour was to wet the flour so that the enzyme present can break it down to hydrogen cyanide gas. The method was a gift from God.

Subsequently the wetting method was checked by Arnaldo Cumbana in Beira, Mozambique, using 30 samples of local flour. Using small samples of flour, on average only one-sixth of the cyanide compound was left 5 hours after mixing the flour with water.

In larger 0.5 kg samples of flour it was necessary to spread the wet flour on a tray in a thin layer 1 cm thick so that the hydrogen cyanide gas could escape from the wet mass of flour.

In 2005 there was a drought in northern Mozambique. More than 100 people contracted konzo and were examined by Dulce Nhassico, Humberto Muquingue and Julie Cliff. At the same time the simple wetting method was evaluated in the field by rural women using the following procedure.

The rural women filled a bowl with flour up to a mark on the bowl. Water was added with mixing until the wet flour came up to the same mark. The wet flour was then spread out on a basket in a thin layer and left in the shade for about 5 hours to enable hydrogen cyanide gas to escape.

The wet flour was then mixed into boiling water to make a stiff porridge. Porridge was also made from untreated flour, and plates of the stiff porridge made from treated and untreated flour were prepared.

Local volunteer tasters in a blind taste test were asked to taste a sample from each of several plates and report which sample they preferred. In two widely separated localities these tests showed that there was a preference for thick porridge made from treated flour, probably because of the removal of the

A boy with konzo is supported by his father.

Children with konzo walking with the aid of handrails.

bitter taste from the cyanide compound.

The wetting method is extremely simple, does not require additional equipment or give rural women any additional work. It was well-accepted by them.

Last year two workshops were held in Nampula City and Quelimane in Mozambique, organised by Dulce Nhassico to show health workers how to use the wetting method to remove cyanide from flour.

The next step is to get the method used by rural women, who make their own cassava flour and mix it into boiling water to make the thick porridge that may be eaten with beans or sauce to give it flavour.

A grassroots implementation program is needed among people whose only means of communication is by word of mouth in their native language. This is not an easy task.

There is a need for female interpreters to be trained in the use of the wetting method. They would then go into the villages in marginal agricultural areas where konzo occurs to show the women how to remove the cyanide from their cassava flour.

A program to change the cooking habits of the people will be expensive. There are various aid organisations that work in different "konzo areas", such as the International Red Cross, with whom we are already working in Nampula Province on an implementation project, supported by funds from the Australian Agency for International Development.

One thing is clear. If the method can be widely implemented in Mozambique, Tanzania, the DRC and the other African countries where konzo occurs, it should greatly reduce and perhaps even eliminate konzo. If the method is not used, then the poorest of the poor in rural areas of these countries can look forward to outbreaks of konzo during drought in the future.

Dr J. Howard Bradbury AM researched and taught chemistry for many years at the Australian National University, and in his "retirement" years works as a Visiting Fellow in the School of Botany and Zoology on the cyanide problem in cassava.