Cyanide in Bamboo Shoots

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Summary

INBAR is involved in an active research programme to develop new food products from bamboo shoots. The objective of the research programme is to stimulate new uses of bamboo shoots in existing markets and to assist developing food security in food-poor areas.

A concern in this project is that, although cyanide is unknown as a problem in the Chinese bamboo shoots food industry, there are several reports elsewhere of bamboo species containing significant, potentially very toxic, amounts of cyanogenic glycosides in their shoots.

There is very little published material, however the available material does confirm that some bamboo species do indeed contain very high levels of cyanogenic glycosides in their shoots. There are clear differences between species and insufficient information to generalise. More work by national agricultural research institutes is necessary.

The cyanogenic glycoside in bamboo is taxiphyllin. Taxiphyllin is unusual amongst the 60 or so known similar compounds in that it degrades readily in boiling water. Thus the normal preparation of bamboo shoots should remove any problem.

However in extending the use of bamboo shoot eating to other regions a problem may occur if people prepare bamboo shoots in a manner similar to that used for another cyanogenic crop (cassava) in Africa.

Introduction

This is an INBAR Working Paper, by which is meant a work-in-progress.

INBAR is currently active researching new food products from bamboo shoots. It has two prongs to this research. One is to expand the market potential for bamboo shoots in markets where their traditional use is relatively unknown. That includes areas of China. The other is to assist in achieving greater food security in food poor regions of the world. However, for various reasons, the food technology developed in China, Japan, Taiwan and Thailand may not be directly transferable. One factor may be the possible presence of cyanide in some species of bamboo shoots.

The situation with regard to cyanide in bamboo shoots is, however, confused and under-researched. It seems that the main edible species of bamboo shoots used in China do not contain or do not contain much cyanide. It is certain that some species do. We need gradually to add to knowledge of this phenomenon. It is important in the search for improved international markets for bamboo shoots and for the contribution of bamboo shoots to food security in food-poor countries.

What is known about cyanide in plants.

It has been known for a long time that some species of bamboo from which bamboo shoots are derived can contain cyanide – or more properly a cyanogenic glycoside. Cyanogenic glycosides are present in more than 2000 different plant species. Sixty different types have been isolated. The cyanogenic glycosides are bitter to the taste but not poisonous by themselves (Nahhrstedt (1993). When plant tissue is disrupted (by cutting or browsing for example) tissue containing cyanogenic glycosides is hydrolyzed by a specific enzyme (glucosidase) to make glucose, an aldehyde or ketone and hydrogen cyanide (HCN). Normally, in live intact tissue, the enzyme is stored by the plant in a separate location to the glycoside. As soon as the tissue is cut off, the enzyme can get into contact with the cyanogenic glycosides thereby causing the rapid release of hydrogen cyanide. This binary system- two sets of components which are inert individually- comprises the "cyanide bomb" and plays a role in the chemical warfare of plants against herbivores, pests and pathogens. Nahrstedt (1993) notes that such compounds are disproportionately found in tissues with a high “value” to the continuing development of the plant such as tips and shoots.

Cyanide (a.k.a. hydrogen cyanide, prussic acid, or bitter almonds) is a potent metabolic poison. Cyanide is a small molecule composed of a carbon and nitrogen atom joined by a stable triple bond. This poison is best known for its inhibition of many enzymes that are important in animal metabolism. Cyanide most notably inhibits cytochrome oxidase, one of a group of enzymes important in cellular respiration. Respiration is the process by which both animals and plants break down glucose in the presence of oxygen to yield carbon dioxide and water and produce valuable energy to maintain cellular processes and growth. Without functioning cytochrome oxidase, respiration is inhibited. Cyanide binds tightly to the enzyme and permanently inhibits its functioning.

Cyanide is made as an anti-browsing compound to discourage plant consumers. Cyanide most often is attached to other molecules in the form of cyanogenic glycosides. An example of one such compound is amygdalin (from stems of cherry, apricot, etc., Prunus spp.). In this form, cyanide is nontoxic to the plant; only in the breakdown of cyanogenic glycosides, during animal consumption or digestion, is hydrogen cyanide gas released. For example, cows feeding on some species of grasses containing cyanogenic glycosides become ill as they chew on the grass. It is thought therefore that cyanide in nonlethal doses effectively deters browsing (Gibson 1984).

The cyanogenic glycoside present in bamboo shoots is taxiphyllin [2-(b-D-glucopyranosyloxy)-2-(4-hydroxyphenyl)acetonitrile]. Taxiphyllin is the cyanogenic glycoside also present in Yew foliage (Taxus spp).

Impact of food-based cyanide on humans

One key food plant that contains significant amounts of cyanide is Cassava. Use of cassava roots as a primary food source has led to high blood cyanide levels in some people in tropical countries. Cyanide can and does cause significant health problems at sub-lethal levels. Some of the cassava-eaters in Africa have suffered harmful effects to the nervous system, including weakness of the fingers and toes, difficulty walking, dimness of vision, and deafness, but chemicals other than cyanide may have also contributed to these effects. Cyanide exposure from cassava was also linked to decreased thyroid gland function and goitre development. These effects have not been seen at levels of cyanide exposure usually found in foods in the developed world; however, some children who ate large quantities of apricot stones, which naturally contain cyanide as part of complex sugars, had rapid breathing, low blood pressure, headaches, and coma, and some died. There are no reports that cyanide can directly cause birth defects or reproductive problems in people. However, birth defects were seen in rats that ate cassava root diets, and adverse effects on the reproductive system were seen in rats and mice that drank water containing sodium cyanide. Other cyanide effects in animal studies were similar to those observed in people. There are no reports that cyanide can cause cancer in people or animals. The United States' EPA has determined that cyanide is not classifiable as to its human carcinogenicity (ability to cause cancer). (Agency for Toxic Substances and Disease Registry, 1997).

How do bamboo shoots compare with other plant materials containing cyanide?

Comparisons are difficult. There are very few published reports. Researchers are inconsistent in how they report cyanide contents and in the units of measurement used. Some report HCN, others cyanogenic glycosides and others Taxiphyllin. Units of measurement vary from milligrammes per 100 grammes to milligrammes per kilogramme. Note that those reporting mg/100g (Tables 1 and 4) are reporting levels 10 times higher than mg/kg (Table 3). Conversions between the two seem, sometimes to lead to anomalies. In comparative tables, researchers usually report only one bamboo species and since there is considerable variability between bamboo species, the relative rankings are greatly affected by that choice.

Nevertheless, most workers report levels of cyanide compounds which place bamboo shoots amongst the most potentially toxic plant materials.

One of the more comprehensive reviews of cyanide compounds in plant materials was made by Nahrstedt (1993) – see Table 1. In this comparison the bamboo species tested was amongst the most toxic, exceeding apricot and bitter almond stones and considerably exceeding that of cassava.

Table 1 Cyanide in various plant materials (drawn from Nahrstedt 1993).

Plant	Part	mg HCN/100g fresh weight
Cassava	Leaves	77-104
	Bark of Tuber	69-84
	Inner part of tuber	7-33
Lima Bean	America white seed	10
	Java Coloured seed	312
	Puerto Rico seed	400
Sorghum	Fruits	0.6
	Etiolated tips of Shoots	240
	Young green leaves	60
Bamboo (*Bambusa vulgaris)*	Unripe stem	300
	Top of sprout	800
Flax	Linseed	21-54
	Seedling tops	910
Bitter Almond	Seed	290
	Young leaves	20
Apricot	Seed	40-400
Cherry	Seed	100
Cherry Laurel	Leaves	150

In another comparative list Professor Gibson (Gibson 1984) ranks bamboo shoots as only moderately toxic (Table 2)

Table 2 (drawn from Gibson 1984) Plant (relative cyanide level)

cassava (++++) Prunus spp. (+++) lima beans (certain ones,+++) sorghum (++) linseed (++) millet (++) bamboo shoots (++) sweet potatoes (+) maize (+)

Bradbury and Haque (2002) also compare various species (table 3). In their comparison, bamboo shoot is once again amongst the most toxic.

Table 3: Total cyanide contents (mg HCN equivalents/kg plant material) of plants/foods/feeds using acid hydrolysis.

Plant material	Total cyanogen contents (ppm)

Flax seed meal	390
Cassava root	27
Sorghum leaf	750
Peach stone	710
Plum stone	696
Nectarine stone	196
Apricot stone	785
Apple seed (Fuji)	690
Giant taro leaf	29
Bamboo shoot (*B. arundinacea*)	1010

One of the reasons for such differences between comparisons may very well be that there is clear evidence for very significant between species variation amongst bamboo species in this trait. Chang and Hwang (1990) tabulate results for 7 different bamboo species (Table 4) which show that while three are totally without cyanogens, four contain significant quantities and the amount varies with season of harvest.

Common name	Scientific name given	Taxiphyllin (mg/100g)	
		Initial Harvest	Peak Harvest
Ma bamboo	*Dendrocalamus latiflours* Munro	1058	830
Launong	*Dendrocalamus giganteus*	690	378
Edible bamboo	*Bambusa edulis* (Odash) Keng	786	556
Green bamboo	*Bambusa oldhamii* Munro	700	410
Makino	*Phyllostachys makinoi* Hayata	-	-
Moso (any season)	*Phyllostachys pubescens* Mazel ex Houz Lehaie	-	-
Usawa Cane	*Pseudosasa usawai* Hay	-	-

Can anything be done to detect cyanide in bamboo shoots?

Fortunately, yes. There are now simple kits to determine the presence of cyanide in bamboo shoots. Together with colleagues, Howard Bradbury from the Australian National University has developed a range of practical kits that can be used by an unskilled person for looking at cyanide levels in cassava roots and products, as well as other cyanogenic plant parts such as sorghum leaves, bamboo shoots and flax seed meal.

The general principle is that a small sample of the plant or product is placed in a container with filter paper containing the required catalyst and a piece of picrate paper that reveals the amount of poison produced. The bottle is left overnight at room temperature. Next morning, when the breakdown to poisonous gas is completed, the colour of the picrate paper indicates the level of toxicity.

The researchers have also developed a similar kit for determining the amount of cyanide ingested after consuming cassava or other cyanogenic plants. Ingested cyanide is converted in the body to thiocyanate, which is excreted in the urine.

The kits are available free of charge to health workers and agriculturalists in developing countries, through funding from the Australian Centre for International Agricultural Research (ACIAR).

Can anything be done about cyanide in bamboo shoots?

The difference between bamboo shoots and cassava is instructive in this regard. The cyanogenic glycosides in cassava are linamarin and lotaustralin (Nahrstedt 1993). In Africa processing of cassava for food consists of peeling the tuber (the peel contains the highest amount of cyanide) and soaking the whole or sliced tubers in water for a time. This process does not completely remove the HCN and poisoning is common. In South America on the other had, the cassava is ground to a fine wet powder allowing optimal contact between poison and enzyme. The juice is squeezed out, expressing much of the cyanide. The residue is then cooked. This procedure produces an acceptably poison-free material.

The cyanogen in bamboo is taxiphyllin which is a p-hydroxylated mandelo-nitrile triglochinin and therefore one of the few of these cyanogenic compounds that decomposes quickly when placed in boiling water. Bamboo becomes edible because of this instability (Nahrstedt 1993). Ferreira et al (1995) found that boiling bamboo shoots for 20 minutes at 98C removed nearly 70% of the HCN while all improvements on that (higher temperatures and longer intervals) removed progressively up to 96%. Thus even the highest quoted figure (800 mg/100g) would be de-toxified by cooking for two hours.

Ferreira et al. (1995) give an equation of :-

HCN (left) = 800 +100(time) + 7(Temperature) – 74 (temperature squared) – 22 (temperature multiplied by time).

Thus eliminating the cyanide from bamboo shoots is something that should occur reasonably easily and as a by-product of preparation. However, if eating of bamboo shoots were to be encouraged in Africa as an adjunct to food security and if African methods of cassava preparation were to be emulated, difficulties might occur.

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