PROCEEDINGS

of the

FOURTH SYMPOSIUM

of the

INTERNATIONAL SOCIETY
FOR TROPICAL ROOT CROPS

held at CIAT, Cali, Colombia, 1–7 August 1976

Edited by
James Cock, Reginald MacIntyre, and Michael Graham

The International Society for Tropical Root Crops
in collaboration with
Centro Internacional de Agricultura Tropical
International Development Research Centre
United States Agency for International Development
Cock, J.
MacIntyre, R.
Graham, M.
International Society for Tropical Root Crops
CIAT
IDRC
USAID


UDC: 633.4(213) 
ISBN: 0-88936-115-0

Microfiche Edition $1
CONTENTS

Foreword  5
Society Council, 1976–79  6
Welcoming addresses  7
Participants  11

Section 1:  Origin, dispersal, and evolution  19
   Papers by:  Léon 20; Plucknett 36; Sadik 40; Martin 44; Mendoza 50;
               Kobayashi and Miyazaki 53; Degras 58; and Warid et al. 62
   Summary of discussions  65

Section 2:  Basic productivity  69
   Papers by:  Loomis and Rapoport 70; Holmes and Wilson 84; Ferguson and
               Gumbs 89; Dharmaputra and de Bruijn 94; Nitis and Suarna 98;
               Obighesan et al. 104; Ngongi et al. 107; Howeler et al. 113;
               Rendle and Kang 117; Mohan Kumar et al. 122;
               Edwards et al. 124; Wahab 131; Umanah 137; Montaldo and
               Montilla 142; Montilla et al. 143; Wilson et al. 146; Tanaka and
               Sekiola 150; and Sykes 151
   Summary of discussions  152

Section 3:  Preharvest and postharvest losses  155
   Papers by:  Lozano and Terry 156; Bock et al. 160; Mukiibi 163;
               Mukiibi 169; Terry 170; Ninan et al. 173; Leu 175; Terry 179;
               Obighesan and Matuluko 185; Bellotti and van Schoonhoven 188;
               Nyiira 193; Yaseen and Bennett 197; Pillai 202;
               Thompson et al. 203; and Albuquerque 207
   Summary of discussions  208

Section 4:  Utilization  211
   Papers by:  Christiansen and Thompson 212; McCann 215; Chandra and
               De Boer 221; Valdes Sanchez 226; Phillips 228; Oke 232;
               Delange et al. 237; Hew and Hutagalung 242; Khajarern and
               Khajarern 246; Varghese et al. 250; Hutagalung and Tan 255;
               Gomez et al. 262; Gregory et al. 267; Narrey 270;
               Nakayama et al. 274; and Jeffers 275
   Summary of discussions  277
profitability in the two countries. Gross margin is defined as: gross revenue minus cost (or imputed cost) of land preparation, planting, cultivating, and harvesting.

For Thailand the average revenue is $358/ha while the average cost of production (excluding purchased inputs, interest, and return on investment) is $84/ha, giving a gross margin of $274/ha. Because average farm acreage of cassava is 3.3/ha, the average farm gross margin derived from cassava is $898.72 from which other variable and fixed costs must be deducted. Comparable figures for Colombia are: cost $111/ha, returns $424/ha; and gross margin $313/ha. Thus, if gross margin is a good proxy measure for profit, it appears that cassava is more profitable in Colombia than in Thailand (on a per unit land basis). If, however, the length of the production cycle is considered, then production in Thailand appears to be more profitable. It may in fact be the Thai's ability to produce a crop of cassava every year that is the single most distinguishing factor of cassava production in Thailand. The annual production of cassava allows the farmer to utilize his land more fully, and enables him to annually alter his cropping pattern in response to emerging market conditions. Such flexibility is not generally possible with production cycles of more than one year, because some land will sit idle if harvesting occurs just prior to a dry season.

This paper has attempted to highlight major factors related to cassava production in Thailand, and to compare Thai production practices with those of Colombia. The analysis reveals no startling findings. Instead it suggests that the methods of production are fairly consistent in different areas of Thailand, albeit factors such as weather, credit, farm size, and method of field preparation appear to affect yield. Furthermore, the comparison of Thai and Colombian production practices suggests that any competitive edge in productivity that Thailand may enjoy is primarily related to a shorter growth cycle.

Thus, Thailand's preeminence among cassava producing countries is not the result of superior technology, but rather the result of superior application of technology that is readily available in many other countries.

The research for this paper was made possible by the generous assistance of the Division of Agricultural Economics (DAE), Royal Thai Ministry of Agriculture and Cooperatives, and the International Development Research Centre. Special thanks are owing to Somnuk Striplung, Chief DAE, and Apichart Pongsrihadulchâi, Thai Project Coordinator, for their efforts in this joint Thai-Canadian venture.


The Prophylactic Action of Cassava

O. L. Oke

Cyanogenic glycosides are toxic in large doses, but the body can cope with small doses, which are converted to compounds of high physiological activity, e.g. glucose, cyanate, and thiocyanate (used for sickle cell crisis and certain hypertension), salicylic acid and isomers (an antipyretic and analgesic), and hydrocyanic acid (a potent cytotoxin). Under certain conditions such as development of neoplasm or schistosomiasis, the cells affected contain high amounts of glucosidases or glucuronidases, which are capable of hydrolyzing the glycosides but are devoid of the enzyme rhodanese for converting the highly toxic hydrocyanic acid to the much less toxic thiocyanate. This therefore results in selective toxicity in which the cells are destroyed, but the somatic cells with high amounts of rhodanese survive. Since the diets of people in developing countries contain a lot of cassava high in cyanogenic glycosides, this might account for the prophylactic property that results in rarity of sickle cell anaemia and bowel cancer.

1Chemistry Department, University of Ife, Ile-Ife, Nigeria.
Hydrocyanic acid does not occur free in plants, but in many plant species, notably the Rosaceae and Leguminoscae families, it occurs in the form of cyanogenic glycosides, and is set free on hydrolysis. The hydrolysis can be brought about by acid in the digestive tract, or by endogenous enzymes in the plant released by damage caused during harvesting or the preparation of the material for food. The glycosides that will be discussed in this paper are those having either a mandelonitrile or ketone aglycon and that are a normal part of the biological experience or diet of the higher animals.

One thing that is common among these glycosides is that they all yield highly toxic aglycones. Therefore, it is not surprising that many studies have investigated the toxic effects of these glycosides (see Nestel and MacIntyre 1973). Thus ingestion of cassava (HCN) has been implicated as the cause of tropical ataxic neuropathy; rats fed cassava develop neuromuscular symptoms due to the HCN, which causes lesions in the central nervous system; several nitriles have been isolated from Lathyrus species, known to be the neurotoxin responsible for lathyrism, e.g. β-aminopropionitrile, β-cyano alanine; the aglycon methyl azoxy-methanol is known to account for some of the following neoplastic exhibitions in rats: renal adenocarcinoma, hepatic carcinoma, colonic carcinoma, and renal mesenchymal tumour. Ingestion of cassava (HCN) has also been suggested as the cause of goitre in man and in animals. Thiocyanate (arising from detoxication of HCN or from glucosinolates) may produce enlarged thyroids in animals, whereas the severe growth depression exhibited by pigs, chicks, and rats consuming raw ground rape-seed could be attributed to nitriles rather than the known goitrogens.

Since all cyanogenic glycosides give off hydrocyanic acid on hydrolysis, this gives a good method of estimating the content of these glycosides in plants. Oke (1966) found that cassava contains 16–40 mg HCN/100 g and that this varies with variety, environment, and age. Oke (1969) also found a high concentration in lima beans (40–60 mg/100 g), and small quantities in maize, guinea corn, millet, and cocoyam.

However, one aspect that has never been treated in detail is what happens when small doses of these cyanogenic glycosides are ingested.

**Ingestion of Cyanogenic Glycosides**

About 200 different compounds have been isolated from coffee and about 100 from oranges. Thus a cup of coffee at breakfast followed by a drink of orange may result in an intake of about 300 compounds, some of which may be toxic, but are detoxified by the body. Because cyanogenic glycosides occur in over 1200 known unrefined foods and grasses, early man, whose diet consisted mainly of whole nuts (which contain a lot of protein, fat, and vitamins), must have consumed a large amount of these glycosides. Over the generations the body had developed an effective mechanism for coping with the high intake of this compound. Thus under aerobic conditions in the presence of thiosulfate or colloidal sulfur, the enzyme rhodanese converts the toxic cyanide (HCN) to the much less toxic thiocyanate (SCN). Another pathway is through combination with hydroxocobalamin to form cyanocobalamin. Others include reaction with 3-mercaptopuorvate to form thiocyanate and pyruvate, and reaction with cystine to form cysteine and β-thiocyanooalanine. The details of these mechanisms have already been reviewed by Oke (1969).

We can therefore say that the cyanogenic glycosides are water soluble, essentially non-toxic, sugary compounds that occur extensively in many edible plants, especially the seeds. On hydrolysis by β-glycosidase, an enzyme produced by intestinal bacteria as well as the body, they yield glucose, hydrocyanic acid, and either benzaldehyde (or its analogue) or acetone. The hydrocyanic acid is detoxified by conversion to thiocyanate by means of the enzyme rhodanese, and in the presence of haemoglobin thiocyanate is converted to cyanate. The benzaldehyde is oxidized to benzoic acid (and subsequently hippuric acid) or salicylic acid isomers (in case of the glycosides with p-hydroxybenzaldehyde aglycon). Thus ingestion of this water-soluble complex compound has produced some metabolites of specific chemical compounds that are physiologically active.

(1) Thiocyanate, which is present in body fluids, has been widely used in both Germany and the United States as an effective agent for hypertension at serum levels upwards of 4 mg%. As far back as 1857, Bernard reported that thiocyanate had a depressant effect on animal hearts. One can therefore infer that certain aspects of hypertension (at least those
responsive to a serum level of thiocyanate of over 4 mg% induced by administering thiocyanate medically) are partially related to deficiency of thiocyanate (and hence cyanogenic glycoside) in the diet.

(2) It has been found that the efficiency of Urea IV solution used for sickle cell patients during crisis is actually due to the cyanate contained in it. Here is another case where adequate intake of thiocyanate (i.e. cyanogenic glycoside) in the diet is related to some ailment.

(3) Benzoic acid, originally obtained from beechwood bark, has certain antirheumatic and antiseptic properties and was widely used prior to the advent of salicylic acid. Salicylic acid is used as an analgesic, antiseptic, and for many other ailments. Again it is a metabolite and there is no question of dosage. Thus the deficiency of cyanogenic glycosides spells a concomitant deficiency in dietary salicylic acid and isomers and benzoates with their antiseptic, antirheumatic, and anti-inflammatory effects.

(4) Hydrocyanic acid is useful in the production of cyanocobalamin (vitamin B\textsubscript{12}) from the provitamin B\textsubscript{12} or hydroxocobalamin (B\textsubscript{12a}). In the presence of light the former is converted to the latter, which can then react with cyanide to regenerate vitamin B\textsubscript{12}. The great affinity of vitamin B\textsubscript{12a} for cyanide is due to the presence of cobalt in the molecule. Baxter et al. (1953) have shown that ampules of B\textsubscript{12} assumed to hold 100 mg of cyanocobalamin contained varying percentages of hydroxocobalamin (B\textsubscript{12a}). Undoubtedly some of the vitamin B\textsubscript{12} existing in the liver occurs in this form, the total amount being less than 100 mg (Drouette et al. 1953).

A closer look at this definition (which is more or less the definition of vitamins) might imply that these glycosides (in small doses) might be playing the role of a vitamin. Otherwise, why are certain diseases that were very rare in early man (who consumed as much as 8000 mg/day) or even in the so-called "primitive man" of underdeveloped countries now so very common among "civilized" man? A priori the main difference between the two types of man is their diet. An analogy is the case of scurvy among sailors in the late 19th century, which was later discovered to be due to the lack of vitamin C, which occurs extensively in citrus fruits and vegetables. Can it then be that changing from primitive food to refined food has resulted in the omission of some important dietary factors that now express themselves in the form of new diseases?

**Sickle Cell Disease**

Sickle cell disease is probably the best understood of the genetic blood disorders, and on the biochemical level it is probably the most completely understood disease of man. Pauling et al. (1949) have proposed that a surface region of the globin near the iron atom in the sickle haemoglobin (which is absent in the normal one) may, on deoxygenation, permit complementary interaction with other sickle haemoglobin causing alignment, birefringence, and distortion of the cell membrane (Castle 1974). He therefore referred to sickle cell anaemia as a "molecular disease," and further proposed that molecular diseases could be resolved by the proper supply of physiological and dietary substances. The most promising of these physiological substances are the hydrogen-bond breaking agents such as cyanate and thiocyanate. Levine et al. (1974) assessed the aggregation of sickle cell haemoglobin in the presence of various solutes and found that polymerization was inhibited by inorganic ions in the following order: Cl\textsuperscript{-}, NO\textsubscript{3}\textsuperscript{-}, Br\textsuperscript{-}, I\textsuperscript{-}, SCN\textsuperscript{-}, with thiocyanate being profound. The effectiveness of urea may be due to the cyanate being in equilibrium with the urea in solution.

Cerami and Manning (1971) and Manning et al. (1972) have shown that cyanate irreversibly inhibits sickling of red blood cells in vitro and extends the life span of treated sickle cells to near normal range in vivo (Gillette et al. 1971; Cerami 1972). The beneficial effect has been attributed to carboxylation, giving a protein with functional properties more like those of normal haemoglobin (Manning et al. 1972). Clinical trials with sickle cell patients in doses up to 35 mg/kg/day for 11 months have resulted in fewer crises, definite hematological improvement, and a decrease in the haemolytic anaemia without significant adverse effects (Gillette et al. 1972, 1974). However, since the repaired cells will be subsequently replaced it means a continuous carboxylation throughout life with sodium cyanate. In accordance with Pauling's hypothesis, there is a dietary factor missing that if supplied by the regular diet, would perform this function. Traces of cyanide in foods are detoxified to both cyanate and thiocyanate. Thus Goldstein
and Reiders (1951) detected cyanide and cyanate in the blood of dogs injected with toxic amounts of thiocyanate.

In developing countries where foodstuffs containing cyanogenic glycosides such as cassava, millet, lima beans, etc. still constitute the major part of the diet, the plasma thiocyanate content is usually about five times that of normal (Delange et al. 1973; Osuntokun 1973) and this coincides with the level obtained in those patients being treated with thiocyanate (Gillette et al. 1972). This therefore suggests that people consuming the glycosides should derive some benefit from them, and that this might even mask the HbS identity and prevent painful crises in those who have sickle cell anaemia. The amount of cyanide ingested will depend on the method of preparation of the food. The cyanate derived from these foods will be acting as a prophylactic.

Apart from cyanate (from cyanide in the tropical diet), another factor that might have contributed to the beginning nature of sickle cell anaemia in Africa is the effect of salicylic acid and its isomers, which are released along with hydrocyanic acid on hydrolysis of cyanogenic glycosides. This has been found to be active against sickle cell by Klotz and Tam (1973). In support of this it was found that the water extract of a local chewing stick Fagara zanthoxyloides used extensively in Nigeria instead of tooth brush and paste, contained some chemicals with antisickling properties (El-Said et al. 1971). Fractionation gave four fractions and the active constituent was shown to be 2-hydroxymethyl benzoic acid (Sofowora and Isaacs 1971).

Thus cyanogenic glycosides have many antisickling factors that are released on ingestion and like the Fagara root, these metabolites will have complementary, if not synergistic benefits.

Cancer

Cancer is a chronic disease, and like all chronic diseases, it should find therapeutic or prophylactic resolution by accessory food factors or vitamins that are common to the normal diet.

There are different forms of cancer but the most common one is that of the large bowel. This cancer, which can also be called social cancer, has a strong link with alternations in dietary habits. It is very common in industrialized countries and Higginson (1967) found that it was related to economic development. The incidence of bowel cancer is very low for African countries, e.g. in Accra with a total of 1192 cases of cancer only 1.8% were bowel, Nairobi 4206 and 2.5%; Dakar 1838 and 2.5%, respectively. Breener and Ackerman (1970) reported rarity of large bowel cancer and extreme rarity of intestinal polyps in Johannesburg Bantu. Burkitt (1971) sent questionnaires to hospitals in many parts of Africa asking for reports of cases; the replies confirmed its rarity.

Let us now consider what happens with neoplastic cells. Hydrocyanic acid and benzaldehyde are two very powerful cytotoxins which, when reacting together, give a powerful synergy several times (about 40 times) greater than the arithmetical sum of their separate toxicities. Otto Warburg found that fermentative metabolism rather than respiratory metabolism plays a large role in cancer. This uses less oxygen (in the free state) and hence oxidation of benzaldehyde occurs much more slowly in the neoplastic cells. Moreover, the neoplastic cells are devoid of rhodanese but are surrounded instead by another enzyme β-glucosidase, secreted by the cells that release the bound cyanide at the site of malignancy and so destroy the cancer cells. With the selective lag of both undetoxified cyanide as well as unoxidized benzaldehyde in the neoplastic cells and the multiplication of cytotoxicity that the combination affords, the neoplastic cells suffer a lethal cytotoxicity and kill the cancer cells while the hostal or somatic cells are totally unaffected — except in a beneficial manner. We therefore have a highly selective substance that shoots at the enemy only; toxic to the cancer cells and completely nontoxic to normal cells. In a series of experiments to determine the efficiency of amygdalin upon mice with spontaneous mammary tumours, scientists in Sloan-Kettering Institute of Cancer Research clearly demonstrated that it significantly inhibited the appearance of lung metastases and increased the inhibition of growth of primary tumours over the appearance of inhibition in untreated animals. This anticancer property has been confirmed in cell culture and in humans. The mechanism was first worked out by Krebs (1970). It will therefore not be surprising if it is found that cyanogenic glycosides are prophylactic against cancer.
Relationship to Other Diseases

If the above hypothesis on cancer is correct then the same principle should apply to other pathological cells that are rich in β-glucuronidases or β-glucosidases but lack rhodanese. A good example is schistosomiasis caused by infection of *Schistosomiasis haematobium* and *S. mansoni*. Patients with this disease excrete as much as 3.08 units/ml of β-glucuronidase compared to 0.95 unit for normal controls (Navarro 1965). Treatment with antimony tartarate causes activity of the enzyme to drop (Fripp 1960). Similar results have been obtained using amygdalin, especially with *S. japonicum* and most other blood flukes living in the blood stream where they can absorb the glycoside. Similarly, the application of amygdalin causes the egg production of *S. mansoni* to drop from 100-200 per day to zero. Krebs and McNaughton (1963) studied some species of snails such as *Helix pomatus* and found they possessed β-glucuronidase or β-glucosidase but lacked rhodanese. Therefore, they advocated exploring the clinical possibility of taking advantage of the selective action of amygdalin (cyanogenic glycoside). This has been done with very good results by Navarro (1965) with schistosomiasis.

Castle, W. B. Proc. 1st Natl. Symp. on Sickle Cell Disease, Maryland, 1974.