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A SURVEY OF TRADITIONAL METHODS EMPLOYED FOR THE DETOXIFICATION OF PLANT FOODS

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ABSTRACT.—From a survey of ethnobotanical reports a list of 216 species of lichens, fungi, algae and vascular food plants that are detoxified during processing was compiled. Major techniques of detoxification are categorized as heating, dissolution, fermentation, adsorption, drying, physical processing and pH change, and a classification scheme that contains details of the specific ways these techniques are employed is presented. An ancillary survey of chemical data indicates that detoxification is used to remove a range of potential toxins. The Cycadales, the families Araceae, Dioscoreaceae, and Fabaceae, plus *Quercus* spp. and *Manihot esculenta* stand out as taxa that are detoxified by people worldwide. Dense carbohydrates available in these plants may have motivated humans to develop detoxification techniques. Although their antiquity is unknown, these techniques may have played a role in the evolution of human dietary patterns.

INTRODUCTION

Although human food procurement is constrained by the same allelochemicals (secondary compounds) that make many plants unavailable as food for herbivorous animals, processing technology is one means employed by humans for making foods more palatable and less toxic. Selection for genetic changes during domestication risks exposing plants to attack by insects and plant diseases. By eliminating undesirable compounds subsequent to maturation of the plant we allow chemicals to play their natural role in defense during vegetative and developmental stages, thus ensuring a harvest for ourselves. Technological innovations, then, allow humans to circumvent the coevolutionary competition that characterizes plant-herbivore interactions (Harborne 1982).

The extent to which plant resources were eaten by early humans and our hominid predecessors is a concern that is relevant for understanding the evolution of the human dietary patterns (Milton 1987; Stahl 1984). Processing techniques for detoxifying wild and cultivated foods may have played an important role in early human food procurement by making plant foods more available. Cultural methods for dealing with toxins augmented the biological detoxication capabilities we share with other animals. Plants were probably always eaten by hominids but processing contributed to improving their dietary quality.

While the use of fire dates back to at least 500,000 years B.P. (Clark and Harris 1985; Isaac 1984), evidence from which to determine the antiquity of other traditional processing techniques is less available. The use of these techniques predates the origins of agriculture, indeed detoxification methods were probably important in allowing humans to interact with certain plant foods to the extent that they could begin a selection process leading to domestication. Study of processing techniques employed in historical times by agriculturalists and gather-hunter peoples, the mechanisms by which they function and their incidence patterns, may provide insights into the possible ways by which they developed. Modern industrial food processes have a partial function in detoxifying foods; these techniques have their roots in practices of the past.

Traditional detoxification techniques are essential to the subsistence of many people around the world, and their importance in specific instances both historically and in the present day has been noted repeatedly. The methods used globally to detoxify bitter cassava (*Manihot esculenta* Crantz.) have been the most extensively studied (Lancaster *et al.* 1982). Fewer authors have addressed detoxification as a general phenomenon (cf. Harris 1977; Hayden 1981). Through a compilation of individual cases, this study attempts to contribute to the understanding of the overall significance of this human activity.

While processing techniques have apparent value, little attention has been given to their efficacy (cf. Christiansen and Thompson 1977; Lancaster *et al.* 1982). Residual amounts of toxins may be present even when acute toxicity is eliminated, and their effectiveness may be relative. Cyanide poisoning, for example, continues to be a problem in many parts of the world in spite of cassava processing (Cock 1982).

Processing may eliminate nutrients along with toxins and requires greater evaluation from this perspective. In addition to cultural methods, humans have physiological ways for avoiding plant toxicity, but little is known about the relationship between the two. Microsomal enzyme activities may depend on nutritional status (Anderson *et al.* 1986). Where humans subsist on diets of limited diversity such as those dominated by cassava, greater evaluation of the risks and benefits of processed toxic foods are needed.

SURVEY OF TRADITIONAL PLANT DETOXIFICATION METHODS

Ethnobotanical reports from around the world were surveyed. One hundred and thirty-seven genera and 216 species from 65 families of lichens, fungi, algae and vascular plants that are used after some detoxification are listed in Table 1. While this survey is comprehensive it is not exhaustive. Although similar processing techniques are used in various other circumstances, this survey lists only those cases where it was explicitly stated that the plants were being detoxified or bitterness was being eliminated. Although the elimination of toxic and bitter constituents is the focus of this discussion, it must be recognized that processing techniques improve foods by making them more digestible or more palatable in several ways (Stahl 1988). For example cooking, soaking, grating and the addition of lye are used widely to soften foods. Increasing the digestibility of foods makes nutrients more available.

Table 1 includes known toxic chemicals reported from the plants of interest. It should be noted that any particular plant may contain a number of potentially toxic allelochemicals, and until more detailed chemical data are available the listed chemicals may only provide an approximation of what compounds are the subject of detoxification efforts.

Of the taxa in Table 1 certain ones are conspicuous. The Cycadales, the families Araceae, Dioscoreaceae, and Fabaceae, plus *Quercus* spp. (Fagaceae) and *Manihot esculenta* (Euphorbiaceae), are notable in their exploitation around the world and this because of the role detoxification has played.

Processing techniques eliminate a large range of allelochemicals representing a cross-section of the classes of chemicals found in plants. No pattern is apparent in these particular chemicals. Just the important taxa listed above include calcium oxalate, alkaloids, MAM (methylazoxymethanol) glycosides, cyanogenic glycosides, saponins, tannins, lectins and non-protein amino acids.

Why do humans bother to process certain plant foods and not others? People who utilize toxic plants exploit other plants which require little or no processing. Perhaps the answer lies in the fact that the major processed plants are all of widespread distribution and produce a reliable, recognizable and abundant food resource. The aroids, cycads, yams, acorns, and cassava are all important carbohydrate-supplying staples for various cultural groups. The legumes represent another source of abundant food. However, none of the major exploited legumes (e.g. beans, peas, and lentils), except edible lupines, require detoxification (other than cooking).

CLASSIFICATION OF TRADITIONAL PLANT DETOXIFICATION METHODS

Processing methods show marked similarities worldwide and are classifiable according to the way in which they function to eliminate toxins. Coursey's (1973) classification of cassava processing served as a basis for the more elaborate scheme presented in APPENDIX 1. Plants considered in Table 1 were classified according to this new scheme. The classification codes provide a convenient way to analyze individual cases of detoxification.

Heat, solution, fermentation, adsorption, drying, comminution, and chemical reaction due to pH change comprise the major means of detoxification. Many detoxification procedures involve more than one of these functions, and it is a matter of judgement as to the most important part of the process. The classification is hierarchical and designed so that the more important a part of the process is in the overall detoxification the higher is its decimal point. For example boiling of a food may involve both detoxification by heating and detoxification by solution. Either of the codes 1.12 or 2.27 is chosen over the other in specific cases where one function is considered the more crucial. The classification might be further complicated if, for example, the material is ground before it is boiled and/or if lye, acid, or clay is added to the water.

METHODS OF PLANT FOOD DETOXIFICATION

1. *Detoxification by heating.*—Heat provides energy to drive chemical reactions within foods and those between chemical constituents of a food and environmental chemicals such as oxygen. Toxins may be converted or degraded to less poisonous chemicals. Heat

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1.*

Plant Group Family Scientific Name Plant Part ( )	Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
Lichens										
Bryoria fremontii (Tuck.) Brodo & D. Hawksw. (P)	British Columbia	vulpinic acid X	X				X		2.1216	Turner 1977
Cetraria islandica (L.) Ach. (P)	Japan; N. temperate	X	X						2.2812	Tanaka 1976
Fungi										
Gyromitra esculenta Pers. ex Fr. (Fb)	Europe	gyromitrin X							2.121	Garnier et al. 1978 Tanaka 1976
Morchella esculenta Pers. ex Fr. (Fb)	Temperate region	X							2.121	Tanaka 1976
Algae										
Asparogopsis sanfordiana Harv. (T)		halogenated hydrocarbons	X				X		2.212	Moore 1977 Tanaka 1976
VASCULAR PLANTS										
Aizoaceae										

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1.* (continued)

Plant Group Family Scientific Name Plant Part ( )	Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
Glinus oppositifolius A.DC.		saponins								Hegnauer 1964
(P)	Philippines	X							2.11	Burkill 1985
Sesuvium portulacastrum L.		salt								Burkill 1985
(P)	W. Africa	X	X						2.2812	Burkill 1985
Tetragona tetragonioides	(Pallas) O.Ktze									
(P)	W. Africa	X							2.12	Burkill 1985
Alismaceae										
Alisma plantago L.		sesquiterpenoids, triterpenoids, choline								Oshima 1983
(R)	Eurasia					X			2.51	Hedrick 1919
Sagittaria cuneata Sheld.										
(T)	W. North America	X							2.12	Johnston 1970
Sagittaria latifolia Willd.										
(T)	E. North America	X							2.12	Hussey 1974
Amaranthaceae										
Achyranthes japonica Nakai										
(L)	Asia	X	X						2.2812	Tanaka 1976

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group / Family / Scientific Name	Plant Part ( )	Location	Chemistry	Processing Classification 1	2	3	4	5	6	7	Code	Reference
Amaryllidaceae												
Lycoris radiata Herb.	(B)	Japan	alkaloids		X						2.221	Wildman 1968; Tanaka 1976
L. sanguinea Maxima.	(B)	Japan			X						2.221	Tanaka 1976
L. squamigera Maxima.	(B)	Japan	alkaloids		X						2.221	Wildman 1968; Tanaka 1976
Anacardiaceae												
Corynocarpus laevigata Forst.	(SF)	New Zealand	nitropropanoyl glucopyranoses	X	X						2.251, 2.214, 2.2111	Moyer 1979; Hedrick 1919; Wright-St. Clair 1972
Semecarpus anacardium L.	(F)	Asia, Australia	pentadecylcatechols	X				X			2.13, 2.51	Hembree et al. 1978; Hedrick 1919
S. austaliensis Engl.	(F)	Australia		X							2.131	Cribb & Cribb 1975; Irvine 1957

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification	1	2	3	4	5	6	7	Code	Reference
Annonaceae												
Mezzettia leptopoda (Hook. f. & Thoms.) King	(T)	Malay Peninsula		X	X		X	X			2.31114	Skeat & Blagden 1906
Apiaceae												
Cymopterus fendleri A. Gray			furocoumarins									Yost et al. 1977; Hegnauer 1973
	(L)	W. North America		X							2.131	Steggerda & Edkardt 1941
Lomatium orientale Coulter &Rose	(R)	Arizona		X							2.131	Steggerda & Eckardt 1941
Cogswellia orientalis)												
Apocynaceae												
Apocynum spp.			cardiac glycosides									Hegnauer 1964
Apocynum angustifolium Wooton	(La)	New Mexico				X					2.4115	Castetter 1935

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Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification							Code	Reference
			1	2	3	4	5	6	7		
Araceae											
Alocasia macrorhiza Schott. *(Colocasia macrorhiza)*			cyanogenic glycosides proteinase inhibitors								Nahrstedt 1975 Sumathi & Pattabiraman 1977
	(St)	Australia	X	X				X		2.132, 2.212	Cribb & Cribb 1975; Irvine 1957
	(T)	Philippines	X							2.121, 2.131	Brown 1920
	(T)	New Caledonia	X							2.13	Tanaka 1976
Amorphophallus abyssinicus N.E.Br.	(T)	S. Africa	X	X						2.2711	Scudder 1971
A. aphyllus (Hook.) Hutch.	(T)	W. Africa	X	X			X		X	2.235, 2.1125, 2.235	Burkill 1985; Busson 1965
A. campanulatus (Roxb.) Blume.	(T)	India	X	X						2.2211	Singh & Arora 1965
	(T)	Asia, Philippines	X							2.121, 2.13	Hedrick 1919; Brown 1920
A. dracontioides N.E. Br.			saponins								Burkill 1985
	(T)	W. Africa	X	X				X		2.22222	Burkill 1985

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
A. glabra F.M. Bailey	(TFSt)	Australia	X							2.13	Cribb & Cribb 1975
A. lyratus Kunth	(T)	India	X							2.121	Tanaka 1976
Anchomanes difformis (Bl.) Engl.	(Rh)	W. Africa	X	X	X				X	2.31134	Burkill 1985
A. welwitschii Rendle	(T)	W. Africa	X	X						2.2211	Burkill 1985
Arisaema amurense Maxim	(R)	Asia	X	X				X		2.2111	Tanaka 1976
A. curvatum Kunth.	(T)	India	X	X	X					2.31112	Hedrick 1919
A. triphyllum (L.) Torr. *(Arum triphyllum)*	(T)	E.N. America	X				X	X		2.11, 2.5122, 2.132	Kuhm 1961; Harris 1890; Havard 1895
Arisarum vulgare Targ.	(R)	North Africa		X						2.22	Hedrick 1919
Arum maculatum L.			cyanogenic glycosides								Nahrstedt 1975
	(R)	Europe	X							2.11	Hedrick 1919
	(L)	Europe	X				X			2.28115	Hedrick 1919

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Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
Calla palustris L.	(R)	Europe; N. Asia; North America	X				X	X		2.112	Hedrick 1919
Colocasia antiquorum Schott	(L)	Australia	X	X						2.2812	Irvine 1957
C. esculenta (L.) Schott	(T)	W. Africa	X	X						2.224	Burkill 1985
	(T,St)	Pacific						X		2.61	Bascom 1965
	(T)	Australia	X							2.12, 2.13	Cribb & Cribb 1975
C. indica Hassk.	(T)	S. Asia	X							2.11	Hedrick 1919
Lysichiton americanum Hulten & St. John	(R)	W.N. America	X							2.121	Gunther 1973
Peltandra virginica Rafin. *(Arum virginica)*	(T)	E.N. America	X				X	X		2.514, 2.131, 2.12	Harris 1890; Hedrick 1919
Plesmonium margaritiferum Schott	(T)	India	X	X					X	2.28114	Tanaka 1976
Stilochiton lancifolia Kotschy & Peyr.	(L)	W. Africa	X	X						2.28112	Burkill 1985
	(Rh)	W. Africa		X					X	2.2611	Burkill 1985

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Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry	Processing Classification 1	2	3	4	5	6	7	Code	Reference
Symplocarpus foetidus Nutt.	(R)	E.N. America						X	X		2.131	Harris 1890
Typhonium angustilobium F.V. Muell.	(T)	Australia		X					X		2.132	Cribb & Cribb 1975
T. brownii Schott.	(T)	Australia		X					X		2.132	Cribb & Cribb 1975; Irvine 1957
T. trilobatum (L.) Schott	(Rh)	West Africa		X				X			2.11, 2.5	Burkill 1985
Areacaceae												
Ancistrophyllum secundiflorum (G. Mann & H. Wendl.)	(St,L)	W. Africa		X							2.12	Irvine 1952
Asclepiaceae												
Ceropegia bulbosa Rosb.	(R)	West Indes	cardiac glycosides	X							2.121	Hegnauer 1963 Tanaka 1976
Asteraceae												
Agoseris retrorsa Greene	(P)	W.N. Africa		X	X						2.2144	Zigmond 1981
Artemisia laciniata Willd.		Manchuria	terpenoids, polyacetylenes	X							2.121	Greger 1977 Tanaka 1976

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Plant Group Family Scientific Name	Plant Part ( )	Location	Chemistry Processing Classification							Code	Reference
			1	2	3	4	5	6	7		
Aster ageratoides Turcz.	(L)	Asia	X							2.12	Tanaka 1976
Balsamorrhiza spp.	(R)	W.N. America						X		2.61	Havard 1895
Hemizonia luzulaefolia DC	(S)	California	X							2.131	Tanaka 1976
Scorzonera hispanica L.	(R)	C. & S. Europe	X	X						2.2112	Hedrick 1919
Vernonia amygalina Del.			elemanolide lactones								Ganjian et al. 1983
	(L)	W. Africa	X	X			X	X		2.2811, 2.222, 2.121	Burkill 1985; Keshinro & Ketiku 1979; Busson 1965
V. colorata (Willd.) Drake			elemanolide lactones								Gasquet et al. 1985
	(L)	W. Africa	X	X						2.2811, 2.22	Burkill 1985
V. thomsoniana Oliv. & Hiern.	(L)	Gabon	X	X						2.2812	Burkill 1985
Brassicaceae											
Arabis glabra Bernh.			glucosinolates								Hegnauer 1964
	(L)	Asia	X	X						2.2812	Tanaka 1976
Dentaria spp.		America	glucosinolates								Hegnauer 1964

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Plant Group Family Scientific Name	Plant Part ( )	Location	Chemistry	Processing Classification 1	2	3	4	5	6	7	Code	Reference
Dentaria maxima Nutt.	(R)	North America		X		X					2.31113	Tanaka, 1976
Isatis tinctoria L.	(L)	China			X						2.211	Tanaka 1976
Senebiera coronopus Poir.	(P)	cosmopolitan		X							2.121	Hedrick 1919
Stanleya pinnata (Pursh) Britton	(L,St)	California		X	X				X		2.2144	Zigmond 1981
Capparaceae												
Boscia senegalensis (Pers.) Lam.	(S)	W. Africa	glucosinolates, alkaloids		X						2.211	Ahmed et al. 1972 Delaveau et al. 1973; Burkill 1985
Capparis retusa Griesb.	(F)	Chaco, South America		X							2.2812	Mêtraux 1950
C. salicifolia Griesb.	(F)	Chaco, South America	glucosinolates	X							2.2812	Ahmed et al. 1972 Mêtraux 1950
C. speciosa Griseb.	(S)	Chaco, South America		X	X				X		2.221222	Mêtraux 1950

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Plant Group Family Scientific Name	Plant Part ( )	Location	Chemistry	Processing Classification 1	2	3	4	5	6	7	Code	Reference
Cleome gynandra L. *(Gynandropsis gynandra)*	(L)	Tanzania	glucosinolates	X	X						2.22, 2.11	Hasapis et al. 1981; Ahmed et al. 1972 Burkill 1985
C. serrulata Pursh.	(L)	Arizona		X	X						2.2812	Steggerda & Eckardt 1941
Courbonia edulis Gilg. & Benedict	(F)	E. Africa	alkaloids	X							2.2812	Delaveau et al. 1973; Watt & Breyer-Brandwijk 1962
Maerua glauca Chiov.		S. Africa	alkaloids	X	X				X	X	2.28123	Taylor & Henry 1973; Scudder 1971
Thylachium africanum Lour.	(T)	E. Africa	glucosinolates, alkaloids	X							2.12	Ahmed et al. 1972; Delaveau et al. 1973; Weiss 1979
Celastraceae												
Celastrus scandens L.	(B)	United States		X							2.121	Tanaka 1976

TABLE 1. ***Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)***

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
Euonymus sieboldianus Blume	(L)	W. Asia	sesquiterpenester alkaloids X							2.121	Bruning & Wagner 1978; Tanaka 1976
Chenopodiaceae											
Chenopodium pallidicaule Aellen.	(S)	Peru		X						2.211	Gade 1970
C. quinoa Willd.	(S)	Andes, South America	saponins							2.221	Hegnauer 1964 Sauer 1950; Kroeber 1950
Cucurbitaceae											
Citrullus colocynthis (L.) Schrad	(S)	W. Africa	cucurbitacins X	X			X			2.212, 2.15	Hegnauer 1963 Burkill 1985
	(F)	S. Africa	X	X					X	2.2812	Hedrick 1919
Hodgsonia capniocarpa Ridl.	(S)	Malaysia	X							2.131	Tanaka 1976
Momordica balsamina L.	(S)	Australia	X	X						2.2511	Burkill 1985
	(F)	China		X				X		2.2111	Hedrick 1919
M. charantia L.	(F)	India, S.E. Asia		X			X			2.2111	Burkill 1985
	(F)	India		X						2.2511	Hedrick 1919

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
Cupressaceae											
Thuja orientalis L.	(S)	W. Asia								2.	Tanaka 1976
Cycadaceae											
Cycas sp.			MAM(methylazoxymethanol) glycosides								de Luca et al. 1980;
	(S)	Australia	X	X				X		2.211, 2.214	Warner 1958
C. circinalis L.	(S)	Guam	X	X			X	X		2.2221	Brown 1920
C. media R. Br.	(S)	Australia	X	X	X		X	X		2.2127, 2.233, 2.132	Cribb & Cribb 1975; Tanaka 1976
	(F)	Australia	X	X	X		X	X		2.2127	Irvine 1957
C. revoluta Thunb.	(St)	Trop. Asia	X					X		2.132, 2.64	Tanaka 1976
C. rumphii Miq.	(S)	Bay of Bengal	X							2.121	Bhargava 1983
	(St,S)	Oceania	X	X				X		2.2112	Barrau & Peeters 1972
C. thuarsii Guad	(St)	E. Africa		X	X		X	X		2.31212	Weiss 1979

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Plant Group Family Scientific Name	Plant Part ( )	Location	Chemistry	Processing Classification 1	2	3	4	5	6	7	Code	Reference
Dioscoreaceae												
Dioscorea spp.	(T)	E. Africa	saponins, alkaloids	X				X	X		2.28222, 2.31211	Takeda 1972; Karnick 1971; Weiss 1979
D. alata L.	(T)	Africa	saponins	X					X			Karnick 1971 Burkill 1985
D. bulbifera L.	(T)	Pacific	saponins, alkaloid: disocorine	X	X				X		2.2812, 2.231, 2.243	Takeda 1972; Willaman & Li 1970; Lessa 1977; Barrau & Peeters 1972; Bascom 1965
D. cochleari-apiculata De Wild	(T)	Africa			X						2.2	Burkill 1985
D. dumetorum Pax.	(T)	Africa	alkaloids, phenanthrenes		X		X		X	X	2.211, 2.213, 2.22, 2.43, 2.25	Willaman & Li 1970; El-Olemy & Reisch 1979 Coursey 1967

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
	(T)	Africa	X	X		X		X	X	2.222, 2.231, 2.261, 2.63, 2.431, 2.432	Corkill 1948
	(T)	Africa		X					X	2.271	Watt & Breyer-Brandwijk 1962
D. glabra Roxb.			saponins, alkaloids								Karnick 1971
	(T)	Bay of Bengal	X							2.121	Bhargava 1983
D. hispida Dennst. *(D. daemona)*			saponins, alkaloids								Karnick 1971; Willaman & Li 1970
	(T)	Malay Penninsula	X					X	X	2.1323	Skeat & Blagden 1906
	(T)	Cambodia		X			X	X		2.2326	Martin 1971
	(T)	Philippines		X				X		2.232	Brown 1920
D. latifolia Benth.	(T)	West Africa	X	X						2.2211, 2.2112	Labouret 1937; Busson 1965
D. praehensilis Benth.	(T)	C. Africa	X	X						2.2812	Burkill 1939
D. prainiana R. Kunth	(T)	Malaysia	X							2.111	Tanaka 1976

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name	Plant Part ( )	Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
D. preussii Pax.	(T)	W. Africa		X				X		2.232, 2.221	Busson 1965; Tanaka 1976
D. sansibarensis Pax.			alkaloids								Willaman & Li 1970; Burkill 1939
	(T)	Africa	X	X				X		2.213 2.253, 2.233	
Tamus communis L.			saponins, phenanthrenes								Takeda 1972; El-Olemy & Reisch 1979; Hedrick 1919
	(St)	Europe; Persia; N. Africa	X	X						2.2712	
Ebenaceae											
Diospyros spp.			naphthaquinones								Hegnauer 1966
D. oleifera Cheng	(F)	China								2.	Tanaka 1976
Elaeocarpaceae											
Elaeocarpus sp.			indolizidine alkaloids								Johns & Lamberton 1973
E. dentatus Vahl.	(F)	New Zealand	X				X			2.5111	Wright-St. Clair 1972

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry	Processing Classification 1	2	3	4	5	6	7	Code	Reference
Euphorbiaceae												
Elateriospermum tapos Blume.												
	(S)	Malaysia, Indonesia		X							2.121, 2.131	Tanaka 1976
Euphorbia lathyrus L.			igenane-type diterpene esters									Hecker 1977
	(S)	S. Europe		X						X	2.251	Hedrick 1919
Hevea brasiliensis Muell.-Arg.			cyanogenic glycosides									Hegnauer 1966
	(S)	S.E. Asia				X					2.311	Tanaka 1976
Jatropha curcas L.	(S)	Mexico		X							2.131	Dressler 1953
	(S)	Trop. America, Asia							X		2.61	Tanaka 1976
J. multifida L.	(S)	Trop. America, Asia							X		2.61	Tanaka 1976
Manihot esculenta Crantz.			cyanogenic glycosides									Hegnauer 1966
many methods of detoxification practiced worldwide												Lancaster et al. 1982
	(T)	Malay Penninsula		X	X				X		2.233	Skeat & Blagden 1906
	(T)	Congo					X				2.43	Miracle 1967

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification							Code	Reference
			1	2	3	4	5	6	7		
Mercurialis annua L.			cyanogenic glycosides								Hegnauer 1966
	(P)	Germany	X							2.121	Hendrick 1919
Fabaceae											
Abrus precatorius L.			lectins, alkaloids								Wei et al. 1974;
	(F,S)	Bay of Bengal	X							2.131	Mears & Mabry 1971; Bhargava 1983
Acacia albida Delile	(S)	S.Africa	X	X				X	X	2.28123	Scudder 1971
Canavalia obtusifolia DC											
	(S)	Australia	X	X				X		2.2113	Irvine 1957
Cassia occidentalis L.	(S)	W. Africa	X								Irvine 1952
Castanospermum australe A. Cunningh. & Fraser			octahydroindolizine alkaloid								Hohenschutz et al. 1981;
	(S)	Australia	X					X		2.131	Tanaka 1976
			X	X						2.234	Harris 1987
Crotalaria spp.			pyrrolizidine alkaloids								Mears & Mabry 1971
C. mucronata Desv.	(S)	E. Trop. Asia	X	X	X					2.2147	Tanaka 1976

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
Entada phaseoloides Merr.	(S)	Australia	saponins, entegenic acid X	X				X		2.233	Yasuraoka et al. 1977; Cribb & Cribb 1975
Erythrina veriegata L.	(S)	Trop. Asia	erythrina alkaloids X							2.131, 2.111	De Silva & Snieckus 1978; Tanaka 1976
Intsia retusa Kurz.	(F)	E. Malaysia	X	X				X		2.214	Tanaka 1976
Lupinus albus L.	(S)	Italy	quinolizidine alkaloids, saponins X							2.121	Mears & Mabry 1971; Hudson & El-Difrawi 1979; Hendrick 1919
L. hirsutus L.	(S)	Europe	quinolizidine alkaloids X							2.121	Batra & Rajagopalan 1978 Tanaka 1976
L. littoralis Dougl.	(R)	British Columbia	X							2.121, 2.151	Turner & Bell 1973
L. luteus L.	(S)	Italy	quinolizidine alkaloid X							2.121	Murakoshi et al. 1979; Tanaka 1976

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name	Plant Part ( )	Location	Chemistry Processing Classification	1	2	3	4	5	6	7	Code	Reference
L. mutabilis Sweet	(S)	Andes, South America	quinolizidine alkaloids, saponins	X	X						2.234, 2.211	Hatzold et al. 1983; Hudson & El-Difrawl 1979; Gade 1969; Sauer 1950
L. termis Forsk.	(S)	Mediterranean	quinolizidine alkaloids		X						2.211	Gabrial & Morcos 1976; Tanaka 1976
Mucuna sp.			proteinase inhibitors, canavanine									Mears & Mabry 1971; Bell 1971
M. cochinchinensis A. Chev.	(S)	Trop. Asia			X						2.211	Tanaka 1976
Neorautanenia spp.			rotenoids, pterocarpans									Brink et al. 1977
N. mitis (A. Rich.) Verd.	(R)	S. Africa		X	X			X	X		2.2182	Scudder 1971
Olneya tesota A. Gray	(S)	Mexico		X	X						2.2812	Felger & Moser 1976
Pachyrrhizus erosus Urb. (*P. angulatus* Rich.)	(T)	China		X							2.11	Hedrick 1919
Prosopis spp.			non-protein amino acids									Krauss & Reinbothe 1973

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
P. pubescens Benth.	(S)	W. North America	X		X	X				2.13, 2.3, 2.41	Castetter & Bell 1942
P. juliflora DC	(S)	W. North America				X		X		2.41141	Hodge 1907; Castetter 1935
Tamarindus indica L.			haemagglutinins								Toms & Western 1971;
	(S)	S. Africa	X	X				X	X	2.28123	Scudder 1971
Fagaceae											
Quercus spp.			tannic acid								Hegnauer 1966
	(S)	E. North America		X					X	2.261	Gilmore 1932; Waugh 1916
	(S)	W. North America	X	X				X	X	2.28123; 2.242	Zigmond 1981; Barrett & Gifford 1933; Gifford 1936
	(S)	W. North America		X		X		X		2.4123	Barrett 1952; Chestnut 1902
	(S)	Persia		X				X		2.232	Gifford 1936
	(S)	Japan	X							2.281	Gifford 1936
	(S)	Sardinia	X			X				2.4123	Gifford 1936
Q. chrysolepis Liebm.	(S)	W. North America				X				2.431	Gifford 1936

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	 2	 3	 4	 5	 6	 7	 Code	Reference
Q. garryana Dougl.	(S)	W. North America				X				2.431	Guther 1973
Flacourtiaceae											
Pangium edule Reinw.			cyanogenic glycosides								Hegnauer 1966
ex Blume	(F)	Malay Penninsula	X	X				X		2.233	Skeat & Blagden 1906
	(S)	Philippines		X						2.211	Brown 1920
	(S)	Trop. Asia, Micronesia			X					2.311	Tanaka 1976
Fumariaceae											
Corydalis ambigua Cham. &			protoberberine alkaloids								Hegnauer 1969
Schlecht.	(B)	Saghalin Is.		X		X				2.2712, 2.4112	Laufer 1930
Haemadoraceae											
Haemadorum coccineum			phenylenone								Hegnauer 1986
Hook. (*H. corybosum*)	(R)	Australia	X			X				2.41131, 2.41142	Grey 1841; Cribb & Cribb 1975; Laufer 1930

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group / Family / Scientific Name	Plant Part ( )	Location	Chemistry / Processing Classification	1	2	3	4	5	6	7	Code	Reference
Hippocastanaceae												
Aesculus spp.			saponins (escin)									Hegnauer 1966
A. californica (Spach) Nutt.	(S)	California		X	X				X		2.243, 2.333	Chestnut 1902; Zigmond 1981; Barrett & Gifford 1933; Barrett 1952
A. indica Colebr. ex Wall.	(S)	Himalayas			X						2.211	Hedrick 1919
A. turbinata Blume	(S)	Japan	saponins	X	X				X	X	2.262	Hegnauer 1966; Tanaka 1976
Icacinaceae												
Icacina spp.			diterpene alkaloids									On'okoko & Vanhaelen 1980
I. senegalensis A. Juss.	(T)	W. Africa			X	X			X		2.2326	Irvine 1952
Lamiaceae												
Ajuga nipponensis Makino	(L)	Japan	diterpene: ajugamarin		X						2.221	Shimomura et al 1981; Tanaka 1976

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry	Processing Classification 1	2	3	4	5	6	7	Code	Reference
Lauraceae												
Beilschmeidia bancroftii	(S)	Australia		X	X						2.233	Harris 1987
B. tarairi Kirk. (*Nesodaphne tarairi*)	(S)	New Zealand		X							2.121	Hedrick 1919
B. tawa Kirk. (*N. tawa*)	(F)	New Zealand		X				X			2.5111	Wright-St. Clair 1972
	(S)	New Zealand		X							2.121	Hedrick 1919
Endiandra pubens Meissn.	(S)	Australia	terpenoids	X	X				X		2.233	Bandaranayake et al. 1981; Cribb & Cribb 1975; Harris 1987
E. palmerstonii C.T. White	(S)	Australia		X	X				X		2.233	Cribb & Cribb 1975; Harris 1987
E. tooram	(S)	Australia		X	X						2.233	Harris 1987
Nectandra spp.			benzylisoquinoline alkaloids									Dos Santos & Gilbert 1975
N. rodioei Hook.	(S)	Tropical South America			X				X		2.222	Lévi-Strauss 1950; Kirchoff 1950

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
Umbellularia californica (Hook. & Arn.) Nutt.	(S)	W. North America	X					X		2.133	Chestnut 1902
Lecythidaceae											
Barringtonia asiatica (L.) Kurz.			saponins								Hegnauer 1966
(*B. racemosa*)	(S)	Bay of Bengal	X							2.131	Bhargava 1983
	(L)			X					X	2.261	Watt & Breyer-Brandwijk 1962
	(F)	Indochina	X							2.111	Tanaka 1976
Liliaceae											
Allium geyera S. Wats (*A. deserticola*)	(B)	Arizona	X							2.131	Steggerda & Eckardt 1941
Allium tricoccum Ait.			saponins								Hegnauer 1963
	(B)	E. North America	X				X			2.51, 2.52	Kuhm 1961
Asphodelus ramosus L.		Europe	X				X			2.12, 2.51	Tanaka 1976
Chlorogalum pomeridianum			saponins								Hegnauer 1963
Kunth.	(B)	W. North America	X							2.11	Harvard 1895

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
Ophiopogon japonicus Ker-Gawl.	(R)	Japan	saponins							2.	Hegnauer 1986 Tanaka 1976
Polygonatum spp.			saponins								Hegnauer 1986
P. lasianthum Maxim	(Rh)	Japan	X	X				X		2.222	Tanaka 1976
Zigadenus venenosus Wats.	(B)	California	veratrum alkaloids: zygadenine	X						2.2376	Windholz 1976 Ray 1963
Malvaceae											
Abutilon theophrastri Medik.	(S)	Asia		X				X		2.2116	Tanaka 1976
Meliaceae											
Owenia cerasifera F. Muell.	(F)	Australia			X					2.3	Irvine 1957
Moraceae											
Artocarpus gomeziana Wall.	(F)	Malaysia	X							2.111	Tanaka 1976

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
Myrtaceae											
Eucalyptus bicolor A. Cunn.	(S)	Australia	terpenoids	X						2.2216	Hegnauer 1969; Roth 1897; Cribb & Cribb 1975
E. largiflorens C.T. White	(S)	Queensland, Australia		X						2.22	Cribb & Cribb 1975
Olacaceae											
Ximenia americana L.	(L)	Australia	X							2.11	Cribb & Cribb 1975
	(S)	Indonesia	X							2.11	Brown 1920
Oleaceae											
Olea europaea L.	(F)	Mediterranean	oleunopein	X	X				X	2.3115, 2.2288, 2.2588, 2.71	Windholz 1976 Hartmann & Bougas 1970

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name	Plant Part ( )	Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
Orobanchaceae											
Orobanche cooperi (Gray) Heller	(St)	Mexico	X							2.13	Felger & Moser 1976
Oxalidaceae											
Oxalis tuberosa Molina	(T)	Andes, South America	oxalic acid	X				X		2.216	Sauer 1950
Pandanaceae											
Pandanus spp.	(F)	Australia	alkaloids, dimethyltryptamine X							2.131	Hyndman 1984 Cribb & Cribb 1975
Pinaceae											
Pinus spp.	(S)	North America	terpenes X							2.131	Havard 1895
P. ponderosa Dougl.	(S)	W. North America	X							2.131	Steedman 1930

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification	1	2	3	4	5	6	7	Code	Reference
Poaceae												
Gigantochloa apus Kurz & Munro	(Sh)	Indonesia	hydrogen cyanide	X							2.11	Hegnauer 1963 Tanaka 1976
Setaria sphacelata (Schum.) Stapf. & Hubbard	(S)	S. Africa	oxalic acid	X							2.12	Roughan & Slack 1973; Watt & Breyer-Brandwijk 1962
Polygonaceae												
Polygonum bistorta L.	(R)	N. temperate	tannins	X	X						2.2113	Hegnauer 1969 Hedrick 1919
Pontederiaceae												
Eichhornia crassipes Solms	(LF)	Asia	phenolic acids, flavonoids, tannins	X							2.15, 2.11	Hegnauer 1986 Tanaka 1976
Portulacaceae												
Lewisia spp.			saponins									Hegnauer 1969
L. rediviva Pursh	(R)	British Columbia		X							2.111	Steedman 1930

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
Proteaceae											
Hicksbeachia pinnatifolia	(S)	Australia	X	X						2.233	Harris 1987
Macadamia spp.			cyanogenic glycosides								Hamilton & Young 1966
M. whelanii F.M. Bailey	(S)	Australia	X	X						2.2113	Cribb & Cribb 1975; Harris 1987
Ranunculaceae											
Clematis spp.			ranunculin								Ruijgrok 1966
C. ianthina Koehne	(L)	Korea	X				X			2.12	Tanaka 1976
Ranunculus bulbosus L.			ranunculin								Ruijgrok 1966
	(R)	Europe	X							2.121	Hedrick 1919
R. eisenii Kellog	(S)	W. North America	X							2.131	Tanaka 1976
R. sceleratus L.			ranunculin								Misra & Dixit 1980;
	(L)	Japan, Eurasia	X							2.111	Tanaka 1976

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
Rhizophoraceae											
Bruguiera sp.	(F)	Oceania	tannins, tropane alkaloids X	X				X		2.2112	Barrau & Peeters 1972; Cribb & Cribb 1975; Saxton 1971; Barrau & Peeters 1972
B. conjugata Merr. (*B. gymnorhiza)*	(R)	Australia	X	X				X		2.223, 2.53	Cribb & Cribb *1975*
Rosaceae											
Potentilla tormentilla Neck.	(R)	N. Asia, Europe	tannins X							2.121	Hegnauer 1973 Hedrick 1919
Prunus campanulata Maxim.	(F)	W. Asia								2.	Tanaka 1976
Solanaceae											
Datura inoxia Mill. (*D. meteloides* DC)	(F)	W. North America	tropane alkaloids			X				2.41141, 2.41142	Hegnauer 1973 Castetter 1935

TABLE 1. ***Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)***

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification	1	2	3	4	5	6	7	Code	Reference
Lycium pallidium Miers.	(F)	W. North America		X			X		X		2.41252, 2.41251, 2.41242	Whiting 1939; Steggerda & Eckardt 1941
Solanum spp.			glycoalkaloids									Hegnauer 1973
S. X *curtilobum* Juz. & Buk.	(T)	Peru, Bolivia			X		X		X		2.366, 2.41152	Johns 1986; Werge 1979
S. gilo Raddi	(L)	W. Africa		X	X				X		2.22122	Keshinro & Ketiku 1979
S. jamesii Torr.	(T)	W. North America					X				2.41152, 2.4125	Johns 1986
S. fendleri A. Gray	(T)	W. North America					X				2.41152, 2.4125	Johns 1986
S. X *juzepczukii* Juz. & Buk.	(T)	Peru, Bolivia			X		X		X		2.366, 2.41152	Johns 1986; Werge 1979
S. simile F. Muell. *(S. semele)*	(F)	Central Australia			X						2.311	Irvine 1957

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
Taccaceae											
Tacca leontonpetalodes (L.) Kuntze. *(T. involucrata)*	(T)	W. Africa	taccalin X	X				X		2.112, 2.222	Scheuer et al. 1963 Busson 1965; Irvine 1952
(T. pinnatifida)	(T)	Pacific	X	X				X		2.222, 2.2121, 2.2112	Lessa 1977; Barrau & Peeters 1972; Bascom 1965; Hedrick 1919; Brown 1920
	(T)	Australia	X	X				X		2.2123	Cribb & Cribb 1975
Tiliaceae											
Tilia japonica Simonk	(F)	Japan, China	X							2.121	Tanaka 1976
Tropaeolaceae											
Tropaeolum tuberosum Ruiz & Pav.	(T)	South America	glucosinolates X					X		2.11, 2.24	Johns & Towers 1981; Sauer 1950

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification							Code	Reference
			1	2	3	4	5	6	7		
Urticaceae											
Urtica dioica L.	(L)	Europe	histamine, serotonin, acetylcholine X							2.121	Hegnauer 1973; Hedrick 1919
Valerianaceae											
Valeriana edulis Nutt.	(R)	W. North America	alkaloids: valerianin X							2.11, 2.13	Hegnauer 1973; Havard 1895; Hedrick 1919
Verbenaceae											
Avicennia marina Vierh.	(S)	Australia	X	X						2.214	Cribb & Cribb 1975
Zamiaceae											
Macrozamia spp.	(S)	Australia	MAM glycosides X	X						2.213, 2.2116	de Lucca et al. 1980; Cribb & Cribb 1975
M. fraseri Miq. *(M. macdonnelli)*	(StS)	Australia	X							2.214	Irvine 1957

TABLE 1. *Survey of Traditional Methods of Plant Detoxification. Each report is categorized for the seven basic techniques outlined in the text and coded according to the schema in APPENDIX 1. (continued)*

Plant Group Family Scientific Name Plant Part ( )		Location	Chemistry Processing Classification 1	2	3	4	5	6	7	Code	Reference
M. miquelii A. Dc.	(S)	Australia	X	X				X		2.112, 2.212	Tanaka 1976; Irvine 1957
M. spiralis Miq.	(S)	E. Australia	X					X		2.112	Tanaka 1976
Zamia sp.			MAM glycosides								de Lucca et al. 1980;
	(S)	Australia		X			X			2.2116	Grey 1841
Zamia chigua Cuatr.	(S)	Panama	X	X						2.2112	Duke 1970
Z. furfuracea Ait.	(R)	Mexico, Central America								2.	Tanaka 1976
Zamia pumila L *(Z. integrifolia)*	(T)	Caribbean		X						2.2	Palmer 1878
Zygophyllaceae											
Balanites aegyptica Del.			saponins								Hegnauer 1973
	(L)	Africa	X							2.121	Burkill 1985
	(S)	W. Africa	X							2.272	Busson 1965

*Plant Part: B = bulb; F = fruit; Fb = fruiting body; L = leaf; La = latex; P = plant; R = root; Rh = rhizome; S = seed; Sh = shoot; St = stem; T = tuber.

may also denature plant enzymes that are necessary to liberate certain active principals from glycosides such as glucosinolates or cyanogenic glycosides. However, in these cases liberation of active isothiocyanates and hydrogen cyanide, respectively, may subsequently be carried out by bacterial or endogenous enzymes. Proteinaceous toxins such as lectins and proteinase inhibitors are usually effectively denatured by heat.

Boiling and some form of roasting or baking are the most common cooking techniques used worldwide. Although many plant foods are eaten raw, most are cooked in some way. However, more often than not detoxification is not the explicit function of the cooking process. Roasting was perhaps the only cooking method used during most of human history since boiling requires watertight and heat-resistant containers. Many peoples solved the problem of applying heat to water by placing heated rocks directly in the contents of watertight but not heat resistant containers. Clay pots can be used for boiling foods, but it was the introduction of metal pots that greatly increased the distribution of this technique.

2. *Detoxification by solution.*—The use of water to remove toxins basically involves the dissolving of compounds in the water and their leaching from the food. The process is enhanced in specific and often sophisticated ways and takes many forms as is apparent in level 2.2 of APPENDIX 1. Heat accelerates the leaching process. When the solubility of a toxin is low a turnover of water, either by repeated pouring off and replacing, by placing the object in running water, or by passing water through a food, will help. Salt increases the polarity of the aqueous environment and can help in making certain compounds more soluble. Any process which causes more tissue to be exposed to the water or which liberates plant constituents by destroying the integrity of the plant cells will speed up leaching.

3. *Detoxification by fermentation.*—Simple fermentation techniques are part of the repertoire of detoxification of human groups worldwide. Microorganisms are ubiquitous and fermentation proceeds spontaneously under appropriate conditions. The metabolism of microorganisms alters the chemical composition of food. Basic techniques involve burying a food plant in the ground or in swamps, or enclosing it in some kind of container so that conditions conducive to fermentation can be achieved.

4. *Detoxification by adsorption.*—Chemical constituents in plants may be bound by physical and chemical processes to other substances. Charcoal is the standard detoxification substance used in cases of acute toxicity in clinical settings in modern medicine (Gilman *et al.* 1985). Both charcoal and clay are made up of small particles and have large surface areas. They undergo weak interactions with organic compounds, primarily through van der Waals and electrostatic forces. Clay mineral lattices may be charged (usually negatively) and adsorption of chemicals may also be by ion-exchange (Johns 1986).

Humans deliberately use the adsorptive properties of clay to bind toxins in food in ways that appear to be elaborations of the geophagous behavior of animals (Johns 1986). Detoxification basically involves adding clay directly to food plants during processing or at the time of ingestion, or soaking the plant product in wet mud.

5. *Detoxification by drying.*—Drying is likely to be an effective technique for removing volatile toxins from food and is usually used in combination with one of the other methods of detoxification. More often than not material is simply dried by placing it in the sun, although ovens or kilns are used in some circumstances.

6. *Detoxification by physical processing.*—Techniques such as grating, grinding, pounding, freezing etc. which break down the tissues of plants are collectively termed

comminution (Coursey 1973). Comminution will greatly enhance fermentation, solubilization and other processes. In methods that utilize the metabolic machinery of the plant cell comminution is a primary means of detoxification. Enzymes contained in the same tissue breakdown certain more stable allelochemicals such as cyanogenic glucosides or glucosinolates to release compounds which are volatile, water-soluble or heat labile.

Grating of cassava *(Manihot esculenta)* is a widespread mechanism for detoxifying bitter varieties of this important staple. Hydrogen cyanide, enzymatically liberated from cyanogenic glycosides, is released into the atmosphere during processing rather than while the plant is being chewed or digested. Processes employed with cassava are diverse and many are elaborate seemingly beyond necessity since comminution followed by enough time for the enzymatic reaction to occur is sufficient (Seigler and Pereira, 1981).

7. *Detoxification by pH change.*—Change in pH can affect the solubility of many chemicals. In addition acidic and alkaline conditions can lead to the hydrolysis of compounds.

The additions of ashes and acids to foods play important roles in a number of chemical processes affected by pH change. Although acid hydrolysis will degrade many organic compounds including glycosides and amides, concentrated acidic substances are rarely directly employed in traditional food processing. Acids formed during fermentation may contribute to the breakdown and/or the solubilization of some toxins. Acidic fermented products such as vinegar, and organic acids from fruits such as tamarind, are occasionally added to foods and may serve some role in detoxification. Pickling is carried out in combination with other techniques and may play a role in producing a final nontoxic product. Tamarind pulp is widely used in tropical regions as a flavor additive to food, although because of its acidity it may play other roles in altering food quality. Tartaric acid which makes up 10% of the weight of tamarind pulp (Windholz 1976) is a good organic buffer. A concentrated solution of tamarind that we tested had a pH of 2.5 although its buffering capacity was not assayed. We are familiar with three cases where tamarind is used to detoxify food. Two of these cases involve plants in the Araceae which may have high levels of calcium oxalate. Significantly tartaric acid may be effective in increasing the solubility of the highly irritating crystals (raphides) of this compound (Oke 1969). The third case of tamarind use with toxic plants involves roots of the legume *Neorautanenia mitis*. The genus is characterized by rotenoids and other toxic flavonoid derivatives.

Alkali materials in the form of lye from plant ash and mineral lime are readily available and widely applied. They participate in hydrolysis reactions of common chemical linkages such as ester and acetals. Ashes are usually used in solution, often with heat which greatly enhances the hydrolysis process.

It is known that interactions occurring when different chemicals are ingested together by animals may reduce the toxicity of one or both of them. The documented cases involve interactions of tannins with cyanogenic glucosides (Goldstein and Spencer 1985) and saponins (Freeland *et al.* 1985). There is no indication from the present survey that chemical interactions such as these are exploited by humans to detoxify foods. Many processes are subtle, and even when effective would not necessarily be understood or articulated by people practicing them. Further research examining the effectiveness of traditional processing must recognize the complexity of chemical systems and should be observant for more subtle ways by which humans may have exploited poisonous plants to their advantage.

THE ORIGIN OF FOOD PROCESSING TECHNIQUES

The question of how humans learned to detoxify plants in particular ways is difficult to answer. The ubiquity of the various techniques and their sophistication supports their antiquity. The use of clays for their adsorption properties has antecedents in animal behavior (Johns 1986). Heating, leaching, fermentation, and drying of foods all have simple cause and effect relationships with change in food palatability that could be observed in common events. Harris (1977) suggested that plants that are detoxified by leaching were originally used for fish poisons. Plants that had been left in streams could be subsequently discovered to be acceptable foods. Comminution of plants and the use of lye and salt to facilitate detoxification require greater sophistication. However, the use of tools is a longstanding human trait that would have been involved in detoxification since early in human history. Once tools were used to open nuts or other foods, refining the techniques to diminish the foods further is not a great leap for human beings. The use of salt in boiling would take place once boiling itself was established. Salt water could have been used initially in coastal areas simply because of its availability. The use of lye also would follow cooking, and ashes would be readily available from cooking sites. Perhaps hot coals or ash covered rocks were initially added only to heat water, but consequently were discovered to improve the food. The use of alkali and acidic substances in processing appears to represent the most sophisticated of the basic techniques.

A preference for nutrient dense foods such as animal protein and fats and concentrated carbohydrates in fruits, tubers and seeds has characterized the genus *Homo* (Milton 1987) and directed our technological achievements over the past 2 million years for scavenging, hunting and processing plant products. The energetic reward offered by dense carbohydrate sources would have provided a strong motivation for the development of detoxification processes and once a technology for detoxifying plant foods was established it is not surprising that deliberate elaboration using available resources would occur. Once the basic mechanisms of detoxification were widespread, their refinement to deal in sophisticated ways with particular plants was a function of human adaptability and intelligence. The adaptation of humans to exploit the resources of a new environment involves the application of detoxification techniques to utilize the available plant resources. Where human groups were in intimate association with a food resource over many generations it is not surprising that considerable refinements took place.

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APPENDIX 1
Classification of Traditional Plant Processing Techniques

2. No special detoxification techniques applied (subdivide as in Coursey, 1973)
2. Special detoxification techniques applied
    - 2.1 Detoxification by heat
        - 2.11 Unspecified cooking
            - 2.111 Cooking of whole pieces
                - 2.1111 Cooking without the addition of salt, lye, or acid
                - 2.1112 Cooking with the addition of salt
                - 2.1113 Cooking with the addition of lye
                - 2.1114 Cooking with the addition of acid
                - 2.1115 Cooking after drying
                - 2.1116 Cooking after soaking
            - 2.112 Cooking after comminution (Subdivide as for 2.111)
            - 2.113 Cooking after peeling (Subdivide as for 2.111)
        - 2.12 Boiling, stewing, etc. (Subdivide as for 2.11)
        - 2.13 Roasting, baking (Subdivide as for 2.11)
        - 2.14 Frying (Subdivide as for 2.11)
        - 2.15 Steaming (Subdivide as for 2.11)
    - 2.2 Detoxification by solution
        - 2.21 Soaking in static water
            - 2.211 Soaking or leaching of whole pieces
                - 2.2111 Followed by unspecified cooking
                - 2.2112 Followed by boiling
                    - 2.21121 Simple boiling (Subdivide as in 2.111)
                    - 2.21122 Repeated boiling in changes of water (Subdivide as for 2.21121)
                - 2.2113 Followed by roasting or baking
                - 2.2114 Followed by frying
                - 2.2115 Followed by steaming
                - 2.2116 Followed by drying
                - 2.2117 Followed by fermentation
                - 2.2118 Followed by pickling
            - 2.212 Soaking or leaching after comminution (Subdivide as for 2.211)
            - 2.213 Soaking or leaching after cooking and comminution (Subdivide as for 2.211)
            - 2.214 Soaking or leaching after cooking (Subdivide as for 2.211)
            - 2.215 Soaking or leaching after boiling with lye (Subdivide as for 2.211)
            - 2.216 Soaking or leaching after freezing (Subdivide as for 2.211)
            - 2.217 Soaking or leaching after drying (Subdivide as for 2.211)

- 2.218 Soaking or leaching after peeling or cutting (Subdivide as for 2.211)
- 2.22 Soaking with change(s) in water (Subdivide as for 2.21)
- 2.23 Soaking in running water (Subdivide as for 2.21)
- 2.24 Leaching (Subdivide as for 2.21)
- 2.25 Soaking in salt water (Subdivide as for 2.21)
- 2.26 Soaking with the addition of ashes or lye (Subdivide as for 2.21)
- 2.27 Soaking with the addition of acidic substances (Subdivide as for 2.21)
- 2.28 Boiling
  - 2.281 Boiling of whole pieces
    - 2.2811 Simple boiling
      - 2.28111 Without salt, lye, or acid
      - 2.28112 With salt
      - 2.28113 With lye
      - 2.28114 With acid
      - 2.28115 After drying
    - 2.2812 Repeated boiling in changes of water (Subdivide as for 2.2811)
  - 2.282 Boiling after comminution (Subdivide as for 2.281)
  - 2.283 Boiling after peeling (Subdivide as for 2.281)

2.3 Detoxification by fermentation

- 2.31 Spontaneous fermentation
  - 2.311 Fermentation of whole pieces
    - 2.3111 Without previous treatment
      - 2.31111 Followed only by washing
      - 2.31112 Followed by washing and heat treatment
      - 2.31113 Followed by heat treatment
      - 2.31114 Followed by comminution
      - 2.31115 Followed by drying
    - 2.3112 After cooking (Subdivide as for 2.3111)
    - 2.3113 After boiling with lye (Subdivide as for 2.3111)
    - 2.3114 After soaking (Subdivide as for 2.3111)
    - 2.3115 With addition of salt (Subdivide as for 2.3111)
  - 2.312 Fermentation after communition (Subdivide as for 2.311)
- 2.32 Fermentation with use of inoculum from earlier preparations (Subdivide as 2.31)

2.4 Detoxification by adsorption

- 2.41 Addition of clay
  - 2.411 Addition to whole pieces
    - 2.4111 Addition during soaking
      - 2.41111 Addition without previous treatment
      - 2.41112 Addition after cooking
    - 2.4112 Addition during boiling (Subdivide as for 2.4111)
    - 2.4113 Addition during cooking (Subdivide as for 2.4111)
    - 2.4114 Addition during comminution (Subdivide as for 2.4111)
    - 2.4115 Addition to consumed product (Subdivide as for 2.4111)
  - 2.412 Addition after comminution (Subdivide as for 2.411)
- 2.42 Addition of charcoal (Subdivide as for 2.41)
- 2.43 Soaking in wet mud
  - 2.431 Soaking of whole pieces

2.432 Soaking after comminution
2.5 Detoxification by drying
2.51 Sundrying
2.511 Drying of whole pieces
2.5111 Sundrying followed by cooking
2.5112 Sundrying followed by soaking
2.5113 Sundrying followed by fermentation
2.5114 Sundrying followed by comminution
2.512 Drying after comminution (Subdivide as for 2.511)
2.52 Kiln or hot-air drying (Subdivide as for 2.51)
2.6 Detoxification by physical processing
2.61 Peeling
2.62 Grating or rasping
2.63 Squeezing
2.64 Pounding
2.65 Grinding
2.66 Cutting
2.7 Detoxification by pH change
2.71 Lye or lime added
2.72 Acidic substance added