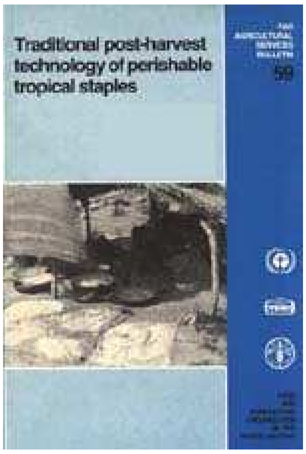

Traditional post-harvest technology of perishable tropical staples

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Contents

Foreword

This Bulletin reviews the limited amount of information that has been recorded relating to the post-harvest technologies of the perishable (non-grain) staple foods that have been developed in the traditional societies of the developing countries of the tropics. These foods are derived primarily from the tropical root crops; cassava, yam, sweet potato and the various aroids; from fruit such as banana and breadfruit; and from the starch reserves laid down by various monocarpic plants (mainly palms such as sago).

The production of this document was originally conceived in a series of informal discussions, initially between Dr. Nay Htun of the United Nations Environmental Programme (UNEP) and one of the present authors (Dr. D.G. Coursey), and gained further justification from one of the conclusions reached at the FAO/UNEP Expert Consultation on "Post-Harvest Losses in Perishable Foods of Plant Origin" (Rome, 1980), which stated:

"Traditional effective methods for preventing and reducing post-harvest losses need to be identified and exploited; this includes maintenance of continuous supply, storage for restricted periods, and transformation to durable products. Some valuable traditional technologies for food preservation are in danger of becoming lost because they are being superseded by more sophisticated methods of doubtful! long-term value. Modern and technology intensive methods should be applied appropriately according to prevailing conditions including cultural factors. Efficient and proper management of such technologies is as important as the types of equipment and facilities selected".

The present publication is a joint effort by the United Nations Environment Programme (UNEP), the Tropical Development and Research Institute (TDRI) and FAO. It is hoped that this document will be of value in indicating the importance of the subject, so acting as a stimulant for further studies and application of traditional technologies.

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Chapter 1 Introduction

Most studies on post-harvest technology have so far concentrated on grains and other durable products, which are stored dry and a substantial technology has been developed to deal with these problems. Much less work has been undertaken on the perishable food crops, yet they are of great importance in many parts of the humid and sub-humid tropics and contribute the staple carbohydrate portion of the diets of some 500-700 million people in the developing countries.

The socio-cultural background to the societies whose material sustenance depends primarily on these staples is also discussed, with emphasis on their ecocentric rather than technocentric philosophies. It is considered that in many cases the traditional technologies, developed in the distant past within subsistence agricultural societies, may be especially appropriate, as is considered further in Chapters 3 and 4. During the last decade or so, much effort has been devoted by bilateral and multilateral aid agencies to investigations and action programmes in the post-harvest sector using such terminologies as "rural technology", "grass roots technology", "small-scale technology", "intermediate technology", or "appropriate technology", but the greater part of the conceptual philosophy of such work has been derived primarily from the conventional scientific approaches of the developed world and has neglected the very considerable corpus of knowledge that has been accumulated in traditional societies, relating to their crops, over the past centuries or millennia.

In the case of the tropical perishable staple foods, which have no close analogues in temperate zone agriculture, this neglect of the traditional wisdom is especially unfortunate, as the underlying philosophies of the cultures in which they are extensively grown are not, to use the terminology of Swift (1979), so much pre-Galilean as non-Galilean, and are extremely alien to those of Europe, within which scientific thinking developed (Coursey, 1976; 1978a) as is discussed further in Chapter 4. The main theme of this document is that this store of traditional knowledge, especially of the post-harvest technology of these perishable staples, has remained largely untapped, but possibilities nevertheless exist for the interaction of modern scientific concepts with these traditional systems. The subject has already been discussed briefly by one of the present authors (Coursey, 1981a; 1982), while recently there has been a development of interest (Howes and Chambers, 1979; Swift, 1979) in giving consideration to the value of the indigenous technical knowledge in various fields.

This document sets out to review what is known, or at least what has been recorded (which, regrettably, is much less) of the post-harvest technology of the perishable, non-grain staple foods of the tropical world, as understood within the cultures which are primarily dependent on them. These are predominantly the indigenous cultures of the humid, low-altitude tropics, to which the majority of the vegetatively propagated food crops belong and within which they are often at an ecological advantage compared with grains (see Chapter 2). Attention is also given to the specific role of women in the post-harvest technology of the perishable staples but little firm data is available on this subject.

The document is fully referenced, as far as possible, from material that itself provides good sources of further reference material.

Chapter 2 The major tropical perishable staple foods

Overall, in the less developed countries of the tropics, as in the temperate world, the most important staple foods, i.e. those which provide the carbohydrate or calorific basis of diets, are the grain crops, but the tropical world, in particular, includes a great variety of ecosystems, typified by widely differing food production systems. Especially in the humid and sub-humid tropics, a large proportion of the staple food is derived from crops other than grains. These non-grain, perishable staples are estimated to provide the dietary base for between 500-700 million people across the tropics. Recent FAO statistics indicate a higher relative importance of perishables in the tropics than in the temperate world (AGS Bulletin, No. 43, 1981; Coursey, 1982).

These perishable staple foods are very largely produced from small-scale subsistence level systems and the technologies employed in both production and utilization are usually simple and founded on long-established traditional practice. The most important are the root crops; cassava, yams, the various aroids, sweet potatoes and white potatoes (Coursey and Haynes, 1970), the total production of which is now around 185 million t/a; fruits such as cooking bananas, (plantains) and breadfruit are also important, still the former being a major food with a world production of over 20 million t/a, while a proportion of the dessert banana crop also is eaten as a staple, cooked while unripe (Burden and Coursey, 1977); there are also crop products derived from vegetative organs such as stem starches of palms and other types of plant.

The principal crops in this group are listed in Table 2.1, which also includes estimates of total production within the developing countries, derived as far as possible from FAO sources but supplemented from personal knowledge of one of the writers (D.G.C.). It should be noted that much larger quantities of white or Irish potato and of sweet potato are produced in temperate countries than in the developing countries. White potatoes, being familiar from the extensive literature of the temperate zone will not be considered in this report.

Under humid tropical ecosystems the perishable staple crops are often far more productive than grain crops, whether in terms of production of tonnage, economic return or available energy per hectare per year (de Vries et al., 1967) as is shown in Table 2.2, derived from Johnston (1958). Especially in the case of cassava and plantain, these crops require a lower labour input to provide a given amount of food than any other crops (Coursey and Haynes, 1970)- The labour input to sago-based food production systems also appears very low (Stanton and Flach, 1980). A schematic layout, originally due to Coursey and Booth (1977) of a system under which these staples can be classfied, is given in Table 2.3.

It is not proposed in this report to give full detailed accounts of the botany or agronomy of these crops; it is assumed that the reader will be familiar with them. Reference can be made to such general works as Purseglove (1968; 1972); Cobley

(1976) or Leakey and Wills (1977), or for more detail to crop-orientated monographs such as Jones (1959); Montaldo (1979); Coursey (1967); Simmonds (1962; 1966); Edmond (1971); Yen (1974); Ruddle et al. (1978) and Stanton and Flach (1980) .

Although the perishable staple food crops are, as already indicated, essentially crops of the humid or sub-humid equatorial and tropical regions, their ecological requirements vary considerably. At one extreme, the Metroxylon sago palms and some cultivars of Colocasia flourish under swamp or even flooded conditions: other edible aroids, some yams, plantains and breadfruit and sweet potatoes are well adapted to semi-continuous production under conditions of high rainfall with only a minimal dry season: at the other extreme, other yam species are essentially seasonal crops of the derived savanna and require a pronounced dry season for full development of dormant and, therefore, long-storing tubers. Sweet potatoes and some aroids can also be produced in the savannas, either under irrigation or as rainy season crops, the former is also grown at relatively high altitudes. Cassava is the most ubiquitous and will grow almost anywhere where there are no severe frosts, a reasonable growing period above 20°C, at least 800 mm of annual rainfall and an absence of waterlogging or extreme salinity. The relative ecologies of the main perishable staple food crops have been discussed by Flach (1979) and Wilson (1977). The different optimal ecologies for growth of a crop can affect the type of post-harvest technology most likely to be appropriate for its products.

TABLE 2.1: The Principle Perishable Staples of the Tropical World

Common Names	Botanical Names	Estimated Production In Developing Countries Megatonnes/a
Cassava (tapioca, manioc, mandioca or yuca)	Manihot esculenta Crantz (often, incorrectly, M. utilissimma, Pohl.)	100-120
Yam (igname, name)	Dioscorea rotundata Poir, D.cayenensis Lam., D. alata L., D. esculenta (Lour.) Burk. and many minor Dioscorea spp.	18-22
Sweet potato (batata)	Ipomcea batatas (L.) Lam.	15-20
Potato	Solanum tuberosum L. (and S. tuberosum X S. andigenum crosses)	25-30
The edibile aroids:		
Taro, dasheen, eddoe, "old cocoyam"	Colocasia esculenta (L.) Schott	
Tannia, ocumo, "new cocoyam"	Xanthosoma sagittifolia (L.) Schott	4-6
Elephant yam	Amorphophallus campanulatus (Roxb.) Blume	
Giant taro, swamp taro	Cyrtosperma spp. Alocasia spp.	
Plantains and other cooking bananas	Musa spp. (AAA, AAB and ABB cultivars	25-30
Breadfruit	Artocarpus altilis (Park) Fosberg	1-2
Ensete	Ensete ventricosa (Welw.) Cheasm.	about 1
Sago	Metroxylon sagu Rott., M. rumphii Mart. and several	1-2
Pandanus	Pandanus odoratissimus L.f less than 1 and some other species	

TABLE 2.2 Relative Production Cost of Staple Crops in West Africa (after Johnston, 1958)

Ranking	Per hectare	Per ton	Per 1 000 cal.
Cheapest	Plantain	Plantain	Plantain
	Millet	Cassava	Cassava
	Maize	Sweet Potato	Sweet Potato
	Sorghum	Cocoyam	Maize
	Rice	Yam	Cocoyam
	Cassava	Maize	Sorghum
	Cocoyam	Sorghum	Millet
	Sweet Potato	Millet	Rice
Costliest	Yam	Rice	Yam

TABLE 2.3 Classification of Staples (after Coursey and Booth, 1977)

STAPLE FOODS (i.e. predominantly carbohydrate)
GRAINS
PERISHABLE STAPLES
REPRODUCTIVE ORGANS
(e.g. fruits: plantains, cooking bananas, breadfruit)
VEGETATIVE ORGANS
STEMS
(reserves for flowering in mono carpic spp., e.g. sago, ensete)
ROOTS AND TUBERS
ORGANS OF DORMANCY (yams, potatoes, sweet potatoes, aroid root crops)
OTHER ROOTS
(cassava-tapioca)

Chapter 3 Basic principles of post-harvest technology of perishable food crop products: and the magnitude of post-harvest losses

The majority of studies so far undertaken in the whole field of post-harvest technology have been concerned with grains, grain legumes and other durable products which are stored dry, usually at moisture contents below around 12-14%. In these products, post-harvest deterioration is largely caused by the attack of external agents such as insects, moulds or rodents and does not arise from endogenous factors. Those investigations that have been undertaken on perishable crops have concentrated on the more typical, high-unit-cost horticultural products such as fruits and vegetables rather than on the low-unit-cost staple foods, Essentially different approaches are, therefore, necessary when dealing with the latter group of crop products and in many cases the traditional technologies, developed in the distant past within subsistence agricultural societies, may be especially appropriate. They were developed within societies subject to serious constraints on the material, and even more the energetic, resources available, and which were further, as indicated in Chapter 4, essentially ecocentric rather than technocentric in their philosophical orientation. There exist possibilities for the injection of modern scientific concepts into these traditional systems, although, most unfortunately, there has often been a tendency among those who have received a modern scientific education to reject traditional technologies as "primitive" and fit only to be displaced by sophisticated modern systems, although the latter may sometimes represent sub-optimal technologies for the situation (Coursey, 1978a; 1982). It is part of the purpose of this report to stimulate interest in these possibilities and their application.

The Essential Features of the Perishable Staples and of their Storage in the Fresh State

The more important of these essential characteristics are given in Table 3.1 in comparison with those of the better-known grains and other durables. This is based on a table prepared at the FAO/UNEP Expert Consultation of the Reduction of Food Losses in Perishable Plant Foods (AGS Bulletin, No. 43, 1981), but has been somewhat expanded by the present authors. Some of these aspects need further discussion, however.

It has already been mentioned that most of the crops being considered belong to the humid or at least the semi-humid zones of the tropics. Thus, in many cases, there is little seasonality of harvesting, and supplies of fresh food are thus available for most or all the year. Societies dependent on these crops can thus practice '"storage avoidance" - the spreading of crop production throughout a large part of the year and/or its processing into stable products immediately after harvest, or as in some cases leaving the crop standing in the ground after the optimal harvest date (a concept originally developed by Booth, 1974; 1982). Elaborate storage techniques were never developed and processing consists merely of detoxification where necessary, or of rendering the food into palatable form - often little more than simple cooking at the household level. This situation is in marked contrast to that of grain-based societies, where harvesting of the staple crop is confined to a limited period and storage for a whole year is needed.

Unlike the grains and similar crops, the perishable staples are all of inherently high moisture content, usually over 50% and often around 60% to 70%. This governs virtually all further considerations that bear on the post-harvest technology of these staple foods, whether in traditional or in sophisticated systems. In particular, consideration of this characteristic in each individual case must influence the fundamental decision: is a particular crop product to be stored, when it needs to be stored at all, in its natural fresh state, or is it to be processed soon after harvest into some more durable form? Processing may sometimes be necessary (e.g. with cassava and some yams) to eliminate toxicity, or to enhance the organoleptic acceptability of the food. In other circumstances, its primary function may be to render the food more easily transportable (for medium to long distance trade in food products among subsistence societies has been much more widespread (Lathrap, 1973; Coursey, 1978b) than is commonly realized). Alternatively, processing, most commonly some form of drying, may represent a means of eliminating the perishability from the fresh crop product by its conversion into a more durable, stable product, although any dried or other processed product will have its own storage problems, often comparable to those of the grains.

The carbohydrate element is normally economically the least highly valued portion of the diet, so all staple foods tend to be of inherently low-unit-value, although there is much variation in preference and, therefore, price between individual staples, depending on culture-historical and organoleptic factors. Nevertheless, carbohydrate foods are generally valued primarily on the basis of their calorific value: the perishables, which consist more than half of water, will normally have a lower unit-weight-value than staples of lower moisture content, such as the grains, though this may be offset by their greater productivity (Table 2.2). The perishable staples are also bulky and awkward to handle and have peeling and other preparation losses of as much as 10% to 30%. As perishables thus tend to be of low-unit-cost even when compared with other staples, the use of sophisticated techniques such as refrigerated or controlled atmosphere storage, often used for high-unit-cost horticultural perishable produce is generally precluded. Attention to simple traditional technology thus becomes especially appropriate.

The edible products of the perishable staples are living organs and remain so after being harvested; in most cases they exhibit relatively high rates of metabolic activity. The correspondingly high rate of respiratory activity needed to support this metabolism implies that throughout any storage period, part of the total mass of the organ is continually being converted from starch into carbon dioxide and water which are lost to the atmosphere. Appreciable weight loss from this process is thus inherent in any storage and ventilation is necessary so that adequate supplies of oxygen from the air are available for the respiratory process, and thus life, to be maintained. Similarly, storage life will always eventually be terminated by factors associated with the organ's natural biological function, as part of the plant from which it was derived. Organs of dormancy, such as most root crops, with storage lives measured in weeks or months, contrast with fruits and cassava roots whose inherent storage life is normally quite short, days, or at most weeks (Coursey and Proctor, 1975; Proctor, 1981).

It is thus necessary to consider the concept of inherent storage life, which is of fundamental importance in the understanding of the post-harvest behaviour of perishable staples in the fresh state. A great deal can be done to reduce postharvest loses in these commodities and to extend their storage life but there is always a limit beyond which they cannot effectively be kept. Beyond this limit, the produce is either shrivelled or rotted to destruction, or has been so changed by its endogenous metabolism as to have become totally unacceptable as food. As indicated, this inherent life is related to the essential natural biological function of the plant organ and may be only a few days, in the case of the most highly perishable soft fruit which are very susceptible to fungal attack especially when fully ripe and which quickly pass from ripeness to senescence or some leafy vegetables which easily wilt; while at the other extreme, organs such as the tubers of potatoes or yams can remain in the dormant state for several months before their storage life is finally terminated by sprouting. Between these extremes could be cited the more durable fruit such as citrus or bananas, but even here the life of the fruit as an acceptable item of food will eventually be terminated by the natural onset of senescence.

Perishable staples are of relatively low mechanical strength which is also related to the high water content. Soft fruit or leafy vegetables are conspicuously susceptible to mechanical damage but even such apparently rugged items as potatoes and yams are also extremely liable to mechanical injury (Coursey and Booth, 1977). Much attention needs to be paid to the preservation of the physical integrity of the produce: this is a field where the respect that the subsistence agriculturalist traditionally pays to his staple crops, contributes greatly to the success of his storage techniques.

To minimize post-harvest losses in perishable staples, the first essential is to maintain the physical and physiological integrity of the detached but still living plant organs, as losses arise from assaults on this integrity (Coursey and Booth, 1971, 1972; Coursey and Proctor, 1975). Secondly, the natural life may be prolonged - but only within limits - by the provision of optimal environments or by manipulation of the physiological state of the material. Thirdly, by the selection of material for storage that is entirely sound and also in an appropriate condition for storage. Summarizing, losses are minimized by choosing healthy material and keeping it healthy, but at the same time accepting that the life of all living material will eventually end. The factors that affect the storage life of perishable produce are discussed in more detail in the papers quoted above and by Coursey (1983).

The Magnitude of Post-Harvest Loses in Perishable Staples

Although the question of the magnitude of post-harvest loss in perishable commodities has been the subject of considerable debate during the last decade, little reliable information is yet available. Conservative loss estimates for stored grain and similar "dry" produce, as used by FAO in developing its PFL Programme, were about 10%. With the perishable crops it has been conservatively estimated from the limited data to be found scattered in the literature, together with what might best be described as anecdotal information (Coursey, 1972; Coursey and Booth, 1972; Coursey and Proctor, 1975; Coursey and Booth, 1977) that the total loss is of the order of 25%.

Even in the U.S.A. perishable produce has been described (Brody and Sacharow, 1970) as "the victim of phenomenally high waste because of incredibly poor handling practices", and "the loss rate as a result of multiple handling ... is frightful". An analysis of the situation in the U.S.A. over the previous thirty years (Pentzer, 1976) concluded that although there had been some reduction in post-harvest loss with: some commodities as a result of many years of research, with other commodities losses had actually become more serious, while a recent study (Harvey, 1978) found market losses of fresh produce in New York markets to range from as little as 1. 7% for apples to 22.9% for strawberries: of especial relevance to this report is that even under U.S. conditions the commodity which suffered the greatest market loss, after the very delicate strawberries, was ewe-et potatoes (15.1%).

In the developing countries of the tropical world, the situation is certainly worse than in the developed world, but even less hard information is available. A number of specific cases of both staples and other perishable produce were reviewed by Coursey and Proctor (1975), Proctor (1981) and Coursey (1983). Apart from the estimates already quoted of a total post-harvest loss in tropical perishables of around 25%, it was suggested by Parpia (1976) that in tropical Africa and India, losses in perishable foods are around 30%. The meeting concerning perishables held in 1977 by the U.S. National Academy of Sciences (N.A.S., 1978) worked, in the absence of any hard factual information, on the Delphi Principle of summarizing the estimates and guesses of a number of professionals of some authority in the field. Some of the figures produced by this process are given in Table 3.2, where they are compared with those in the T.P.I. (now T.D.R.I.) publications quoted. Probably the most useful outcome of these discussions, together with those that took place at the FAO/UNEP Expert Consultation in 1980 (AGS Bulletin, No. 43, 1981) was to etablish that the magnitude of post-harvest losses in fresh perishables is virtually impossible to quantify without reference to a particular commodity and individual situation. It is evident that under different conditions and length of storage and with different commodities, almost any loss figure between 0% and 100% may genuinely be found. Overall, losses of perishable staples are extremely serious and it is probable that the total loss of perishable staples in the developing world is between 10% and 30%, varying according to commodity and location-specific storage conditions. Each local situation needs investigation and analysis on a particular individual basis and broad global figures of loss such as have been quoted are of value mainly in indicating the magnitude of the problem that exists which in turn implies the need for urgent action. These loss figures would be far higher were it not for the widespread practice of storage avoidance with the perishable staples in traditional societies in the tropics.

Processing of Perishable Staples in Traditional Societies

The processing techniques adopted within traditional societies for perishable staple foods are usually extremely simple, in keeping with the ecocentric philosophies of most of these societies. As already indicated, processing is used either to eliminate toxicity, or to convert the more highly perishable food products,- i.e. those with extremely short storage life into more stable products. Only manual operations and manually operated equipment are considered in this publication. Mechanical devices are not considered as traditional but as improved methods which actually may reduce drastically the length of the processing and partially eliminate the tedious work. Traditional processing requires no special devices beyond pans, mats, woven basketry and wooden sticks and is, therefore, a low investment cost method.

Drying techniques are used for the manufacture of relatively stable, low-moisture-content products which may be more convenient for long-term storage or for transportation. As will be seen in Chapter 5, most of the perishable staples are sometimes dried, usually be slicing or chipping, sometimes followed by parboiling, drying and finally pounding or grinding into flour. The essential drying phase of the operation is usually carried out using some form of uncoated heat energy: most commonly sundrying is adopted, the sliced, chipped or occasionally grated material being spread out in the sun, usually on mats, or hard prepared surfaces, to minimize contamination. Little is understood of the nature of the drying process and few investigations have been made, except on cassava chips in the commercial context (Manurung, 1974; Best, 1978) which indicate that air flow may be more important than the degree of insolation. Alternatively, the "waste" heat from household fires lit primarily for cooking or other purposes may be used and in these cases some contribution to preservation may also be made by the insect-repellent effects of the smoke. Only in comparatively rare instances such as the manufacture of farinha or gari from cassava, are substantial amounts of heat energy, derived from wood fires, generated especially for the processing operation: even here, some initial removal of water is undertaken by pressure, e.g. by using the tipiti, which is a more energetically economical method of drying than the application of heat (Lancaster et al., 1982). In general, therefore, traditional processing methods for the manufacture of dried products make only minimal energy demands.

Detoxification, e.g. of cassava and some yams is most commonly undertaken by soaking the product, either whole, sliced or grated, in water. Most commonly, the running water of streams is used, but where this is not available, static water in pots or other containers may be used. In either case little or no energy is required by the processing. Soaking processes are also used, quite irrespective of the need for detoxification, to extract starch from the crop product, for use in various forms as food. Many traditional food processing operations involve what are loosely described as "fermentations" (Hesseltine, 1965; Hesseltine et al., 1967). Little is known of the actual nature of the processes involved, except in the case of the fermentation of cassava to make farinha or gari where a number of micro-organisms are known to be involved, but in other cases the changes that take place may be purely endogenous biochemical ones without the involvement of any exogenous micro-organisms. The function of these "fermentations" may include detoxification, as in the case of cassava; the development of sourness or acidity in the food material, for example under the influence of lactobacilli, which can enhance the storage life even of undried products such as the Polynesian ma-type foods (Cox, 1980a); or simply the development of preferred organoleptic properties. As with the other types of processing described, no significant external inputs of energy are required, although some proportion of the original crop product may be consumed or lost in the course of the "fermentation", in supporting the metabolic processes of the micro-organisms involved.

TABLE 3.2 Estimates of Post-Harvest Losses in Perishable Staples (%)

Commodity	**Early TPI Estimates[1]**	**NAS[2] (1978) Estimates**
Potatoes	8, 30	5-40
Sweet Potatoes	35-65, 95	55-95
Yams	5, 15	10-60
Cassava	—	10
Taro	12-15	—
Plantains	33	35-100

1. Coursey, 1972; Coursey and Proctor, 1975; Coursey and Booth,
2. NAS = National Academy of Sciences

Chapter 4 The ego-cultural nature of societies dependent on perishable staple foods

The majority of the societies that depend substantially on the perishable, non-grain, staple foods have developed, often in extremely ancient times, largely or entirely independently of the domestication of grain crops and the larger herbivorous animals in South-Western Asia that constituted the so-called "Neolithic Revolution". They belong within the tropical/equatorial world, rather than within the sub-tropics or temperate regions. Modern agricultural science has developed very largely within the culture-historical matrix of Western Europe and like most other areas of scientific thought and endeavour, its philosophy has been much interpenetrated by what should really be regarded as the folk ethnocentricism of the Western European peoples (Uchendu, 1970). Even when scientific thinking is applied in the field of tropical agriculture, its application has been deeply influenced by conventional "European" modes of thought, many of which are of nonscientific or pre-scientific origin. This situation has been exacerbated by the political and cultural hegemony which Western Europe has exerted over most of the world community from The Renaissance until very recent times, which has led to the false but widely held view that the cultural values of Europe (with its extensions in North America, Australasia, etc.) are inherently superior to those of other cultures. Modern Europe with its "Scientific Revolution" descended culturally through Renaissance and Medieval Europe from the Mediterranean cultures of ancient Rome and Greece, as indeed is evident in everyday social matters. Those Mediterranean cultures descended in turn through the Judaeo-Hellenic tradition and other cultural contacts from the still older cultures of the Nile Valley and the Mesopotamian region of South-West Asia. A continuous cultural-historical tradition thus exists, direct, even if of great time-depth, between modern Europe and the so-called "Neolithic Revolution" which took place in Mesopotamia or on the fringes of that region, some 10 000 years ago, when the initial domestication of the grasses that gave rise to the grain crops and of the animals that are still the basis of modern animal husbandry, took place (Coursey, 1976; 1978a).

Throughout the entire cultural history of modern Europe and its antecedents, grains, together with some leguminous plants and animal products, have been the major foods. The vegetable foods, the grains and pulses were all propagated from seed. As a result, the concept of "seed time and harvest" has entered deeply into the thinking of peoples in all of the civilizations that have developed within this culture-historical continuum. In these cultures, food is often instinctively and indeed symbolically and ritually identified with grain or its products, such as bread. Many of the pre-Christian religions of the Mediterranean cultures and of early Europe were based on a reverence for corn, while in more recent times, corn and bread have retained a cultural significance far beyond their nutritional role, within the framework of Christian symbolism (Jacob, 1944). To the present day, the originally Biblical term "daily bread" remains virtually a synonym for food within European-derived cultures. Vegetatively propagated crops were of little importance in these cultures prior to the introduction of the potato which when first introduced into Europe was a subject of much approbium and was adopted mainly by the most economically depressed social groups (Salaman, 1949). Although root crops were known, the radish being extensively grown in ancient Egypt and the carrot domesticated in Europe during Roman times, they were all seed propagated and were accommodated within the conceptual framework of grain crop agriculture. The vegetatively propagated staple food crops such as the tropical root crops and other sources of perishable staple foods that form the subject of this document were unknown.

The perishable staple foods are derived essentially from the vegetatively propagated food plants discussed in the previous Chapter 2, of which the tropical root crops are the most important. These are all essentially plants of the humid or sub-humid lowland tropical or equatorial regions, except for the potato and some minor root crops, derived from the highland tropics of the Andes; in recent years, some of those crops have spread into the more humid parts of the tropical savannas, or even to the temperate regions. The patterns of food production based on these crops have been appreciably influenced in comparatively recent history and especially during the last century, by contacts with peoples predominantly those of European origins. Nevertheless, the initial origins of these crop plants and the processes of domestication which first brought them into symbiosis with man as crops were independent of the Neolithic Revolution and its associated cultural concepts. The cultural patterns that have developed in the tropical/equatorial regions based on perishable staples are perhaps most clearly seen today in the yam-orientated cultures of West Africa (Coursey and Coursey, 1971) and Melanesia (Barrau, 1970; Coursey, 1972; Tuzin, 1972; Yen, 1973a) but there is evidence for the existence, at a very early stage of human history, of "a continuous ring of gardening cultures", based on the use of vegetatively propagated crops, extending right across the tropical/equatorial zone of the Old World (Lomax and Berkowitz, 1972). This cultural continuum has been largely destroyed by incursions of grain-based cultures into Northern and Eastern Africa, the Middle Eastern area, India, the Indo-Chinese peninsula and Indonesia, several thousand years ago, but nevertheless more recent than the original domestication of either grain or root crops. In these intervening areas, except amongst a few relict peoples, cultural patterns associated with yams and aroids have declined very greatly under the influence of cultures descended from the Neolithic Revolution, but at the two extremities of this former continuum, the earlier root crop orientated cultures have survived. In West Africa, the ancient yam cultures have retained their traditional structure until recent years while assimilating the introduction of cassava. In Oceania, root crops, notably yam and taro, have remained predominant in Melanesia and also accompanied the Polynesian migrations which started from the South-East Asian mainland to the furthest islands of the South Pacific (Barrau, 1965a; 1965b).

Similar evolution of cultures with root crops as their nutritional base, took place independently in early pre-Colombian times in tropical/equatorial latitudes in the New World where Xanthosoma, sweet potato and, most importantly cassava were domesticated, paralleling in many ways the yam and Colocasia cultures of the Old World. Likewise, also paralleling Old World history, destructive culture contact took place in northern South America, firstly with indigenous Amerindian maize cultures and secondly, and even more disruptively, subsequent to European contact, following Colombus' "discovery" of the Americas in 1492. This latter contact, however, has facilitated the dissemination of New World crops to the Old, and vice versa. Cassava, in particular, has expanded rapidly across the Old World tropics mainly in the present century, very largely through its spontaneous adoption by subsistence agriculturalists, already accustomed to other vegetatively propagated crops who have recognized the production potential of the crop; its adaptability to marginal climatic and soil conditions; its immunity to many pests; and above all its high return of food per unit labour input. Similarly, Asian and African yams, Colocasia and the plantains and other cooking bananas were transferred from the Old to the New World and breadfruit was taken in domestication from the South Pacific to tropical America and Africa.

The philosophies of peoples whose cultures are built nutritionally on vegetatively propagated crops as their staple resource, are essentially different from those of peoples who depend on the grain crop/animal husbandry complex. These differences derive from cultural origins, specifically from the methods by which the different types of crop were originally brought into domestication by Man. In these processes, Man not only modified plants to make them more suitable for food production, but by initiating artificial food production systems became himself the product of an artificial nutritional complex. Human culture is thus, at least in part, an artefact of Man's relationships with his crop plants. Plant domestication can thus be regaded as a reciprocal process, in which Man is himself domesticated by the crops with which he has become associated just as he has domesticated them. The consequences for Man of the evolution of these contrasting food production systems have not been explored except in very general terms, but major cognitive and conceptual differences certainly exist. These have penetrated deeply into human culture and ways of thought, eventually becoming formalized and ritualized in order to maintain cultural and social continuity, for in pre-literate (or even in literate) societies, "Ritual is ……. the DNA of society, the encoded informational basis of culture …… the memory core of human achievement" (Campbell, 1966).

An important difference in cultural behaviour between grain-based agricultural societies with systems derived from the Neolithic Revolution and those with vegecultural systems was first pointed out by Haudricourt (1964). The former, dealing with crop plants which require a direct, active and selective approach by Man have led to an "interventionist" mentality and ultimately to the type of cultural system that has now become dominant over most of the world and which automatically perceives Man as dominant. Conversely, the more indirect and less positively active relationships developed between Man and the vegetatively propagated crop plants of the tropical/equatorial regions have led to a "non-interventionist" attitude of mind resulting in an altogether different view of Man as an integral part of the overall ecosystem rather than as something above, separate and dominating it (Coursey, 1978a; 1981b).

The Neolithic Revolution was essentially a traumatic process, initiating rapid cultural changes which came about originally as a response to stress (Wright, 1971). The culturehistorical process that led from there to the development of modern technology passed through two further traumatic discontinuities that served to reinforce and emphasize the interventionist type of attitude that already had been inculcated by the initial stressreaction of the grain crop domestication situation. Firstly, there was the emergence of bronze-using cultures, whose metallurgical base depended on scarce, highly localized, mineral deposits. Possession of the metal conferred great military and economic advantages on those who controlled it, so favouring the development of more closely organized, hierarchic social structures among those who had access to copper and tin, and these groups because of the advantages conferred by the metals and the organizations their possession inculcated became dominant in the South-West Asian and Mediterranean worlds and later and separately in much of Southern and South-Eastern Asia. Secondly, the adoption of medieval Christianity, itself deriving from South-West Asian and Mediterranean sources, by the vigorous but barbarian cultures existing in Northern Europe around 1500 to 1000 BC, provided these peoples for the first time with a theoretical basis for regarding themselves as a separate and inherently superior creation from the rest of the biological world. This, as their descendants achieved world domination in the paleo-Colonial era, laid the foundations for the rapidly approaching ecological crisis now facing the entire world (White, 1967).

No such sudden break with the past or with adjacent or interpenetrating cultures was involved in the processes which brought the perishable staples into symbiosis with Man in the tropical/equatorial regions. The domestication of these crops can be viewed merely as a phase in the slow evolution of a symbiotic inter-relationship between plant and Man, emerging from the concepts of "protection" which nonagricultural peoples have concerning their wild food plants (Burkill, 1953; Barrau, 1970; Coursey and Coursey, 1971; Coursey 1972). The beginnings of this evolutionary process may indeed be as old as humanity. The relationship between pre-human hominids and their plant foods may have contributed as much to physical evolution as the more recent domestication process has to Man's cultural evolution (Coursey, 1973b).

After the domestication of the vegetatively-propagated crops and the establishment of food production systems based on them had occurred, no further traumatic changes took place in the cultural evolution of the tropical "gardening" societies comparable with those that have just been discussed until very recent times. Some cultures remained using only stone tools until the ethnographic present or made the transition directly from stone to the use of the more democratic iron without any significant intermediate use of the elitist copper-based metals. Highly socially stratified societies with technologically sophisticated artefactual complexes did not, therefore, emerge. The pagan religious systems that remained dominant throughout their history until very recent times laid much emphasis on maintaining a proper balance between Man and the ecosystem of which he formed a part and indeed those elements within traditional pagan religion that are concerned with plant life and food production are often very largely systems of ritual sanction designed to regularize and control the interaction of Man and his crop plants to mutual advantage (Barrau, 1965a; 1965b; Coursey and Coursey, 1971; Tuzin, 1972; Coursey, 1978a, 1981b).

The agricultural systems based on grains could also be compared to the reproductive strategy adopted by those species which produce large numbers of offspring but take little care of them, so that only a small proportion survive (K selection), whereas vegecultural food production systems, essentially horticultural, may be compared to those species which have few offspring, but take efficient care of them to ensure a high rate of survival (r selection).

Taking all these factors into consideration, the tropical cultures based on perishable staple foods may be regarded as being essentially ecocentric, i.e. orientated toward the maintenance of an overall ecological balance, in contrast to the technocentric approach, which pertains in most "Western" cultures, where the introduction of a new technology is normally regarded as the first essential towards the solution of any problem that may arise (Dawson, 1981). Because of the ecocentric rather than technocentric approach; the relatively simple technologies that have therefore emerged; and also because of the identification of the civilizations ancestral to those of Europe with a graincrop basis, it is often assumed that any culture based on the use of non-grain or perishable staples must be at an inherently low level and that it is only the grain-orientated cultures that can be based on a symbiotic relationship between Man and plant; and that these must be contrasted sharply with all other cultures where Man is viewed as being purely parasitic on his environment. In many parts of the tropics, however, the reverse is true and peoples who depend on perishable food crops or who use grains only to a very secondary degree have often achieved very substantial cultural levels where relationships to the total environment are often far more profound than those which occur in the more highly socially organized grain-based agricultural civilizations.

As has already been discussed in Chapter 3, the post-harvest technology of the perishable staples is often based on the avoidance of long term storage, rather than on the evolution of sophisticated storage or processing techniques. Thus, storage and processing have often been developed primarily as extensions of normal household food preparation activities, and are thus seen, in many societies, as essentially a woman's function, as opposed to food production which in many societies is often a traditionally male role. It must be emphasized, however, that there are extremely wide degrees of cultural and philosophical diversity between cultures which are nutritionally based on perishable staple foods some of which diversity fundamentally affects woman's roles in the crop storage/processing situations. Overall, however, it appears that the role of woman in the storage and even more in the processing of foodstuffs, is a very substantial one and the more complex the nature of the processing techniques employed, the greater the woman's role is likely to be. It must be emphasized, however, that no general rules can be drawn in this matter, across the whole varied spectrum of cultures oriented towards perishable staple foods.

Chapter 5

A. Cassava

Cassava (Manihot esculenta Crantz), also known as yuca, manioc, mandioca or tapioca, differs from the other major root crops in that its edible roots are not organs of dormancy and do not appear to have a natural function in the preservation of the plant through the dry season. Thus, the roots are not inherently adapted for survival and once harvested they deteriorate rapidly, developing a vascular discoloration within a few days which renders the roots unpalatable and also unsuitable for subsequent processing (Averre, 1967; Booth, 1976; Montaldo, 1973; Noon and Booth, 1977) .

Traditionally, the problem of storage has usually been overcome by leaving the roots in the ground until needed and once harvested to process immediately into a dry form with a longer storage life (Ingram and Humphries, 1972; Rickard and Coursey, 1981) . The roots can be left in the ground for several months after reaching maturity but a disadvantage of this system is that large areas of land are occupied by a crop which is already mature and is thus unavailable for further use. Also the roots become more fibrous and woody and their starch content and palatability declines (Greenstreet and Lambourne, 1933; Jones, 1959) and in addition, susceptibility to pathogenic losses increases (Doku, 1969) .

One means of storing fresh cassava roots which has been used since ancient times by the Amerindians of Amazonia (Edmondson, 1922), is to bury the harvested roots in pits or trenches, a technique probably derived from the common practice of leaving the cassava unharvested. Similar techniques have also been reported in other areas of the world (Affran, 1968; Irvine, 1969). For a short period cassava roots can be kept fresh by being heaped and watered daily (Affran, 1968) and a coating of paste made from earth or mud is said to preserve the roots for four to six days (Hiranandani and Advani, 1955; H.A.G. Rao, 1951).

Improved storage techniques, not used traditionally and, therefore, not described in this publication, have recently been reviewed by Rickard and Coursey (1981) . Such techniques range from the simple methods of storing the roots in clamps or boxes to the more advanced techniques of cold storage or freezing.

In general, most cassava, if not used immediately after harvest, is processed into a more durable form and a wide variety of food products and beverages are traditionally prepared from the root using a large number of often very complex processes (Lancaster et al., 1982). However, the need to produce a storable product, although clearly important, has not been the only reason for the development of these processes, an additional stimulus having been the need to reduce the toxicity of the root.

Cassava contains two cyanogenic glycosides, linamarin and lotaustralin, which hydrolyse in the presence of the enzyme linamarase, also found in cassava plant tissue, to release hydrogen cyanide (HCN) (Nartey, 1978). Contact between the cyanogenic glycosides and the enzyme occurs only when the tissues are mechanically damaged or there is a loss of physiological integrity, as for example during post-harvest deterioration or wilting of the leaves (Coursey, 1973a). Many of the traditional techniques appear to be designed specifically to bring about the contact between substrate and enzyme by cell rupture, for example, by grating or pounding and elimination of the released HCN is then achieved by volatization or solution in water (Coursey, 1973a).

Studies on the effectiveness of traditional cassava processing techniques in reducing the HCN levels in the roots have been carried out and have been reviewed by Coursey (1973a). This work has shown that the techniques do reduce the total cyanide content of the roots, although the results are often of questionable reliability, due in part to the analytical methods used (Cooke and Coursey, 1981). Recently, however, a new more reliable and sensitive assay for cyanide has been developed which distinguishes between free and bound cyanogenic glycoside (Cooke, 1978) and using this technique it has been shown that while free cyanide is reduced considerably, substantial amounts of bound cyanide may remain in the processed roots (Cooke and Maduagwu, 1978). Using roots with an average initial HCN content of 63 mg HCN/kg, of which 8-12% was free cyanide, the effectiveness of drying, boiling and steeping cassava chips in water was tested. Boiling for 25 minutes removed over 90% of the free cyanide and 55% of the borend. Air drying at 46-50°C removed 82.5% of the free cyanide and 29% of the borend cyanide, with smaller losses in borend cyanide at higher temperatures. Stirring in cold water for short periods was ineffective in reducing cyanide levels but over a period of 18 hours, during which time fermentation set in, a 50% loss of borend cyanide occurred (Cooke and Maduagwu, 1978).

Cases of acute poisoning from ingestion of cassava are occasionally reported (Hanlon, 1981) and high incidences of chronic degenerative diseases, goitre and cretinism have been linked with the consumption of a cassava diet (Oshuntokun 1972; Delange et al., 1982). However, the cases of poisoning are comparatively rare considering the millions of people who regularly consume cassava, suggesting that the traditional detoxification techniques are generally effective (Coursey, 1973a). Both chronic and especially acute cassava poisoning appear generally to be associated with diets that are grossly deficient in sulphur-containing amino acids such as methionine and cysteine which are necessary for the detoxification of cyanide in the body.

Cassava cultivars are frequently referred to as either "sweet" or "bitter", bitterness being associated with higher toxicity, but while this forms a rough guideline there is no exact correlation between HCN content and degree of perceived bitterness (Sinha and Nair, 1968). However, using this terminology it is the "bitter" varieties which are generally subjected to the more complex processes such as are involved in the preparation of farinha or gari in order to reduce the HCN levels, while the sweet varieties are often eaten after more simple preparation methods such as boiling or roasting, or occasionally even raw although they are also processed by more complex methods. The widespread myth that "bitter" varieties have higher dry matter contents and are thus more suitable for processing, has no foundation in fact.

Cassava is believed to have originated as a cultivated plant either in south Mexico and Central America or in northern South America (Rogers, 1963; Renvoize, 1972); it spread in cultivation throughout tropical America before European contact in 1492, and was later introduced to other tropical regions of the world. A great diversity of processing techniques has developed in different regions. Some of the processes are used in all areas either because they are standard methods for preparing starchy food, such as boiling or roasting or because they were introduced with the cassava when it was introduced from South America. Other techniques are unique to particular localities having been developed independently, sometimes based on methods used to prepare indigenous staples (Jones, 1959).

The simplest techniques used to prepare cassava for immediate consumption are boiling, roasting or baking. Peeled roots are boiled whole or sliced and served in a variety of ways. For example, in African countries they are popularly eaten as a vegetable served in a sauce (Affran, 1968; Doku, 1969; Dovlo, 1973; Ekandem, 1961; Favier et al., 1971; Goode, 1974; Whitby, 1972), while in India boiled slices are often incorporated into curries (N.S. Rao, 1951) or grated and mixed with shredded coconut into a product known as puttu (H.A.G. Rao, 1951; Subrahmanyan, 1951). Slices of cassava root are commonly added to stews of other vegetables and meat such as the sancocho popular almost throughout South America (Alba, 1963; Schwerin, 1971). Roasting the roots is less popular with the Amerindians than boiling and generally only resorted to when no cooking utensils are available. Frying is believed not to have been used traditionally but to have been introduced by Europeans (Schwerin, 1971). In contrast, both techniques are widely practiced in Africa both East and West (Alberto, 1958; Doku, 1969; Goode, 1974; Leitao, 1971; Whitby, 1972). Roots are roasted by placing them whole in the ashes of a fire or slices of peeled root are fried in oils of various kinds according to availability and taste. In Vanuatu grated cassava is wrapped in banana leaves and baked in an oven (Massal and Barrau, 1955a).

The more complex technique involving pounding of the cassava roots into a paste is particularly popular on the African continent where it is a very widespread method, also applied to other starchy staples such as cocoyams, yams and plantains (see appropriate sections). The resulting paste from all these crops is generally known in West Africa as fufu, also foofoo, fuifai, foufou, foutou and vou-vou depending on the locality. The term futu or one of its variants is also applied to pastes prepared from cassava starch, flour and grated roots.

Fufu can be prepared by boiling or steaming peeled cassava roots and then pounding them in a wooden pestle and mortar until a homogeneous paste is obtained which is eaten with soups or stews of meat or fish (Affran, 1968; Anasanwo, 1942, Collins, 1911; Ekandem, 1961). An alternative method is to soak the unpeeled roots in water to soften them for pounding, soaking normally being done in running water, i.e. streams, although stagnant water can also be used, for 3 to 4 days, during which time some fermentation may occur. When soft, the roots are removed from the water, peeled and pounded into a paste either to be boiled or steamed and eaten immediately or stored for about a week, often in baskets until needed for cooking or until sold in the market (Ekandem, 1961; Favier et al., 1971; Joseph, 1973; PFL/GAB/001, FAO Technical Report). In Cameroun the paste is made into long stick-like shapes (30-60 cm long and 2-4 cm in diameter) known as batonde-manioc or balls known as chickwangue. These are wrapped in banana or Colocasia leaves and tied firmly for cooking or sale (Favier et al., 1971).

A fermented paste (attieke) popular in the Ivory Coast is prepared by steeping peeled roots in water and then grinding them to a paste which is left for two days in a jute sack under heavy stones to ferment. The paste is removed from the sacks, crumbled by hand and steamed to be consumed with milk or with meat and vegetables (Leloussey, 1970).

The main means of preserving cassava roots for storage is to produce some form of dried product, the end product generally being a flour although the dried roots are often stored in some other form. Many different methods are used for producing flour from cassava around the world, some techniques being used in most cassava growing areas, others being more localized in use.

A technique widely used in Africa to prepare cassava flour is to first prepare a fufu paste as described above and then to dry this either by sun-drying or over a fire. For smokedrying, a method used for example in the forest zones of Cameroun, the paste is made into balls or chickwangue, wrapped in leaves and placed on a screen over the hearth for about 15 days although it can be left longer until needed. After removing the leaves and scraping off the black coating which forms during drying, the dry paste is ground into a flour (Favier et al., 1971; Joseph, 1973). If sun-dried, the paste is simply spread out onto mats for 2-3 days and then ground into a flour (Anasanwo, 1942; Adriaens, 1951; Favier et al., 1981; Joseph, 1973; Whitby, 1972).

In Zambia, cassava roots (either soaked or unsoaked according to taste and the necessity to eliminate cyanide) are mixed with a fermentation starter known as kapapa which consists of partially dried cassava slices that have been allowed to develop a coating of mould. The mixture is left to ferment for 1-6 days, then sun-dried, pounded and sifted into a flour (Whitby, 1972) .

The simplest method used and probably the most widespread certainly in Africa or Asia, for preparing flour from cassava is by sun-drying slices or chips of peeled roots which can then be stored as dried chips and ground into a flour when needed (Alberto, 1958; Anonymous, 1919; Anonymous, 1941; Doku, 1969; Dovlo, 1973; Godfrey-Sam-Aggrey and Bundu, 1979; Tallantire and Goode, 1975; Velcich, 1963) or stored in the form of flour. The sun-dried pieces are known, for example, as gaplek in Indonesia (Anonymous, 1919; Anonymous, 1941) and kokonte in Ghana (Doku, 1969; Dovlo, 1973). Drying generally takes 3-10 days although only 1 or 2 days is sufficient in ideal conditions and once dry, the chips can be stored for 3-6 months, the main problems being attack by moulds predominantly Aspergillus and Penicillium spp., infection generally beginning during the drying stage (Clerk and Caurie, 1968; Rawnsley, 1969) and insects (Ingram and Humphries, 1972 ; Parker et al., 1981; Parker and Booth, 1979) . A method for extending the storage life of chips to up to 12 months and also speeding up the drying process is by parboiling them before drying, a technique often used in India and West Africa (Hiranandani and Advani, 1955; Doku, 1969; Ingram and Humphries, 1972) .

In some areas the roots may be soaked, unpeeled, for about 5 days before drying. For example, in Nigeria a flour known as lafun, an important staple foodstuff amongst the Yoruba of Western Nigeria (Oke, 1965), is prepared in this way and in Angola, bombo or makessu are dried chips prepared from soaked roots which are stored and ground into flour known as fuba (Alberto, 1958).

In East Africa, particularly Uganda and Kenya, the cassava roots are encouraged to develop moulds, before being completely dried ready for storage, by placing the roots either fresh or only partially dried in the dark for several days (Anderson, 1944; Goode, 1974; Tallantire and Goode, 1975).

A variety of methods are used traditionally for storing dried chips. For example, a common method in Zaire is storage in baskets over the hearths where the smoke probably serves to inhibit insect attack (Jones, 1959) while in contrast, in Uganda, storage near a smokey fire is said to make the chips unpalatable and dried chips there are stored in ridded baskets, sealed by plastering with cow dung and standing on stilts (Kerr, 1941).

Dried Cassava chips are sometimes cooked, as for example in India, by boiling or frying (Anonymous, 1952; Subrahmanyan, 1951) but more often they are ground into flour and generally elsewhere flour is the end product. In Africa, the flour is most often mixed with water to form a thick sticky mass or porridge similar to fufu and called by a variety of different names including fufu or one of its variants (Adriaens, 1951; Alberto, 1958; Dovlo, 1973; Ekandem, 1961; Favier et al., 1971; Whitby, 1972). Cassava flour is also made into a sort of porridge in South India (Subrahmanyan, 1951) but more often it is used to make one of the traditional Indian foods such as chappatis (Anonymous, 1952; Hiranandani and Advani, 1955). Cassava flour is sometimes mixed with flours from other crops such as millet and made into a porridge (Tallantire and Goode, 1975) or bread (Ekandem, 1961; Jones, 1959).

Amongst the most important products from Cassava roots are the coarse meals known as gari in West Africa and farinha de mandioca (also called farinha seca, farinha surahy) in Brazil and which are again storable products. The techniques used in the preparation of gari and farinha are very similar, the basic technology having been introduced into West Africa by settlers from Brazil in the early 1800's (Affran, 1968; Jones, 1959). Peeled cassava roots are grated, squeezed or pressed to remove the juice and then sifted and "garified" by roasting on a metal plate. The essential difference between gari and farinha de mandioca lies in the degree of fermentation which occurs before or during the squeezing or pressing stage, gari being left for longer so that a greater degree of fermentation occurs giving it its characteristic sour flavour which distinguishes it from the farinha, and which is preferred by the West African palate.

In South America, once grated, the cassava was traditionally squeezed in a long cylindrical basketry press or tipiti which is suspended from a house beam or tree branch by a loop. It is so constructed by diagonal weaving that when stretched lengthwise by hanging a weight on it or by using a lever at the lower end, its diameter decreases, so compressing the contents (Dole, 1956; Lowie, 1963). Less sophisticated devices are traditionally used in West Africa and the pressing stage takes longer, 3-5 days generally, compared to just overnight using the tipiti. The grated Cassava mash is placed in jute sacks or cloth bags and squeezed by a variety of techniques, often by simply placing heavy stones or logs on top of the sacks for 35 days (Affran, 1968; Anasanwo, 1942; Doku, 1969; Dovlo, 1973; Jones, 1959; Oke, 1968; Vignoli and Cristau, 1950).

After this stage the processes again converge in the two localities, the partially dried cassava being sifted to remove any coarse fibres and heated over a fire in a wide shallow pan with continuous stirring to prevent the formation of lumps, resulting in a free flowing granular meal (Doku, 1969; Jones, 1959; Schwerin, 1971). Gari and farinha can be stored for several months if properly dried during manufacture and kept dry during storage (Jones, 1959; Schwerin, 1971).

Most commonly gari and farinha de mandioca are eaten as a gruel prepared by mixing the meal with water or mixed with less water as a dough, accompanied by soup or stew. The gruel may be sweetened with sugar or accompanied by groundnuts or grated coconut. In Brazil, farinha is often sprinkled as a condiment on a variety of foods and is known by the name farofa when used in this way (Affran, 1968; Doku, 1969; Ekandem, 1961; Schwerin, 1971; Jones, 1959) .

Farinha can also be prepared from roots which have been soaked for 3-8 days in water before grating and is then known as farinha d'agua or farinha puba (Anonymous, 1971; Goldman, 1963; Lecointe, 1922; Metraux, 1963; Schwerin, 1971 ; Tastevin, 1954).

In South America a second popular product is made from grated and pressed cassava roots, a "bread" known variously as cassave, casabe, beiju or couac depending on the locality (Jones, 1959; Lecointe, 1922; Lowie, 1963; Metraux, 1963; Montaldo, 1979; Reynavaan and Vos, 1954; Schwerin, 1971; Tastevin, 1954). When heating the partially dried cassava pulp on a griddle, instead of stirring continuously as for farinha the pulp is pressed into a thin layer and toasted on each side forming a large flat circular cake. This can be eaten fresh while still soft inside (Goldman, 1963) but is more commonly sun-dried several days until hard all through in which state it can be stored for several months (Schwerin, 1971).

The extraction of starch from cassava roots is a technique used widely throughout the cassava producing regions and basically the same process is used everywhere. Grated cassava roots are washed with water and the starchy liquid strained through a cloth into a container where the starch is allowed to settle out. The water is decanted off and the starch dried and used for baking, for boiling as dumplings or stored until needed (de la Cruz, 1970; Doku, 1969; Ekandem, 1961; Hiranandani and Advani, 1955; Sturtevant, 1969). In South America starch is traditionally obtained as a by-product of the manufacture of farinha, the starch being allowed to settle out from the juice squeezed out of the grated cassava in the tipiti (Schwerin, 1971) . Starch is generally baked into cakes, called sipipa by the Caribs of tropical America (Schwerin, 1971), roskete in the Trust Territories of the Pacific Islands (de la Cruz, 1970) or pot bamie in Jamaica (Sturtevant, 1969). In parts of Nigeria, starch is collected from roots that have been soaked several days, then rubbed through a sieve into water in which the starch settles out, the water being decanted off and the starch boiled, pounded, reboiled and made into a dough known as fufu or other products (C.K. Coursey, 1973).

In many parts of the world cassava starch is further processed into what is known as tapioca in world trade. Wet starch is heated in a pan while stirred continuously until the grains burst and gelatinise into globules. This is generally consumed as a sort of porridge mixed with milk or water and it can also be stored (Affran, 1968; Anonymous, 1933; Hanson, 1939; Lecointe, 1922; Oke, 1966; Schwerin, 1971). This product is, however, little used in traditional societies.

Another dried product which should be mentioned is the traditional Philippine product known as cassava rice or landang (Cedillo, 1952). This is made either from roots which have been peeled and soaked in water for 5-7 days and then macerated and air-dried, or from freshly grated roots which have been pressed to squeeze out the juice. The pulp from either method is placed into a winnowing basket and whirled until pellets are formed. These are then dried on a mat and steamed in a coconut shell or on screen mesh placed over a vat of boiling water, after which they are sun-dried for 3-5 days and stored until needed. They are said to keep for 3-6 months in a cool, dry place before going mouldy. Landang can be eaten without further cooking but if preferred it is soaked, boiled, re-soaked, mixed with coconut milk and reboiled.

In tropical America, particularly the Amazon lowlands, cassava beers are an important product and these are also prepared in parts of Africa but on a much more limited scale. In South America, fermented cassava beverages are commonly called kashiri or chica (the term chica is also applied to maize beers) and are prepared by a number of different techniques often involving mastication of the cassava root or one of its products. Mastication has the effect of speeding up fermentation due to the action of the salivary enzymes which initiate a conversion of starch to sugar. Cassava bread is often used as a basis for the preparation of beverages; left to ferment for several days after first moistening in water or masticating and sometimes toasting and then mixing with water it produces an intoxicating drink (von Hagen, 1949; Montaldo, 1979; Schwerin, 1971). Alcoholic beverages are also made from roots which have been soaked in a flowing stream for a week during which time they ferment (Schwerin, 1971), from grated cassava left to ferment under leaves (Montaldo, 1979) and from boiled pieces of cassava which are first chewed, mixed with water, heated and left to ferment in jars half buried in the ground for 2-3 days (Metraux, 1963). Both alcoholic and non-alcoholic beverages are also made from the cassava juice or yard collected during the processing of farinha (Schwerin, 1971) .

In Uganda cassava beer is made from cassava flour which is mixed with water and left to ferment for a week, after which time it is roasted over a fire, put into a container with water and yeast and left for another week. The liquid is then drained off, sugar added and left for a further 4 days before drinking (Goode, 1974).

Another important use of the cassava juice or yari squeezed out of grated cassava is in the preparation of a spiced sauce known as cassareep in the West Indies, tucupy in Brazil and kasiripo in Surinam (Anonymous, 1933; Hanson, 1939; Lecointe, 1922; Reynvaan and Vos, 1954). The yard is seasoned with peppers, pimento, garlic, herbs, etc. and boiled to a thick syrupy consistency. In the Caribbean cassareep forms the basis of the "pepper pot" in which meat, fish and vegetables are cooked and maintained for years by boiling each day and adding further ingredients as necessary (Anonymous, 1918).

In the South Pacific the fermented product known as ma is normally made from breadfruit and sometimes from banana or taro (see sections below). However, on the Solomon Islands of Anuta and Tikopia cassava forms the basis of this product which is known here as ma manioka or masi manioka (Yen, 1973b; 1978). The roots are soaked in water for a few days on Tikopia and when soft, peeled, squeezed and ensiled in pits lined with leaves. On Anuta there is no suitable surface water for soaking and so the roots are placed in pits and left for a few weeks, then recovered, peeled and returned to the pits for a further period. To prepare for consumption, ma is baked alone or with freshly pounded starchy roots or fruits.

There are numerous other products prepared from the cassava roots in various countries of the world and these have been catalogued more fully in a recent review (Lancaster et al., 1982). However, the products discussed here are among the most important in terms of their contribution to world diets, and serve to indicate the range of traditional processing techniques and also the range of storable products that can be prepared from the cassava root.

The processing of cassava by the traditional techniques is often a very laborious and timeconsuming occupation and is invariable carried out by women. A survey of several villages in Nigeria showed that it takes an average of 90 hours to produce a 103 kg bag of gari, the whole process from uprooting the cassava and transporting it from the field through to the "gasifying" being done by women alone or in groups. The most unpleasant part of the process was considered by the women to be the "gasifying" as during this they are exposed to steam for many hours at a time (Williams, 1979). Similarly, in South America, the women of many Amerindian groups spend a large proportion of their time both in the cultivation and processing of cassava. For example, the daily preparation of foods such as cassava bread, which involves arduous tasks such as grating the raw roots by hand, may take up to 75% of a woman's working time and during festivals her whole time may be devoted to the preparation of special alcoholic beverages from cassava (Goldman, 1963).

B. Yams

The genus Dioscorea contains about 600 species, although most of the edible yams are derived from only about 10, and of these the Guinea yam, Dioscorea rotundata Poir. and D. cayenensis Lam. are generally the preferred carbohydrate staple in Africa while D. alata L. and D. esculenta (Lour.) Burk. are the more widely used species in the Caribbean and Pacific (Coursey, 1967). The first three named normally produce annually a single large tuber often weighing from 5 to 10 kilograms while D. esculenta produces a large number of small tubers. Also in widespread cultivation is D. bulbifera L. which forms small aerial tubers or bulbils in the leaf axils. Other edible species include D. hispida Dennst. grown in many parts of Asia, D. dumetorum (Knuth.) Pax. grown in Africa and D. trifida L.f. which is native to central America and the Caribbean. Also D. opposite Thunb. and D. japonica Thunb. are grown in temperate areas of China and Japan.

Yam tubers are organs of dormancy, having evolved to enable the plant to withstand the hot dry season of savanna areas in the dormant state and hence they are inherently well suited to storage in the fresh state when required by man as food. In practice most yams, unlike cassava, are normally stored in the fresh state while only a very small percentage are processed. The storage life varies greatly between species and even between cultivars, but the best keeping cultivars, principally forms of D. rotundata deriving from the drier areas of the savanna, can be stored for 3-4 months and sometimes for longer periods (Coursey, 1967).

The basic principles of successful yam storage are the provision of adequate ventilation, access for regular inspection and protection from direct sunlight (Wilson, n.d.) and many of the more sophisticated techniques incorporate these principles.

The simplest storage technique is to leave the tubers in the ground until needed, as is practiced with other root crops and this method is still used to a limited extent in some of the remoter parts of West Africa. Extending this technique, freshly harvested tubers may be packed in ashes and covered with soil or simply covered with a few inches of soil and grass mulch. Another simple method involves stacking the tubers into small heaps after harvest as is done in some parts of Africa and Asia. Some protection from sun and flooding is often afforded by careful selection of the sites in crevices of rock outcrops or in large trees and the small size of the heaps insures adequate ventilation throughout. However, the yams are very susceptible to termite and rodent attack and also to pilfering when stored in this way. Yams may also be stored in heaps on the floor or on shelves in sheds or huts which may or may not have been constucted for the purpose, or in the case of Southeast Asia where the houses are often built on stilts, underneath the house (Coursey, 1967; Irvine, 1969).

In the Ivory Coast, yams are often stored in small thatched shelters known as koukou, or in small earthen silos (Miège, 1957). The silos are simply hollowed out pits in the ground, the earth which is dug out being used to form a low wall around the edge: these are used mainly for early crop yams harvested before the end of the rainy season which will be kept only for limited periods. A similar technique is used in parts of northern Ghana (Coursey, 1967). The small thatched huts of one metre in height are generally constructed in the shade of large trees and the yams are stacked one on top of the other up to the top of the hut. Hence, only the harder varieties which do not bruise easily can be stored in this way and these stores are said to be conducive to attack by scale insects (Miège, 1957).

The commonest type of store used in West Africa is the yam barn which has been discussed in some detail by Coursey (1967). The barns vary considerably in design and construction between different areas but all consist in principle of a vertical or nearly vertical wooden framework to which the tubers are fastened individually with string or other local cordage material such as raffia. The frames are usually 1-2 metres in height but can be as much as 4 metres high and are from 2 metres upwards in length according the the amount of material to be stored. The vertical posts of the frame are often made from timbers which when left unbacked will take root when set in the ground, for example, species of Dracaena, Gliricidia, Ximenia and Gmelina. This reduces the risk of collapse as a result of termite attack or rotting and also helps to provide shade. Poles of 5-10 cm in diameter are placed in the ground about 1 metre apart and cross members of lighter wood, bamboo or palm-leaf midribs (Elaeis or Raphia species) attached, and finally to these are fastened lighter vertical sticks providing a fairly rigid structure.

There are two variations to this basic design which should be mentioned. One which is widely used in Ghana, involves the use of a larger number of vertical poles set closer together in the ground, only 10-30 cm apart with cross members as before, but avoiding the need for the secondary sticks. In the second, paired cross members are fixed parallel to one another either side of the vertical poles or on two poles set side by side. This means the yams can be tied perpendicularly to the frame instead of parallel to it, so increasing the storage capacity of the barn.

Two or more frames may be erected alongside each other and surrounded by a fence or hedge for security, or four frames may be constructed to form a rectangular enclosure with the yams tied only to the inner walls for security. A thatched roof may be added for shade or the branches sprouting from the "live" poles may provide the only shade. Barns are often built, however, under the shade of forest trees. Although a short period of exposure to the sun may facilitate the "curing" of yam tubers (Been et al., 1977), it is essential that they be protected from direct insolation for long term storage (Coursey and Nwankwo, 1968; Rickard and Coursey, 1979).

Essentially similar, but often elaborately ornamental structures are found in parts of Oceania such as Papua New Guinea, Trobriand Islands and New Caledonia (Barrau, 1956; Girard, 1967). Barrau (1956) describes a structure consisting of a platform of poles supported on vertical poles about half a metre above ground level and shaded by a thatched roof. The yams are stacked vertically on the platform held in place by a rim of horizontal poles around the edge of the platform. The same author also mentions a simpler method used in Vanuatu whereby individual tubers are suspended from a horizontal pole supported about 1 or 2 metres above the ground by 2 forked sticks set in the ground: a technique occasionally used in West Africa. In Papua New Guinea huts of two floors are sometimes used, closed in on 3 sides by walls of leaves and reeds and supported above the ground on poles. The yams for planting are placed on the lower platform while those for eating are placed on the upper floor. Yam tubers may also be suspended on hooks from the roof (Girard, 1967).

The storage life of yams is finally terminated by the breaking of dormancy and subsequent sprouting but storage of tubers for food use can be extended by as much as a month by breaking of the emergent sprouts when they are 20-30 mm long (Coursey, 1981a). Most farmers in traditional yam-growing societies are well aware that only sound, healthy tubers are suitable for storage and reject others for immediate consumption or processing. Further, they know what has only recently (Passam et al., 1976) been scientifically established, that a bruise or abrasion is far more likely to lead to decay in storage than a clean cut. It is normal traditional practice to cut away any bruised or decayed portions, and often rub the clean wound with alkaline material (lime, chalk or wood ashes) to discourage reinfection.

In both West Africa and Melanesia, yam is essentially a man's crop, and this extends to the post-harvest sector. Indeed, in most of West Africa, a well-built and well stocked yam barn is one of the major factors through which a man gains prestige in his community, although women, especially widows, also grow and store yams in their own right. The sexual tabu is much stronger in Melanesia, where women are usually totally excluded from all operations, pre- or post-harvest, connected with the ritually important D. alata, although they are allowed to grow and store D. esculenta, which although less highly regarded, probably makes a greater contribution to the total diet.

In most yam-growing areas the major protion of the yam crop is stored and transported in the fresh state and in West Africa long distance trade in fresh yams has existed for centuries, in contrast to the cassava trade which is generally in the processed product and is a recent development (Coursey, 1978b). A small proportion of the yams are, however, processed into a dried form and yam flour is particularly popular in Yoruba speaking districts of West Africa, although in other areas generally only those yams which are misshapen, damaged or partially decayed are processed. The whole topic of yam processing, both traditional and nontraditional, has recently been reviewed by Coursey and Ferber (1979).

Yam flour is prepared by cutting the tubers into slices of about 1 cm thickness, peeling the slices and sun-drying them. Slices may be boiled or parboiled before sun-drying to soften the tissues giving a more palatable product. After drying the pieces are ground in mortars to give a coarse flour or may be stored as pieces until needed. The main problems of storage of the pieces or flour are attacked by insects, most commonly Araecerus fasciculatus De G. and Sitophilus zeamays Mots. and rodent attack of unmilled pieces can be severe. The flour is prepared for consumption by reconstituting in boiling water to form a paste (Coursey, 1967). Preparation of dried yam slices and flour is also practiced in other parts of the world including Indonesia (Ochse, 1931), Madagascar (Decary, 1946) and parts of the Far East (Clemente, 1918).

Some edible yams such as D. dumetorum (Knuth.) Pax. and D. hispida Dennst., are highly toxic due to presence of alkaloids of the dioscorine group and consumption of these without careful preparation can be fatal. Traditionally, the toxicity is overcome by soaking the sliced or grated tubers so that the alkaloid leaches out into the water. Sulit (1932) describes a technique used in the Philippines for D. hispida. Thin slices of peeled tuber are placed in a basket and submerged in the sea or a solution of salt water for 2 to 3 hours. They are then removed and squeezed under weights for a few hours and then replaced in the baskets and left in a running stream for 36 to 48 hours with occasional stirring. The slices are tested for toxicity by squeezing a drop of liquid into the eye and if the eye smarts, soaking is continued for a further period. Similar techniques are used for

D. dumetorum in West Africa. The soaked yams are prepared for consumption by flavouring with coconut and sugar. Other techniques reported from India, Solomon Islands and Madagascar, for example, involve boiling the yams before immersing in running water either whole, mashed or sliced (Barrau, 1956; Decary, 1946; Karnik, 1969). Wood ashes or tamarind are also sometimes added to the water for boiling in parts of India as an aid to the removal of the acridity of the toxic yams (Karnik, 1969).

Non-toxic yams are prepared for consumption by a variety of ways, often simply by boiling, roasting or frying and may be eaten raw (Decary, 1946; Coursey, 1967; Ochse, 1931). For boiling, the yams are usually peeled and cut into pieces and boiled until soft, although smaller tubers may be left whole and unpeeled (Coursey, 1967). Yams are generally roasted by simply placing the unpeeled tubers in the ashes of a fire, although in the Pacific Islands the tubers are usually cut into pieces or, less commonly, grated and wrapped in green leaves often with other ingredients such as coconut cream and chicken or fish and roasted in stone ovens (Barrau, 1956; Malcolm and Barrau, 1954). Frying pieces of yam in vegetable oil is common practice; in West Africa, palm oil is frequently used, the pieces usually having been boiled or parboiled first, although the most important edible product prepared in this area from yams is fufu which is eaten as an accompaniment to stew (see also sections on cassava, plantains, cocoyams). The tubers are peeled, cut into pieces and boiled until soft. The water is then drained off and the pieces pounded in a wooden mortar and pestle until a stiff glutinous dough is formed, usually taking 15-30 minutes (Coursey, 1967).

C. Sweet potato

The sweet potato (Ipomoea batatas (L.) Lam. is grown throughout the tropics and to a greater extent in some warmer temperate areas such as southern United States, southern China, Japan and New Zealand. In tropical regions the fresh tuber is generally considered to be difficult to store, especially in areas where pre-harvest attack by Cylas weevils is common and so storage is usually avoided by "mumuting", or progressive harvesting of the crop only when it is needed (Siki, 1979). There are few examples of storage techniques in these areas (Keleny, 1965). It is in the temperate areas where the tuber is grown as a summer crop that the more elaborate storage techniques have been developed in order to protect the sweet potato from cold during the winter (Cooley, 1951), the tubers being susceptible to chilling injury at about 12°C. A period of curing at high temperature and humidity before storing is also necessary to encourage the development of a suberized layer in any wounds present and so inhibit invasion by pathogens. A technique which meets the requirements of curing and protection from the cold has been used by the Maoris in New Zealand for centuries (Cooley, 1951).

The Maoris traditionally stored sweet potatoes in specially constructed underground storage houses, dug into the side of a hill. The floor is covered with a layer of gravel and rotten wood or dunnage of dried manukau (Leptospermum species or fern brush) and the tubers placed on top. The seed stock is placed in first at the back of the store with the food tubers in front, the two types being separated by fern leaves. Any cut or bruised tubers are placed nearest the entrance so that they are used first and the whole store is then sealed and left for some time, presumably to allow curing to occur under the influence of respiratory heating, before any tubers are removed for use (Best, 1925; Cooley, 1951; Keleny, 1965) .

Pit storage of sweet potatoes is also practiced in Simbabwe (Blyth, 1943) and Malawi (Anonymous, 1949) where the tubers are placed in pits with alternate layers of wood ash and in Papua New Guinea where the tubers are alternated with layers of grass in grass-lined pits (Siki, 1979) . The Kakoli people of the Kaugel Valley in Papua New Guinea store the tubers in groups of 3 or 4 tunnels dug into natural banks, each tunnel capable of holding about 11 kg of tubers and sealed with turf (Yen, 1974). The Bantoc of Luzon in the Philippines often adapt their wooden rice storehouses for the storage of sweet potato tubers, with additional space provided in the form of plank bins (Yen, 1974).

Sweet potato tubers are often stored for short periods of two to three weeks before use (Hrishi and Balagopal, 1979; Kimber, 1972; Siki, 1979; Villanueva, 1979). For example, in Papua New Guinea tubers are placed on platforms in the house in a dark, well-ventilated area where heat or smoke from the cooking fires appears to aid curing of the tubers (Siki, 1979) . Storage for a few days is said to improve the eating quality due to loss of moisture giving a greater energy value per unit weight and also to allow hydrolysis of starch to sugars (Kimber, 1972).

Owing to the perishability of the crop, in parts of East Africa where there is a pronounced dry season a proportion of the sweet potato crop is peeled, sliced and sun-dried for storage (Acland, 1971; Aldrich, 1963; Allnutt, 1942; MacDonald, 1970). In Tanzania, the tubers are boiled for an hour before drying and the dried product is said to be capable of being stored for two years without deteriorating (Allnutt, 1942). When needed for consumption the dried pieces are washed and boiled (Allnutt, 1942) or ground into a flour for making local dishes (Acland, 1971) .

The Maoris of New Zealand also stored some of the sweet potato crop in the dry state, two methods of preparation being known (Best, 1925). In the first, the tubers are simply scraped and sun-dried and either stored or prepared for consumption immediately, after first soaking and mashing with warm water to form a gruel. In the second method, roots from storage pits are oven-cooked and then dried (Best, 1925). The production of dried sweet potato as a snack is still practiced in parts of New Zealand (Yen, 1974). In the Philippines, dried flakes of sweet potato are prepared for storage and pounded into a flour as required for use in the preparation of a gruel. A popular dish is prepared by mixing the flour with water, and sometimes with sugar, and making small balls of dough which are wrapped in sugar cane leaves and boiled (Yen, 1974). The production of sweet potato flour is also commonly practiced in China (Yen, 1974).

There are no particularly elaborate processing techniques traditionally associated with the sweet potato, the tubers generally being prepared for consumption by boiling, steaming, baking or frying. In the islands of the South Pacific unbolted tubers are usually baked or braised in an oven or peeled tubers are boiled to be eaten as they are or mashed with coconut milk. Sliced tubers are also sometimes mixed with other tubers and green leaves, moistened with coconut milk, wrapped in a banana leaf and braised in an oven (Massal and Barrau, 1955c).

Roasting peeled or unpeeled tubers in the ashes of a fire is popular in parts of East Africa where they are usually eaten alone or perhaps with milk; however, boiling or steaming tubers is more common (Acland, 1971; Goode, 1974). Occasionally, slices of sweet potatoes are fried with other root crops, cereals or vegetables (Acland, 1971) . Ochse (1931) describes several dishes made in Indonesia, for example, in Java getook is made by pounding boiled roots with grated coconut and is eaten with sugar and salt; while groobi consists of peeled tubers cut into fine pieces, fried until hard and dry, dipped in a solution of sugar, fried again until dry and finally scooped into a banana leaf and pressed.

Sweet Potato tubers are also sometimes used as a substitute in the more complex processing techniques normally applied to other starchy root crops. For example, the tubers are used by Amerindians for making an alcoholic beverage normally prepared from macerated cassava (Yen, 1974), while in Hawaii sweet potato tubers are sometimes used instead of taro to make poi (Handy, 1940). (see Aroid Root Crops).

D. The aroid root crops

The most important food crops within the family Araceae belong to the two species Colocasia esculenta (L.) Schott (taro, "old" cocoyam, dsaheen eddoe) and Xanthosoma sagittiforium (L.)

Schott ("new" cocoyam, tannia). The edible portion of the plant is a corm or a group of small corms or cormels found largely or entirely underground, although the leaves of several species are also eaten as green vegetables.

The cultivars of C. esculenta can be grouped roughly into two types: one with a relatively small corm surrounded by large, well-developed cormels, known in the West Indies as the eddoe and the other, known as dasheen in the West Indies which has a large central corm and few side cormels. However, the names dasheen and eddoe are not always strictly applied to these groups in this way, while further there are intermediate forms, and in the South Pacific islands the term taro is used for both types. To add to the confusion the name cocoyam in West Africa is used to describe both Colocasia and Xanthosoma although "old" cocoyam is sometimes used for the former and "new" cocoyam for the latter. Purseglove (1968) considers it most reasonable to differentiate two varieties of C. esculenta, var. esculenta for the dasheen type and var. antiquorum for the eddoe type.

Colocasia and Xanthosoma are particularly important food crops in the islands of the South Pacific, the Carribbean and West Africa (Alexander, 1969; Coursey, 1968; Lambert, 1979; Massal and Barrau, 1955b) and Colocasia is also a staple food in parts of the Philippines where it is known as gabi (Pardales, 1980). Other genera, Alocasia, Amorphophallus and Cyrtosoerma also contain edible species but these are of localized importance only.

There are few descriptions of traditional storage systems for aroids. Normally the corms are consumed shortly after harvest so avoiding the necessity for storage and similarly to other root crops some aroids such as Colocasia and Amorphophallus can be left unharvested in the ground until needed (Lewis, 1976; Plucknett, 1970; Plucknett and White, 1979). Cyrtosperma, in particular, is usually left in the ground for several years, for its gigantic cormous system to attain its full size of 50 to 100 kg (Plucknett, 1977). Reports of postharvest storage life vary considerably from several months to less than a week, experimental work having demonstrated severe losses due to sprouting and diseases, but reported storage losses vary considerably from country to country and also appear to vary with cultivar (Baybay, 1922; Gollifer and Booth, 1973; Praquin and Miche, 1971). The variation may be due, at least in part, to variations in the degree of dormancy of the corms at the time of harvest.

For storage for short periods of 2 to 4 weeks in the Philippines, Colocasia corms are tied in bundles and hung in the shade or left in the baskets or jute sacks in which they were transported from the field, or simply left in a pile in the shade (Villanueva, 1979). For longer term storage of up to 6 months corms may be placed with alternate layers of grass, straw or leaves and covered with a final layer of leaves and soil either in piles above ground or leaflined pits below. These techniques are used in Papua New Guinea, Nigeria and China (Nwana and Onochie, 1979; Plucknett and White, 1979; Siki, 1979). In India Amorphonhallus corms are said to keep for months after dipping in a cow dung slurry and ash (Hrishi and Balagopal, 1979). Sometimes in China a special enclosure is built within the house into which alternate layers of taro corms and soil are placed (Plucknett and White, 1979), while in Nigeria, Colocasia and Xanthosoma corms are often stored in specially constructed barns made from palm (Nwana and Onochie, 1979).

For immediate consumption aroid corms are normally boiled, baked, roasted or fried, a thorough cooking for several hours often being needed to remove the irritating effect of calcium oxalate raphides and other acrid principles present in many species (Sakai, 1979). In Southeast Asia, tamarind or lime are often added when cooking Colocasia or Alocasia corms to counteract the acridity (Allen, 1940; Ghani, 1982). The aroids are so ubiquitous in the humid tropics that there are numerous local variations to the dishes prepared from them. For example in Fiji and other Pacific Islands, Colocasia is often grated and mixed with coconut milk and then wrapped in leaves before boiling or baking, or peeled corms may be boiled or steamed and then pounded and made into balls to be eaten with coconut milk and sugar (Anonymous, 1951; Greenwell, 1947; Harwood, 1938; Massal and Barrau, 1955b; Parham and Raiqiso, 1939). Similar dishes are commonly prepared in Java where fried corms are also prepared (Ochse, 1931). In West Africa Xanthosoma cormels are used to prepare fufu by pounding boiled pieces into a doughy mass often eaten with soup (see also cassava and yam) (Karikari, 1971; Pele and Berre, 1967). In Egypt, cubes of Colocasia corms are commonly given an initial washing and soaking in warm water for 15 minutes or are washed and lightly fried in order to remove the mucilaginous material and are then prepared for consumption by cooking with meat to which either onion and tomato or garlic and chard are added (Warid, 1970).

A fermented product known as poi is prepared in Hawaii from Colocasia. Traditionally, it was prepared by the men as it was said to be too important to be left to women. Traditionally, corms are first baked or steamed, then peeled and pounded with a stone pestle in a long, shallowly hollowed-out board or stone. Water is added gradually until the correct consistency is obtained after which time the dough is placed in a calabash and left to ferment for several days, the extent of the fermentation being varied according to taste (Greenwell, 1947; Stewart, 1928 (in Allen and Allen, 1933)). Poi prepared in this manner will keep for only a few days but is said to keep for months if prepared without adding water and pounding, so obtaining a harder, drier product, which is diluted with water only when needed (Stewart, 1928 (in Allen and Allen, 1933)). A similar preservation technique is used on Rapa in the Anuta Islands with Colocasia and with Cyrtosperma on Kiribati (formerly Gilbert Islands) (Massal and Barrau, 1955b). Again in the Anuta Islands, Colocasia is made into the fermented ma by placing grated corms in leaf lined pits which are sealed over and the material left to ferment (Yen, 1973b) (see also sections on cassava, breadfruit, banana).

In some regions a storable product is obtained from aroids by sun-drying the corms as, for example, in Papua New Guinea where the Colocasia corms are processed in this way when there has been a particularly good harvest (Ochse, 1931). In Kiribati, Cyrtosperma tubers are sometimes scalded, chopped and sun-dried and are said to keep for several months (Massal and Barrau, 1955b). In Japan Amorphophallus rivieri Durieu is stored in the form of a flour konnyaku or konjac (Chevalier, 1931; Motte, 1932). The tubers (which consist of mannans, not starch) are first peeled, washed and cut into pieces which are then skewered on lengths of bamboo to dry in the sun for about a week. The dried pieces are broken into fragments known as arako and further pulverized into flour. The flour is prepared for eating by mixing with water to form a paste which is mixed with slaked lime and water and boiled until it forms a gelatinous mass. This can be eaten in this form or processed further to produce another storable dry product, by cutting the dough into pieces and placing these in hot ashes for 5 to 6 days. The pieces are then left to dry for 2 weeks and are said to keep indefinitely in this form (Motte, 1932). Both Colocasia and Xanthosoma are used in West Africa to prepare sun-dried chips, known in Nigeria as achicha (Nwana and Onochie, 1979), essentially similar to cassava kokonte: like the cultivation of these crops, this is essentially a woman's function in this part of the world.

* Mannana are starch-like compounds which are formed, however, by the condensation of mannose instead of glucose and similarly under hydrolysis split into mannose rather than glucose.

E. Bananas and plantains

Only a small proportion of the world's bananas are preserved for storage, most of the fruit being consumed raw, in the case of dessert bananas, or cooked for immediate consumption in the case of cooking bananas and plantains (Simmonds, 1966). No extensive post-harvest technology for these foods exists in most traditional societies dependent on them.

Nearly all edible bananas and plantains are derived from two wild diploid species Musa acuminate Colla. (AA) and M. balbisiana Colla (BB) of the Eumusa series of the genus Musa (Musaceae) and most are triploids believed to have been formed as a result of hybridization within or between these two species. Simmonds (1966) has developed a classification of bananas according to the contribution to the genetic make-up of the hybrid and using this technique the bananas used as staple foods can be considered as falling within three triploid groups (AAA, AAB and ARE). The first (AAA) comprises the sweet cultivars having a low starch content and high sugar content when ripe and which includes the Cavendish sub-group which dominates the international trade in bananas. These are only used for cooking when green and are used as staple foods mainly as by-products of export orientated industries. The AAB group consists predominantly of fruit of the plantain sub-group which are starchy even when ripe and hence eaten only after cooking and the ABB group consists of the starchy cooking bananas known as "bluggoes" in the Caribbean. The importance of the different cultivars varies in different areas of the tropics. As a cooked vegetable, bananas and plantains form an important source of carbohydrate throughout the tropical world, except possibly India and Southeast Asia where, while dessert bananas are consumed in large quantities, the use of cooked bananas and plantains is not so widespread. In many parts of tropical Africa, most notably Ghana and Uganda, they are important staple food crops. In contrast, the preserved products do not generally contribute very greatly to diets, although they are important in some localized areas, especially in times of food scarcity.

Once ripe, the shelf-life of bananas and plantains is only a few days but traditionally plantains are harvested as an entire bunch while still green and hung in the house or other building. The fruits within the bunch ripen progressively from the proximal end of the bunch to the distal end and in this way the fruit is available for use over a longer period of time. Also the fruits may be cooked when green, half ripe or when fully ripe and so if not used while green, are still available for use at a later stage of ripeness (Coursey, 1981a). Thus, within traditional societies, there is seldom a high degree of wastage, although there may be in modern urban markets.

The methods used to cook bananas and plantains for immediate consumption do not generally entail elaborate processes, the fruit normally being prepared by one of three main techniques: boiling or steaming, baking or roasting and frying. However, in some areas, particularly West Africa, the fruit is also pounded, like other perishable staple food crops in these regions into a fatu-type product (see cassava, yam, aroids).

The preferred technique varies from region to region. In Uganda, where bananas are an especially important part of the diet, steaming is the normal method. In a typical dish, green bananas are peeled, wrapped in banana leaves, placed in a pan on a base of other leaves and steamed for 1 to 2 hours. When ready, the bananas are removed from the pan and mashed while still in the leaves to obtain a solid mass of pulp which is either eaten as such or resteamed for a while (Goode, 1974; Mukasa and Thomas, 1970). Other preparations in Uganda involve boiling green bananas or plantains, often with beans and peas or groundnuts, with ghee, onions and condiments added for flavour (Goode, 1974).

In West Africa, plantains boiled in their skins and then peeled are eaten alone or with a sauce usually based on palm oil and containing meat and/or fish, vegetables and seasonings (Dalziel, 1937; Johnston, 1958; Tezenas du Montcel, 1979; Walker, 1931) . Often the plantains are pounded in a mortar after boiling to form a paste or dough known variously as fufu, foofoo, foufou or foutou which is eaten with soup or a sauce of meat and vegetables (Johnston, 1958; Lassoudière, 1973). Fufu is also prepared from a mixture of plantains and cassava (Hartog, 1972; Lassoudière, 1973), and from cassava alone or yams or cocoyams. Frying ripe or unripe slices of bananas and plantains in oil, usually palm or groundnut oil, is also popular in this region of Africa (Boscom, 1951; Dalziel, 1937, Johnston, 1958; Tezenas du Montcel, 1979; Walker, 1931). In Ghana, a type of pancake is prepared from a mixture of pounded ripe plantains and fermented wholemeal maize dough (Del-Tutu, 1975). This is known as fatale and is prepared by steeping the maize in water for two days, then draining off the water and washing the grain which is ground into a dough with water and left to ferment for three days. The pounded plantain pulp is mixed with the fermented maize dough into a paste which is seasoned with ginger, pepper, onion and salt and then fried in palm oil. The pancake may be served with beans as a main meal or used on its own as a snack or dessert. A similar product known as krakro is made by mixing pounded plantains with corn dough, ginger, onion and salt. This mixture is left to rise for half an hour and then formed into balls and fried (Eshun, 1977) .

Roasted or baked bananas and plantains are also prepared in both East and West Africa by placing peeled or unpeeled fruit either in the ashes of a fire or in an oven (Boscom, 1951; Dalziel, 1937; Goode, 1974; Tezenas du Montcel, 1979; Walker, 1931; Whitby, 1972).

A product similar to fufu is also prepared in the Caribbean area from semi-ripe bananas which are boiled and pounded and eaten with soup, although more often the bananas are simply boiled and eaten with salted fish or meat. Over-ripe fruit is normally sliced and fried (Kervégant, 1935). In the South Pacific, unpeeled, ripe bananas are traditionally cooked in hot stone ovens or in the embers of a fire, while unripe bananas are peeled, grated, sometimes mixed with coconut cream, wrapped in leaves and cooked in an oven. In Samoa, pounded bananas are mixed with coconut cream, scented with citrus leaves forming a liquid mash called poi which is generally reserved for the chiefs (Massal and Barrau, 1956) .

Bananas and plantains are traditionally preserved by drying or fermenting the dried products and, in particular, flour being the most important nutritionally, although beer is also a major product in Uganda and Rwanda where the utilization of green bananas is particularly high.

Drying as a means of preservation is a widely used method for both unripe and ripe bananas and plantains, the end product from unripe fruit generally being chips which are pounded into flour while the ripe fruit is used to make sweet meats known as banana figs which are very popular in many areas but do not contribute very largely to a total diet. Traditionally, the fruit is sun-dried or sometimes dried in ovens or over fires; usually as slices, although banana figs are sometimes prepared from whole fruits (Fawcett, 1921; Goode, 1974; Hayes, 1941; Kervégant, 1935; Mukasa and Thomas, 1970; Simmonds, 1966; Walker, 1931).

Typically, slices of unripe banana are spread out to dry on bamboo frameworks, on mats, on cemented areas, on roadsides or simply on the ground (Kervégant, 1935). In Uganda, dried slices known as mutere are prepared chiefly as a famine reserve, the slices being stored and used only in times of need when they are cooked directly or first ground into a flour (Goode, 1974; Mukasa and Thomas, 1970). After sun-drying for one to two weeks the slices are packed into oval shaped bundles made of banana fibre and hung either in the house, or if large amounts are to be stored, in millet granaries (Hayes, 1941).

A method for preparing banana figs from a local variety known as rajeli (a French plantain type) used in the Bombay area of India has been described in some detail by Kulkarni (1911) . The fruit are harvested green and ripened by placing them in layers, covered with plantain leaves inside a storehouse and left for about three days, during which time a patch of bare earth is prepared as a drying area. A mat is spread out on this area and the peeled bananas arranged in rows to be dried for three days, each night being gathered in and covered and then spread out again the next day. The dried fruit is then wrapped in leaves for sale at the local market. The bananas prepared in this way are said to keep for six months.

In Polynesia ripe fruit are normally oven dried and then wrapped in leaves and bound tightly to store until needed (Massal and Barrau, 1956), while in East Africa peeled fruit is said sometimes to be dried over a fire for 24 hours before sun-drying in order to hasten the drying process (Kervégant, 1935).

The dried product keeps well in the form of slices, although liable to insect attack, whereas flour is hydroscopic and deteriorates rapidly under tropical conditions, tending to lose its flavour (Kervégant, 1935; Tezenas du Montcel, 1979). The dried slices of banana known as mutere in Uganda can be cooked as they are by soaking, boiling and then mashing to be served with a fish sauce (Goode, 1974) but more normally the slices are ground to a flour. In East and West Africa flour is used to make a thick paste known as fufu (or one of its variants) (Goode, 1974; Tezenas du Montcel, 1979) .

Traditionally, banana beer is made in both Uganda and Rwanda by the following method: Bananas are harvested green and ripened artificially by placing them in a pit, surrounded and covered with banana leaves and soil. In Rwanda the ripening process is aided by lighting a fire near or around the hole containing the fruit or by placing the bananas on the hot ashes of a fire previously lit in the hole. The fruit are left to ripen for 5 - 6 days and then removed, peeled and placed in a wooden trough made from a hollowed-out tree trunk. In Uganda the task of mashing the fruit to release the juice is carried out by the men who trample on the bananas which have been mixed with grass (Imperata species) whereas in Rwanda it is the women's task to knead the fruit by hand with the aid of handfuls of hard grasses such as Agrostis species. The juice is filtered into jars and the troughs washed with water to transfer the last traces of juice into the jars. Roasted sorghum flour is added to the banana juice and the mixture left to ferment for 1 to 2 days after which time the beer, known locally in Rwanda as urgwawa is ready for drinking (Adriaens and Lozet, 1951; Champion, 1970; Masefield, 1938). A similar method is used in Benin, but fermentation is initiated using some beer previously prepared or fermented banana flour (Kervégant, 1935). The juice before fermentation is sometimes consumed as a nonalcoholic drink while a very potent beverage is obtained by mixing honey with the banana pulp before fermenting; irrespective of their alcohol content, most banana beers have a high solids content and contribute substantially to the carbohydrate intake. Banana wines and distilled spirits are made in other areas of the world such as the West Indies and South Pacific but are of only minor importance (Fawcett, 1921; Kervégant, 1935). However, bananas and plantains do not appear to be used for this purpose in India or Southeast Asia (Simmonds, 1966).

Finally, in Western Samoa unripe bananas are preserved by fermentation using a technique normally applied to breadfruit in the Pacific Islands (Cox, 1980a). The product is a fermented paste which is baked to form a bread-like substance called mast. Both the paste and the bread can be stored or buried in leaf-lined pits for over a year until needed and exceptionally bread recovered after generations has been found still to be edible. To prepare, the unripe bananas are peeled, washed and placed inside pits lined with and covered by leaves of Heliconia paka A.C. Smith, and banana, forming a relatively air-tight pocket which is finally covered by soil and rocks. The fruit are left for 34 days and then uncovered to reveal a homogeneous paste which is formed into loaves, wrapped in leaves and baked.

F. Breadfruit

Breadfruit (Artocarpus altilis (Park.) Fosberg), is native to Southeast Asia, but is now found throughout the tropics and is an important staple in the South Pacific and parts of the Caribbean. The fruit is only suitable for use over a very limited period, that is when mature or nearly mature, but before it ripens, as during ripening rapid flavour and texture changes occur which render it unpalatable. It cannot, therefore, be stored in the fresh state for more than a few days, although in parts of Jamaica the storage life is extended a little longer by keeping the fruits under water in large tanks (Thompson et al., 1974).

For long term storage breadfruit is normally either dried or subjected to a period of fermentation. Most simply the fruit is cut into slices and dried in the sun as is done, for example, in the West Indies where the dried fruit is subsequently prepared for consumption by pounding and sifting for use as a breakfast food or in puddings (Brotbaum, 1933). However, a number of more complex techniques have evolved in the various islands of the South Pacific. For example, a method observed on Kapingamarangi in the East Caroline Islands is used to prepare dried sheets of breadfruit known as tipak. The skin, seeds and core are removed from nearly mature fruits which are then cut into small pieces and packed in coconut leaf baskets. The baskets are placed in an oven of hot coral stones covered with mats and sand and left for one day. After this time the fruit is removed and mashed in a wooden bowl and the resulting brown, sweet smelling paste is then spread out on coconut leaf mats to dry in the sun. The paste dries in sheets, usually about 1.5 m by 50 cm, which are then rolled up, wrapped in Pandanus leaves and tied with strings of coconut fibre. The Islanders claim that in this form the breadfruit can be preserved in good condition for at least three years (Coenen and Barrau, 1961).

A method used in the Reef Islands (Solomon Islands) involves firstly cooking ripe breadfruit in the ashes of a fire for about an hour. The fruit is then left for a day after which time it is peeled, quartered and the seeds removed and then cut up further into smaller pieces. The pieces of fruit are then placed to a depth of 10 - 12 cm on a net which is suspended over a hole 60 - 90 cm in diameter and 30 cm deep containing the coals of a smokeless fire and hot stones. The net is lowered as the fire and stones cool and the pieces turned continuously for about 6 hours until dry. The fruit is then placed in coconut baskets lined with breadfruit leaves covered with more leaves and the baskets sown up with bark fibre. The breadfruit biscuits or nambo are stored on racks above the kitchen fire and are said to keep for a year or more (Tedder, 1956).

The practice of preserving breadfruit by fermentation was traditionally used in the islands of the South Pacific and similar techniques are found on many different islands, the fermented paste being called by names such as masi in Samoa, ma in the Marquesas, mahi in Tahiti, maratan in Ponape and namandi in Vanuatu (Cox, 1980b; Massal and Barrau, 1954). A detailed description of the technique used in Samoa for both breadfruit and banana has been given by Cox (1980a), and has already been referred to in the section on banana in this report. Briefly, the fruit is peeled and washed, placed in a hole lined with Heliconia leaves which are folded over the fruit forming a fairly air-tight pocket. The whole pit is then covered with more leaves and layers of soil and rocks. After 34 days the fermented product, now a dough-like fermented paste, is removed and kneaded, made into loaves, wrapped in leaves and baked. The fermented paste can be left in the pits for over a year without deteriorating, although successful preservation is said to be dependent on the type of leaves used in construction of the pit, the care taken in building the pit and local conditions. A similar technique has been described from Anuta (Yen, 1973b). In Namu atoll a different technique is used. Fallen breadfruit is collected in June, peeled and placed in sacks which are then immersed in salt water for a day. The fruit is then laid on palm fronds for 2 - 3 days during which time it ferments and the fruit, which is by now soft, is kneaded. The pulp is placed in pits lined with breadfruit leaves and covered with sacks and stones where it is left until required: generally it is all used between the months of July and September when fresh breadfruit is unavailable. The fermented paste is most often prepared for consumption by rubbing on a board to produce a dry crumbly substance called drikwal which is wrapped in the breadfruit leaves and baked for about an hour (Pollock, 1974).

There are numerous ways of preparing fresh breadfruit for consumption but generally the fruits are either baked or boiled. Traditionally, on many of the South Pacific Islands breadfruit is baked or roasted simply by placing fruits on heated stones, coral or charcoal (Anonymous, 1951; Coenen and Barrau, 1961; Pollock, 1974). In Hawaii an underground oven or imu is used (Miller et al., 1937). In the East Caroline Island of Kapingamarangi a dish known as ti-kul palpon is very popular. The breadfruit is picked when nearly mature and stored until ripe. The rind, core and seeds are then removed and the hole left by removal of the core filled with coconut cream. The hole is plugged using a section of the core and the fruit wrapped in green breadfruit leaves tied firmly and baked for 1 hour (Coenen and Barrau, 1961).

A Tahitian dish known as poe uru is prepared by first cooking the entire breadfruit in an oven, peeling the fruit and reducing it to a paste to which is added a mixture of cassava starch and water. The paste which has gelatinous consistency is sweetened and seasoned with lemon juice and then divided into portions, wrapped in banana leaves and cooked again in an oven. Poe uru is served with sweetened coconut cream (Massal and Barrau, 1954).

Roasted breadfruit is also an important part of the West Indian diet, ripe fruit being piled over glowing embers and allowed to cook slowly for about 1 hour after which time the charred skin and fruit core are removed before eating (Brotbaum, 1933). Steamed breadfruit mixed with grated coconut is also popular, and pounded, steamed or boiled fruit is used to prepare a mashed product, cou-cou, which can also be prepared from other starchy ingredients (C.I.A.T./I.A.D.B., 1979). In parts of Indonesia the seedless form of breadfruit is cut into slices and fried in oil either as a main meal or for consumption as a delicacy (Ochse, 1931). In some areas the fruits of seeded varieties are considered not fit to be eaten although the ripe seeds are sometimes prepared as a delicacy (Ochse, 1931).

G. Pandanus

There are about 600 species of Pandanus, the most widespread being P. odoratissimus L.f. (P. tectorius Soland ex Park.), which is commonly found on sea coasts and islands from southeastern Asia eastwards to the islands of the South Pacific (Purseglove, 1972). Other edible species include P. brosimus Merr. and Perry, P. jiulianetii Mart., P. leram Jones, P. utilis Bory. The Pandanus fruit is an important food on many of the Pacific atolls, especially in Micronesia, although it is little used elsewhere. It is eaten raw or cooked and is preserved in the form of flour or paste (Stone, 1963).

The fruit is allowed to ripen naturally on the tree although ripening is sometimes hastened by twisting the fruit to separate the fruit stem (Hiyane, 1971). When eaten raw the fleshy base of the fruit is chewed to extract the soft pulp and sweet juice (Hiyane, 1971). The boiled fruit is often mixed with either coconut milk or grated coconut, or with other starchy foods and eaten hot or cold (Catala, 1957; Stone, 1963). For storage purposes a flour or paste is prepared, the former being more common in Kiribati while the latter is used more in the Marshall Islands of the Trust Territories of the Pacific Islands (Stone, 1903).

A paste known as mokan in the Marshall Islands is prepared by either boiling the phalanges of the fruit or baking them in an earth oven for 12 to 48 hours. The pulp is then grated and spread out on leaves for sun-drying to form a dry paste which is then further dried over a hot stove into thick firm cakes. These are then wrapped in Pandanus leaves and tied with coconut cord for storage (Hiyane, 1971; Miller et al., 1956). The pulp is sometimes mixed with arrowroot flour and sugar before drying (Hiyane, 1971). Flour is made in a similar way but the fruit is only cooked for about an hour. After cooking the pulp is pounded, sun-dried and dried further over heated rocks. The cakes thus formed are then pounded to obtain a coarse flour (Miller et al., 1956) . Both the flour and paste can be stored for several years and traditionally formed an important part of the provisions taken on long sea journeys (Hiyane, 1971; Miller et al., 1956; Stone, 1963). A number of other dishes are prepared from Pandanus fruit and have been described by various authors (Catala, 1957; Hiyane, 1971; Miller et al., 1956).

H. Starches derived from stem crops

Some vegetative stem crops have a localized importance as foods, most notably the Ensete bananas, Ensete ventricosa (Welw.) Cheesm. in Ethiopia and the sago palms Metroxylon sagu Rottb. and M. rumphii Mart. in Southeast Asia and Melanesia and other palms used similarly elsewhere. Once felled, these plants are never stored for any substantial period but are processed immediately.

SAGO

The techniques used to extract sago starch and the methods of storage of sago are very similar throughout the tropics and have recently been reviewed in some detail by Puddle et al. (1978) and Stanton and Flach (1980) . Palms are selected for high starch content, determined according to the stage of maturity of the palm or sometimes by sampling the pith, felled and cut open. Generally, the pith is removed by a combination of pounding and scraping and the starch is then washed out, the pith being kneaded with water by hand in a trough or trampled with the feet. The water in which the starch is suspended is then run off through a filter into a settling vessel. The system of troughs used for these processes is frequently made out of portions of the felled palms, and is usually erected near a stream from which water is collected by means of a simple long-handled dipper of palm spathe or coconut shell. Sago starch can be stored for some time. For example, it can be stored for a few weeks by wrapping in leaves and hanging to dry in the sun or, for longer storage, by burying the leaf-wrapped packets under mud and water in the sago swamps. Heating or toasting the sago extends its storage life further (Ruddle et al., 1978).

In Southeast Asia much of the sago used for subsistence purposes is consumed as pearl sago. This is prepared in Sarawak by taking wet sago which is mixed with rice bran and grated coconut and leaving the misture overnight. This allows time for yeasts and lactobacilli to give the mixture a slightly acidic flavour. The next day the dough is mixed thoroughly on a Pandanus mat during which process it forms into small pellets. The material is then sieved and any unformed dough re-shaken. The moist pellets are then baked on a clay hearth for 20 to 30 minutes with constant stirring during which time the pearls of sago develop a dark brown colour (Ruddle et al., 1978).

Sago starch can be cooked in a variety of ways. For example, it is often mixed with boiling water to produce a thick porridge or combined in water with leafy greens and meat to make a stew. It may be roasted in bamboo tubes or wrapped in leaves or baked as a flat cake on griddles of stone, earthenware or metal (Ruddle et al., 1978).

ENSETE

In the Sidamo area of Ethiopia the population relies on Ensete as a staple food (Taye and Asrat, 1960; Westphal, 1977). The pseudostem pulp is extracted and placed in a circular leaf-lined pit about 1 m in diameter and 1 m deep and when full covered over and weighted with stones and left to ferment. After 3 or 4 weeks the pit is opened and some strongly fermented Ensete from an older silo is added to accelerate the fermentation. After a further 4 weeks the pit is opened again and the contents rearranged and the pit reclosed, the total fermentation time taking from a few weeks to several months and sometimes up to a year. The fermented product is known as kojo and is mixed with spices and used for making bread which is generally baked on iron griddles or clay pans over a fire. However, in one district the spiced dough is wrapped in leaves and put in a pit about 80 cm in diameter and 80 cm deep and covered with layers of soil and Ensete leaves, on top of which the fire is kept burning for at least 12 hours. The bread thus prepared will keep several days (Anonymous, 1958; Smeds, 1955; Taye and Asrat, 1966).

Another product known as boulla is prepared from the scrapings of parenchymatous tissue of the pseudostem from which the juice is pressed out and the residue then dehydrated. This is then packed in Ensete leaves and left in a silo for fermentation after which it is eaten in the form of a porridge (Anonymous, 1958; Smeds, 1955; Taye and Asrat, 1966).

Chapter 6 General conclusions

The perishable staple food crops are second only to the grain crops as providers of human food. Grown mainly in the developing countries of the humid and sub-humid tropics, where they are often much more productive than grains, they provide the main staple of carbohydrate foods for some 500 - 700 million people. The root crops, especially cassava and yam, together with cooking bananas (plantains) are the most important.

Owing to the ecological conditions prevailing in the regions, production is often continuous or semi-continuous, in contrast to grain crop staples, whose harvesting is highly seasonal normally taking place during only a few weeks, so that long term storage for nearly a year for part of the crop is necessary. With the perishable staples many societies traditionally practice a greater or lesser degree of "storage avoidance", i.e. harvesting only for immediate or short term requirements throughout much of, or even the whole year. Thus, storage systems are usually relatively short term (the yams, the most highly seasonal of the perishable crops, provide a marked exception). Processing is often undertaken as much for the necessary removal of toxic principles (cyanide from cassava, alkaloids from certain yams or the irritant principles from some aroids) as for the manufacture of processed products of long storage life, although the need for more durable products for long distance travel or as famine reserves is often recognized. Although this is the traditional pattern, changes associated with increasing urbanization and the growth of market economies are reducing the validity of the "storage avoidance" approach.

Nevertheless, many traditional societies which have been primarily dependent on the perishable staples for centuries or often millennia, have devised many highly ingenious storage and processing techniques for these staples. The culture-historical evolution of these societies in relationship to their food plants has, in general, made them strongly ecocentric in their thinking, in contrast to the technocentric philosophies prevailing in the developed world, while further their material resource bases are strictly limited. Their storage and processing systems are generally, therefore, extremely simple and have only minimal impact on the total environment. Owing to their simplicity and the fact that they are usually individually small-scale, they have often been disregarded or even despised as "primitive" by qualified agricultural scientists; this attitude has been reinforced by the fact that the vegetatively-propagated crops from which those staples are derived are poorly understood within and alien to the "Western" cultures within which scientific thinking developed.

The valuable store of traditional knowledge of the postharvest biology and technology of these crop products existing within these societies is, however, well capable of interacting with and hopefully being improved by modern agricultural science. Certainly, it should not be neglected and this report forms a first attempt to review and classify such of the available information in the subject area that has already appeared in the scientific literature. Much more doubtless exists that has never been written up. It is suggested that, especially within the concepts of "appropriate technology" or "rural technology", traditional thinking and practice could very well be applied more extensively in the development of post-harvest technologies than has been the case hitherto.

The different staples are best adapted to particular, different ecosystems, although many are nevertheless extremely ubiquitous within the humid tropics. Similarly, the crop products need different approaches in their post-harvest technologies.

The most important non-grain staple of all, cassava, has very highly perishable roots, which normally have a storage life of only days; at the same time all known cultivars contain precursors of hydrogen cyanide though at widely differing levels. Although some societies have devised techniques for storing the roots for substantial periods (which techniques have been substantially improved by recent research on curing of the fresh roots) most cassavausing cultures process the roots by any of a variety of soaking, drying or fermentation techniques to produce stable dried products in which the level of the toxic cyanide is substantially reduced.

Yams, in contrast, are fairly highly seasonal in production, although harvesting may be spread over 4 - 6 months with different species and cultivars. The edible tubers being natural organs of dormancy, they are inherently well adapted for storage when destined for use as food and indeep most of the world's yam crop is stored in the fresh state, and simple but ingenious structures have teen devised by most yam-growing societies. Nevertheless, as with virtually all the perishable staples, techniques for the preparation of dried chips and flour exist in most yam-growing societies. Grating and soaking techniques are used to detoxify certain minor species which contain alkaloids.

Both sweet potatoes and the aroid root crops are examples of perishable staple crops where "storage avoidance" is extremely widely practiced although the root tubers of the former, especially, can under optimal conditions be stored for several months. Sweet potato is mainly grown in the cooler tropics, e.g. at altitudes over 1 000 m and protection from cold is a first essential in storage: under more typical lowland tropical conditions, losses in storage are extremely high mainly owing to pathogenic factors. Similarly, the aroids which are often harvested on a year-round basis, regardless of the state of dormancy of the corms, usually have very short storage life, but it is likely that if the corms are harvested when fully dormant, longer storage life could be obtained. Processing, essentially the production of sun-dried chips or flour, is occasionally resorted to with both these crops.

Plantains and other cooking bananas have an inherently short storage life in the fresh state, though from a practical point-of-view this is somewhat mitigated by the fact that they can be utilized as food in different ways, when unripe; partially ripe; ripe or even moderately over-ripe. As ripening of the individual fruit proceeds sequentially from the proximal to the distal end of the stem, the fruit of a single stem, once cut from the plant, can often be used over a period of a month or more. For longer term storage, especially as a famine resource, sun-dried chips and flour are sometimes prepared. In certain parts of the tropical world the preparation of beer (of high solids content, and therefore nutritious) or other fermented foods is practiced, the latter having a long storage life.

Breadfruit has probably the shortest inherent storage life of any of the perishable staples, being fit for consumption only in the few days between maturity and the onset of ripening. Commonly, it is harvested only as required, or its storage life extended a few days by keeping under water. Drying into chips or flour is sometimes practiced and anaerobic fermentation techniques have been developed in the South Pacific which produce a paste which may be kept for months or even years.

Pandanus fruit are also highly perishable. They are often eaten fresh, but are also preserved as sun-dried pastes or flours, the fruit being first boiled or roasted. It is said that the flour, especially, may be kept for several years.

The stem starches laid down by monocarpic plants such as sago and other palms, and also by Ensete, are invariably processed almost immediately; the felled stems are not stored any longer than is necessary. Processing usually depends on physical removal of the stem starch, followed by wet extraction, settling and drying, usually in the sun. Fermentation techniques are used for Ensete and occasionally for sago starches.

Very little information is available in most cases concerning the division of labour between the sexes in the postharvest technology of those staples. Processing is generally little more than an extension of domestic preparation for food and is thus, most commonly seen primarily as women's work. This is especially true of cassava products.

With storage of fresh material there seems little systematic sexual differentiation of labour, both men and women being involved, either separately or together in various societies. An important exception is with yams. Virtually all operations concerning the major (though not necessarily the minor) species of yam are conducted largely, or in some societies exclusively by men, including storage and processing, only actual culinary preparation being undertaken by women.

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