SOUTH PACIFIC
COMMISSION

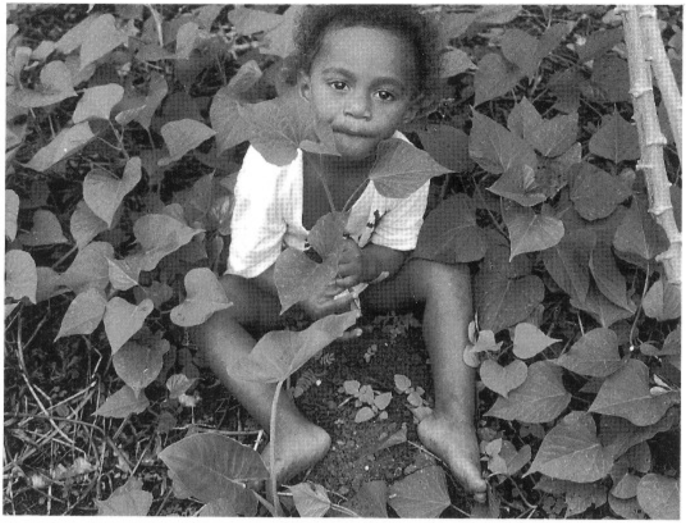
The Leaves We Eat

John M. Bailey

PACIFIC
FOODS

CTA

SPC Handbook No. 31, 1992



Cover picture

The boy is sitting among sweet potatoes. In the foreground there is a young *Xanthosoma* taro plant and near his feet are some 'weed' seedlings — possibly amaranth or nightshade. On the right are stems of cassava.

Technical Centre for Agricultural and Rural Cooperation (ACP–EU)

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Pacific Foods

The Leaves We Eat

by

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PREFACE

This booklet provides new information about Pacific green leafy vegetables. It is hoped that it will be particularly interesting and stimulating for agriculture, health and nutrition educators in all the Pacific Island countries. New nutrient data are discussed, together with some relevant health issues which are now of growing importance in the Pacific.

The nutrient contents of leafy vegetables vary a great deal, depending on the type or variety of plant and growing conditions. This variability must be fully appreciated and recognised whenever the relative merits of one vegetable over another are considered.

The information presented here is intended to enrich and supplement previous work on Pacific foods, in order to help nutritionists and agriculturalists encourage an increased general consumption of locally produced green leafy vegetables.

The many and valuable contributions of earlier workers are acknowledged and a brief historical background is therefore included for the reader's benefit.

Since its early years, the South Pacific Commission (SPC) has been concerned with improving the nutrition of Pacific Islanders. Two projects existed in 1949, one concerned with the collection of existing data on diet and nutrition of communities and individuals in the South Pacific and the other with maternal and infant welfare

In 1950, these projects were further expanded to include the study of infant foods, especially the preparation from local resources of a suitable food for the weaning period and determination of the nutritive value of island foods. The SPC's dietitian and nutritionist carried out extensive research in Papua New Guinea, along the East Coast of New Ireland and in the Trobriand Archipelago.

A biochemist, F. E. Peters, appointed in May 1951, carried out research on the nutritional value of Pacific Island foods, especially coconut and samples of breast milk collected from the New Hebrides (now Vanuatu) by Miss Malcolm, the nutritionist. The analytical work was done in the Institute of Anatomy in Canberra, Australia. The SPC also gave a grant to the Laboratory of Biochemistry, Otago University, New Zealand, for a research study on the amino-acid composition of Pacific Island foods.

During 1952, the biochemist continued his work in Canberra on the composition of coconut and breast milk and the thiamine content of Fijian rice. Approval was given for an expansion of the food composition project to include a study of the usefulness of protein from coconut as a food source. Between March and September, 1953, Mr Peters visited the United States, England and India. On his return, he began analytical work at the ORSTOM laboratory in Noumea on water, ash, fats, starches, reducing sugar and fibre.

In 1955, the equipment needed for amino-acid and vitamin analyses arrived. During the year, sixty-five foods were received, but some were in an unsuitable condition for an accurate analysis. The laboratory could determine the amino-acid profile of a food in about ten days and a vitamin assay in about two weeks. It could therefore study about thirty food samples in one year. Staple foods were given the highest priority

By April 1956, the laboratory was fully staffed and equipped. It was now able to analyse foods for 'proximates', amino acids and some vitamins.

Most of the foods analysed were from New Caledonia. All the tubers examined (taros, sweet potatoes, yams) were deficient in one or more essential amino acids. Generally speaking, the proteins were reasonably good and a mixed diet of taro and yams, or taro and sweet potato, or each of these with green leaves, would supply the balance of amino acids needed for a satisfactory diet. Coconut was found to be low in the sulphur amino acids. The protein and carotene (provitamin A) of sweet potato varied widely with varieties, but the amino-acid profiles did not differ significantly. Sago consisted mainly of starch and water.

During his service with SPC, the biochemist compiled a *Bibliography of nutritional aspects of the coconut*, (SPC Technical Paper No. 58, 1954), a revised edition (Technical Paper No. 95, 1956) and an annotated bibliography, *Chemical composition of South Pacific foods* (Technical Paper No. 100, 1957). This publication contains 105 pages with 326 references (many with food composition data), an author index, an index of food plants, a glossary of scientific names and a food composition table containing data on seeds (14), starchy foods (17), leafy vegetables (10) and fresh fruits—(14). All foods are given their scientific names and figures are presented for energy, water, protein, fat, carbohydrate, fibre, calcium, phosphorus, iron, carotene, thiamine, riboflavin, niacin and ascorbic acid.

The analytical work was suspended at the end of 1956. In 1957, the biochemical laboratory was closed and its personnel disbanded.

During the next 20 years, food analysis received no further attention from the SPC Health Services.

By 1979, several surveys of health problems among Melanesian and Polynesian populations had been carried out. The results of these surveys suggested that certain populations were susceptible to a variety of chronic diseases commonly associated with urbanisation, western lifestyle and diet. The SPC received financial support in 1980 for a study of the dietary and nutritional status of Pacific Islanders. During 1981, with funding provided by the United Nations Development Programme, all the various survey results and information on the effect of urbanisation and western diet on the health of Pacific Islanders were brought together. Several in-country workshops were held and recommendations were made for the formulation and implementation of national food and nutrition policies. Finally, a regional meeting was convened by UNDP and SPC in December 1981 on the theme 'The effect of urbanisation and Western diet on the health of Pacific Island populations'.

The Meeting recommended (*inter alia*) that SPC organise a technical workshop to gather, review and make available existing (but often unpublished) data on the nutrient composition of Pacific foods, and make recommendations concerning needs for additional food composition data in the region. It also recommended that SPC investigate the facilities available in the region for food nutrient and food contaminant analysis, with the aim of upgrading existing facilities to ensure that a prompt food analysis service was available within the region.

A working group on food composition tables, convened by SPC in November 1982, considered that SPC's *Food composition tables for use in the South Pacific* was the most suitable set of tables available for routine dietetic and public health practice in the Pacific region and should be used until a better set of tables was produced. It recommended that a nutrient database of indigenous and imported foods consumed in the Pacific be established. It also recommended that additional nutrient composition data on indigenous and imported foods consumed in the Pacific be produced. and suggested that much of this food analysis could and should be performed within the Pacific region.

Meetings of Pacific Island Heads of Health Services (1983) and Heads of Agriculture and Livestock (1984) recommended that SPC once again promote food composition studies for the benefit of people in the Pacific region. As a result, a project entitled 'Development of food composition tables in the Pacific region' was included in the Commission's nutrition work programme in 1985.

The following year, the South Pacific Commission organised the First Technical Workshop on Pacific Food Composition Tables, with funding from the United States Agency for International Development (USAID). Representatives from four Pacific analytical laboratories were present— the Institute of Natural Resources of the University of the South Pacific (INR, USP, Fiji); Department of Primary Industry, Papua New Guinea; the National Analytical Laboratory, University of Technology, Lae, Papua New Guinea; and the Institute of Medical Research, Madang, Papua New Guinea. Nutritionists, dietitians, home economists, agriculturists and food technologists from the region took part, along with observers from international, regional and national organisations.

The workshop defined the main aims of the Pacific Islands Food Composition Programme (PIFCP) and asked SPC to appoint a full-time co-ordinator to implement the programme. It drew up lists of priority foods for inclusion in the PIFCP, nutrients and analytical methods to be used, analytical equipment needed and potential research projects which could flow from the programme. The recommendations and plans were both comprehensive and ambitious. The majority of participants unfortunately had unrealistically high expectations of what could be achieved by the limited technical resources available in the Pacific.

The first Food Composition Co-ordinator, Dr Heather Greenfield, from the University of New South Wales, Australia, was appointed in November 1987 for a term of one year. Despite the limited funding available, she purchased some equipment and arranged preliminary training for the laboratories involved. A pilot project was initiated in two of the laboratories and a user questionnaire was produced to determine what foods should be analysed first.

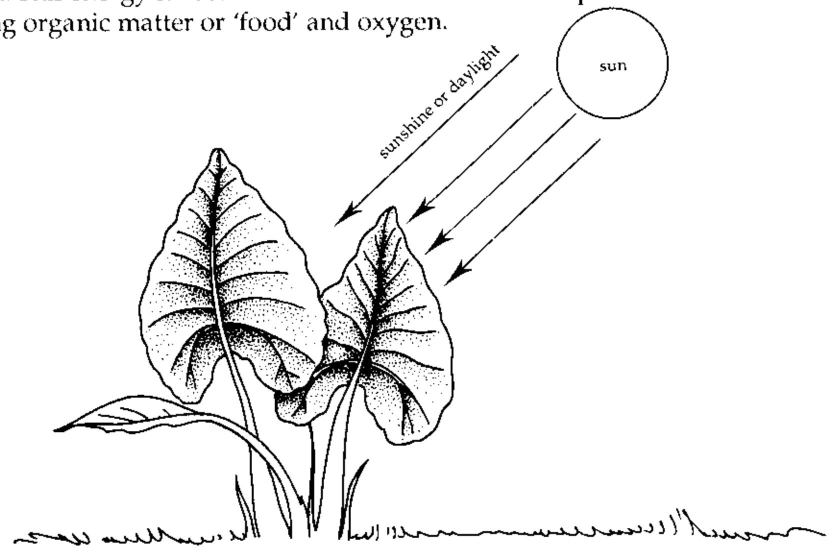
After the departure of Dr Greenfield, the programme continued under the guidance of the SPC Nutritionist, Dr Jacqui Badcock, until a new co-ordinator, Mr John Bailey, from the United Kingdom (formerly the Chief Agricultural Chemist for the Government of Papua New Guinea) was appointed in April 1989.

Nearly a hundred replies were received to the user questionnaire which had been sent out early in 1989. These were evaluated (Bailey, 1989) and a list of foods, in order of priority for analysis, was drawn up. The order requested was root vegetables, green leafy vegetables, locally processed foods, fruits, nuts, mixed cooked Pacific foods, snack foods, breast milk, cereals, beverages, meats, herbs and spices, poultry, milks, eggs and confectionery.

Root crops such as sweet potatoes, taros and yams had been analysed by Bradbury and Holloway (1988), so it was decided to concentrate on green leafy vegetables. The PIFCP laboratories validated their analytical methods in 1990 and by early 1991 had completed the analysis of 19 commonly eaten green leafy vegetables. The results of these analyses, together with colour photographs and information about green leafy vegetables, are published for the first time in this handbook.

I. ABOUT LEAVES

Leaves of one kind or another are all around us. They are usually green. This is no accident. The green colour is given by substances called chlorophylls. These are vital for the miraculous process called photosynthesis, which uses them to capture energy from the sun. This energy causes carbon dioxide from the atmosphere to combine with water, creating organic matter or 'food' and oxygen.



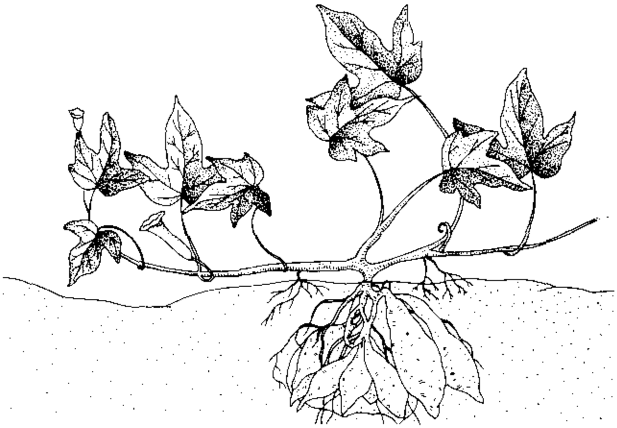
Green leaves are designed and positioned on each plant in such a way that they can make the best possible use of energy coming from the sun in a great variety of environments over the entire globe.

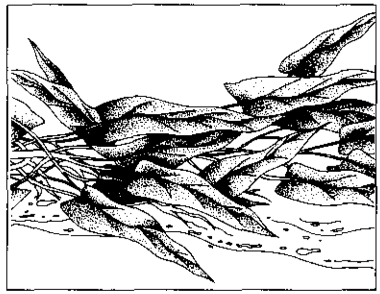
The 'food' formed in leaves can be used directly (by animals which eat the leaves) or indirectly (after accumulating in different parts of the plant, such as fruits, tubers or nuts, in a variety of forms — starch, fat and protein).

The larger the leaf area a plant is able to expose to daylight, the more 'food' it produces. It consequently requires not only more water and carbon dioxide, but also more of a whole range of elements from the soil in which it is growing.

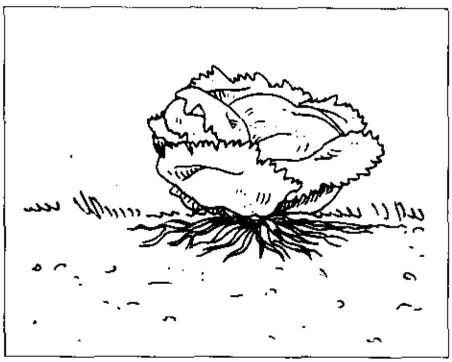
Plants adapted to a desert existence generally have very small leaves and deep roots, while aquatic plants have larger leaf areas and relatively insignificant rooting systems.

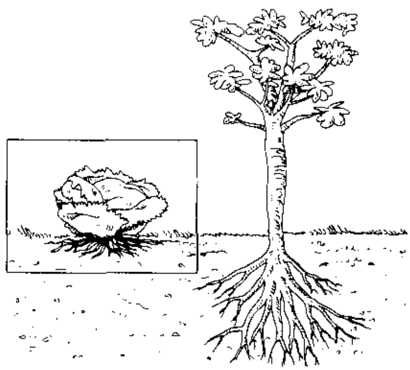
Food plants of the same family illustrate the wide range of environments that they can exploit. The sweet potato *(Ipomoea batatas)* needs excellent drainage for success, while its relative kangkong *(Ipomoea aquatica)* thrives in water.





Leaves from deep-rooted trees or other well established perennial plants are less affected by abrupt changes in the weather. Annual crops, on the other hand, have shallow root systems and more delicate leaves which respond quickly to changes in environmental conditions. Shallow-rooted seedlings and most fast-growing green leafy vegetables are particularly vulnerable to lack of water.





Animal life, another miraculous process, depends entirely on the green plant and humans are no exception. Leaves eaten by animals are one of the most efficient converters of the sun's energy that exist on earth.

II. LEAVES FOR HEALTH — COMPOSITION AND HANDLING

General composition

Fresh leaves generally contain a lot of water, some high-quality protein, a little fat (mostly unsaturated), some energy, fibre, minerals, and a wide range of vitamins, especially the pro-vitamin A pigments called carotenoids (see Appendix I). According to Beecher and his colleagues (1990), the most usual carotenoids found in commonly eaten Pacific foods, especially green vegetables, were lutein and beta-carotene. Yellow, orange and red fruits and vegetables contained the widest variety of carotenoids. All Pacific fruit and vegetables contained beta-carotene together with at least one other carotenoid. Pale-coloured foods such as taro flesh, light-yellow sweet potato flesh, and light coloured pineapple contained very little beta-carotene.

Cancer protection

Carotenoids seem to play an important role in protecting animal cells from cancer. According to Mathews-Roth (1989), skin tumours induced by ultra-violet B radiation were significantly delayed by carotenoids. He concluded that carotenoid pigments, irrespective of their pro-vitamin A activity, could prevent or delay the growth of skin tumours especially those induced by ultra-violet B alone.

Dark green leafy vegetables also contain a wide range of other highly chemically active substances which interact with other nutrients to make them more available to animals. Vitamins C and E are both described chemically as 'reducing agents'. These make minerals such as iron more available to the animal. They too are thought to play a role in cancer protection, because of their capacity to neutralise active oxygen.

Flavours and aromas

Some plants contain a lot of 'essential oils', known chemically as terpenes. These substances are present in higher concentrations in herbs and spices but they are also to be found in the different fruits and vegetables eaten by man and give them their special smells or flavours. These 'essential oils' can be extracted from leaves and are used in flavourings, perfumes and for traditional medicine. We can smell these 'oils' because they are highly volatile. This means that they are easily lost to the atmosphere when leaves containing them are crushed or cooked.

Toxic substances

Unfortunately some substances found in leaves are harmful or prevent the proper absorption of other nutrients. Examples of these are oxalate crystals in taro leaves, cyanide in cassava, phytates in cereals, goitrins in cabbage, and enzyme inhibitors in beans.

Oxalate crystals in taro leaves and tubers can make the mouth and throat sore. The oxalate also makes calcium less available and may lead to the poor absorption of iron, magnesium and copper (Beier, 1990). Large quantities are also poisonous to animals. They can be removed from taro leaves by boiling well and pouring off the liquid.

Cassava leaves also need to be properly boiled to get rid of any cyanide present in the leaf. 'Bitter' varieties contain more cyanide compounds than 'sweet' varieties. Sweet cassavas usually have a lower cyanide content, which is confined to a layer just under the skin, and softer and whiter flesh than the firm yellow flesh of the higher cyanide types. They mature earlier (6 months) and only keep about one year in the ground, compared with over three years without deterioration for the bitter or high cyanide cassavas (Purseglove, 1968). The leaves usually contain more cyanide than the tubers.

Phytates make iron less available and goitrins interfere with the uptake of iodine, an essential element for the thyroid hormone, thyroxin. Certain enzymes in beans prevent the digestion of proteins, but these can be removed by soaking the beans in water and pouring away the water before cooking.

Traditional Pacific food preparation methods have eliminated or reduced many of these unpleasant substances by a process of trial and error over the years.

Boiling does, however, destroy some of the other vitamins, such as Vitamin C and folates, and pouring away the water will mean that water-soluble minerals and vitamins such as potassium, sodium and some of the B group vitamins will be lost also. Pro-vitamin A carotenoids are reduced by boiling but not to the same extent as the other vitamins.

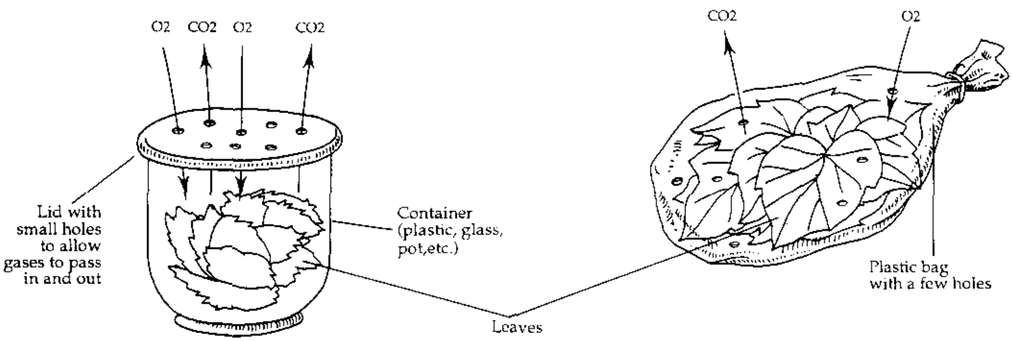
Food processing, storage and handling also seriously affect the nutrient levels in green leaves. As soon as the leaf is removed from the plant, its enzymes begin to break down many substances. The degree of enzyme action depends on the extent of the damage suffered by the leaf.

Maximum health benefits

In order to obtain maximum health benefits from green leaves, they should be eaten fresh or as lightly cooked as possible. Cooking methods which are quick and retain all the cooking water are the best, but of course they are not suitable for leaves which contain cyanides or oxalates. At every stage from harvesting the leaf to the eventual consumption some vitamins and minerals will be lost. Most of the substances which are said to be health-protecting, except proteins, are extremely vulnerable to loss or degradation.

Green leaves need to be handled very carefully. Physical damage, whether caused by cutting, bruising, freezing, over-heating, excessive exposure to light (especially sunlight) during drying or storage, insects or disease, should be minimised for maximum nutrient retention.

As a general rule, the most active substances are the ones which are lost first. Unfortunately many of these special health-protecting substances are also very active chemically. Green leaves need to be washed very carefully before being eaten fresh. This is not always possible when water is in short supply or is polluted. Cooking the green leaves is then the best method of processing, especially for young children. Green leaves are still alive and respiring shortly after gathering. That means they need oxygen, so green leafy vegetables should never be sealed in air-tight containers. When sealed, they quickly start producing chemicals which damage the cells, cause brown spots, change the flavour and generally make them inedible.



Other cooking effects

Some green leaves are changed chemically during the cooking process. This can increase their smells or flavours (McGee, 1984). Herbs have strong smells and flavours when raw, but a cabbage leaf can develop very strong odours when it is cooked for a long time. These odours come from a family of substances which contain sulphur and are called isothiocynates. Hydrogen sulphide is also produced — giving the smell of rotten eggs. So a general rule when cooking the cabbage family (mustard, brussels sprouts, cauliflower, broccoli, turnips) is that fewer nutrients will be lost with shorter cooking periods and fewer objectionable sulphur compounds will be formed. Stir-frying or eating raw in salads are two ways of using vegetables from the cabbage family that will reduce nutrient losses and unpleasant smells.

Darker the better

A useful guideline for estimating the relative nutritional value of green leafy vegetables is 'The darker their colour, the more vitamins they contain'. This is because plants make Vitamin C from simple sugars supplied by the leaves from photosynthesis, the energy-trapping process mentioned earlier. The more light the leaf receives, the more photosynthesis there is and thus more sugars are produced, which in turn give more Vitamin C. In addition, in order to handle more light-energy input, the plant needs more pigments, such as chlorophylls and carotenoids, in the leaves and therefore the leaves and stems are a much darker green.

The pale inner leaves of lettuce and cabbage contain only a fraction of the carotene of the dark green outer leaves—possibly 30 or 40 times less. The trouble is that these outer leaves are more likely to be damaged either by insects or the weather and probably end up being thrown away or used as animal food.

Nutrient value

Some final comments about the nutritional value of green leafy vegetables are worth repeating. As mentioned at the beginning of this section, green leafy vegetables supply vitamins, especially Vitamins A, B, C and E, and some minerals. Vitamin A precursors, the carotene pigments and substances with Vitamin E activity are not water-soluble but fat-soluble, while B and C group vitamins, together with the minerals, are water-soluble and are liable to be lost in the cooking water if it is poured away. Carotenes are relatively stable, while thiamine and folates are heat-sensitive and Vitamin C and Vitamin E substances are very sensitive to both oxygen and heat.

Reducing nutrient loss

For cooking green vegetables, therefore, use the shortest possible cooking time and the least possible water, with undamaged or uncut pieces of vegetable. In other words, cook the leaves intact and only add salt to taste after cooking. Salt added during cooking increases the loss of soluble nutrients.

A useful list of green leaves is shown in the table below (taken from *South Pacific Foods Leaflet 6*, 1983) together with their photographs. Some of the leaves shown have now been analysed in more detail and the results are shown in Figures 1—17 and in Appendix 1.

The leaves we eat

ENGLISH NAME	SCIENTIFIC NAME	LOCAL NAME (fill in)	FOOD VALUE	DESCRIPTION OF PLANT	PREPARATION METHOD
1. aibika, pele	*Abelmoschus manihot*		very good	small woody bush; many different kinds	Easy Method (no longer than 5 minutes, turn leaves once)
2. amaranth, tropical spinach, Ceylon spinach	*Amaranthus* species		very good	plant with stand-up stems and spikes of flowers; many different kinds	Easy Method or Stir Frying
3. basella, creeping spinach	*Basella alba* *Basella rubra*		good	climbing or bushy plant with pink or white flowers	Easy Method (no longer than 5 minutes), Stir Frying, or raw in salads
4. breadfruit leaves	*Artocarpus altilis*		very good	large fruit-bearing tree	Choose very young leaves, softened over a fire; remove stalk, then cook by Easy Method for 20 minutes
5. cassava leaves	*Manihot esculenta*		very good	root-bearing shrub	Choose young leaves; cook by Special Method. Do not eat raw
6. chilli leaves	*Capsicum frutescens*		very good	small fruit-bearing bush	Easy Method or Stir Frying
7. Chinese cabbage, pak choi	*Brassica chinensis*		good	dark green leaves with light stalks	Easy Method, Stir Frying, or raw in salads
8. cowpea leaves*	*Vigna unguiculata*		good	climbing or bushy plant with long pea pods	Easy Method or Stir Frying
9. drumstick tree, horse radish tree	*Moringa oleifera*		very good	small tree with yellowish-white flowers and long pods	Easy Method or Stir Frying
10. European cabbage	*Brassica oleracea* (var. capitata)		fair	solid round heads of light green leaves	Easy Method, Stir Frying, or raw in salads
11. fern	*Athyrium esculentum*		good	large wild fern that grows in wet places	Use top of stalks, split into four pieces, then cook by Easy Method
12. gnetum, jointfir spinach	*Gnetum gnemon*		very good	small nut-bearing tree that usually grows in the bush	Choose very young leaves, use Easy Method or Stir Frying. Do not eat raw
13. Indian mulberry tree	*Morinda citrifolia*		very good	small tree with white flowers and bumpy fruits	Choose very young leaves and use Easy Method
14. kangkong, swamp cabbage	*Ipomoea aquatica*		good	trailing plant that grows in water or on dry land	Easy Method, Stir Frying, or raw in salads
15. pumpkin leaves	*Cucurbita moschata*		good	fruit-bearing vine	Choose young shoots and leaves, use Easy Method or Stir Frying
16. roselle, red sorrel	*Hibiscus sabdariffa*		good	small bush with woody branches	Easy Method or Stir Frying
17. sweet potato leaves	*Ipomoea batatas*		good	root-bearing vine	Easy Method or Stir Frying
18. taro leaves	*Colocasia esculenta, Xanthosoma* species		very good	root-bearing shrub	Choose soft young leaves with pale stalks, use Special Method. Do not eat raw
19. water-cress	*Nasturtium officinale, Roripa nasturtium-aquaticum*		good	trailing plant that grows in water	Collect only from clean water. Easy Method (only 3 minutes), Stir Frying, or raw in salads
20. winged bean leaves	*Psophocarpus tetragonolobus*		very good	climbing plant with long four-sided pods	Easy Method, Stir Frying, or raw in salads

*No photograph is shown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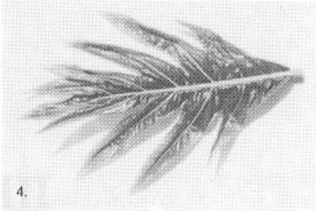
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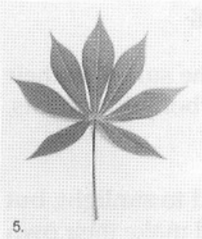
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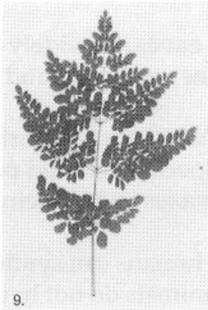
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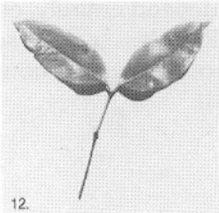
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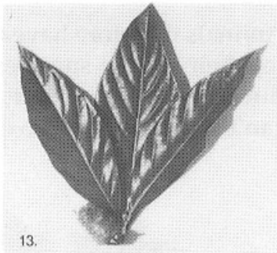
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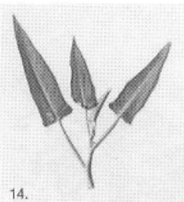
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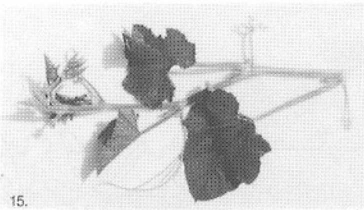
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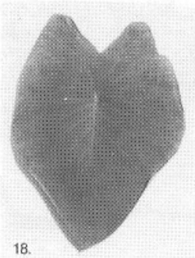
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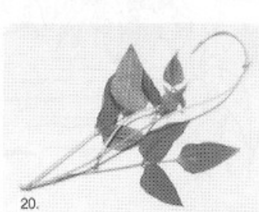
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III. USE OF LEAVES

Leaves are widely eaten in the Pacific. They are also used to wrap other foods, usually the root crops and protein foods such as fish or meat, during cooking.

As mentioned earlier, green plants are able to absorb energy from the sun with their special coloured pigments and store it in different forms such as carbohydrates, fats, waxes and proteins.

Humans can synthesise Vitamin D in their outer skins when exposed to sunlight, but animals do not have special pigments to capture the sun's energy and make their own food as plants do.

Animals therefore have to depend entirely, either directly or indirectly, on plant food for their energy supplies. Reptiles, such as some types of lizards, do need the sun's direct warmth, however, in order to have enough energy to digest their plant food. They can't eat if they are too cold!

Humans use leaves for food either indirectly, by eating the herbivores—sheep, cows, rabbits, etc. which have obtained their energy by eating grass and other plants, or directly, by eating green leafy vegetables.

In man's early days he was described as a 'hunter and gatherer'. He hunted, fished and gathered leaves, nuts, tubers and fruits. Later he kept animals under his control and grew his own crops — what we now call agriculture.

As a food source

A greater variety of leaves was probably eaten in the days before agriculture, because the different herbs, bushes and trees would have been widely distributed throughout the area where the early Pacific Islanders lived and hunted.

Eating a large variety of leaves is a good practice, because no particular leaf contains everything that is needed for good health. Man's survival must have depended a lot on the variety of leaves eaten. Nutrition studies in the Pacific in the early 1950s stated that green leaves were generally considered a substitute for meat. Meat or fish was only eaten on average about three times a week.

Settled agriculture with domestic animals and cultivated vegetables probably resulted in a reduction in the variety of leaves consumed, either because not all the plants would be able to grow on the farms or because people would tend to eat more leaves from those plants which could be grown more easily or took less space. Perhaps people began to grow more of certain food crops for status reasons, or for security against natural or other disasters. The yam, for example, is given high priority as a root crop in many Island countries.

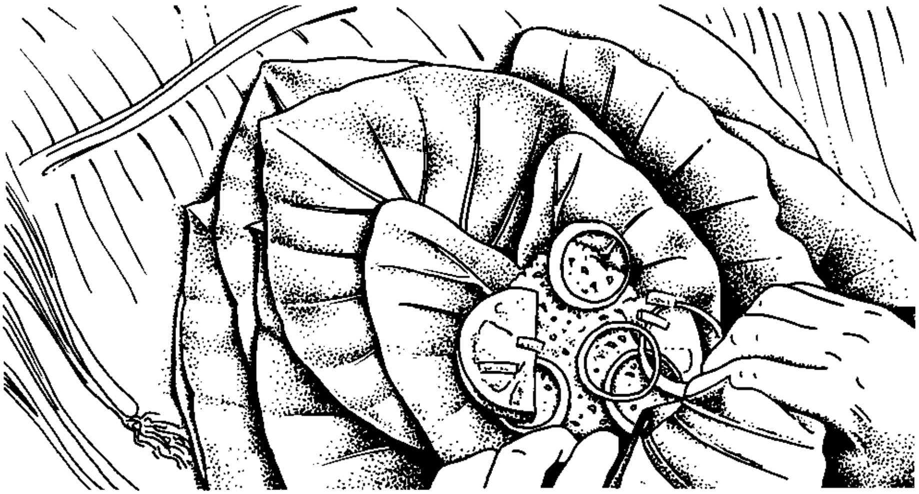
For colour and flavour

As humans became more sophisticated, leaves were used to make food more interesting and acceptable. Leaves were used to add colour, flavour, moisture and different textures to food.

— Kangkong with tinned meat, onions and baby tomatoes (top left)
— Green salad (lettuce, watercress, spring onions and nightshade leaves) (top right)
— Pumpkin tips in coconut milk (bottom left)
— Snapper, bele leaves and yam, steamed (bottom right)

In food preparation and storage

Banana or other green leaves are often used in the Pacific to wrap up root vegetables such as yams, taro and sweet potatoes and meat or fish for baking in earth ovens ('lovo', Fiji; 'umu', Tonga; 'mumu', Papua New Guinea). Breadfruit leaves can be used for this purpose, but, like all green leaves, they must always be washed well with clean water before use. The leaves are often softened slightly over the fire or hot stones to prevent them cracking or splitting when they are wrapped around the food. Sago and cassava leaves are also used as wrap food before cooking. 'Leaf lap lap', *Heliconia* sp. and 'burao' ('fao'), *Hibiscus tiliaceus* are used in some island countries for the same purpose.



Coconut fronds can be woven into baskets to hold large fish or pieces of meat. Pandanus is commonly used to wrap seafood such as beche-de-mer. Banana mid-ribs or pandanus and coconut leaf fronds are generally used for tying up the food bundles before they are placed in the earth oven.

The wrapping leaves seal in moisture and nutrients during cooking. Flavours are retained and the cooked food more palatable as a result.

Wrapping leaves also have additional effects on the food. Some leaves, such as papaya, contain the protein-splitting enzyme papain and tenderise any meat they are covering.

Fat-soluble Provitamin A and Vitamin E are partially extracted from the enclosing leaves by fatty food, thus improving the overall food value. The leaves also act as a protective buffer between the food and the fire or hot stones, thus helping to retain more heat-sensitive vitamins in an active state and protecting food from contaminants.

Some of the larger leaves from plants such as breadfruit, taro and banana were commonly used as 'plates' in the old days before Captain Cook arrived in the Pacific with his ceramic plates, crockery and other European customs. Plaited coconut leaves can be used as food bowls and storage baskets to store large quantities of baked food from the 'umu, or to contain food for traditional feasts ('pola', Tonga).

Food processing

Some simple food processing techniques use leaves. For example, many cocoa producers in the Pacific and Ghana, Africa, utilise banana leaves to produce high quality cocoa. The freshly harvested cacao fruits are removed from their pods and wrapped with banana leaves in large bundles. The bundles are left to ferment for about seven days, and then, after drying, can be ground or pounded to produce a kind of cocoa paste.

Certain leaves are used directly to make hot and cold beverages. The young tips and leaves from a particular type of camellia bush are plucked, partially fermented and then dried to make the familiar drink, tea. Lemon grass and orange and lemon leaves are all widely used in the Pacific to make pleasantly flavoured drinks. One or two small blades of lemon grass are infused with a cup of hot water for about five minutes to give a refreshing hot drink.

In medicine

Many of today's modern drugs or medicines have been developed from the thousands of natural products found in plants. Either they have been extracted directly from the leaves or organic chemists have synthesised them in the laboratory from the appropriate organic molecules. More than 20 per cent of commercially prepared drugs originate from plants (Beier, 1990).

A commonly used pain-killer has its origins in the willow tree — *Salix* sp., hence acetyl salicylate and the familar drug 'aspirin'.

Two classes of chemicals regularly employed in medicine and found in plants are the alkaloids and terpenes. Alkaloids often have quite remarkable effects on the body and the group includes quinine, extracted from the bark of the cinchona tree and is used to treat malaria; atropine, which comes from a member of the solanum family, and is used to treat organo-phosphorous insecticide poisoning; morphine, a powerful painkiller made from poppies; and many others. Terpenes, which are used in perfumes and medicaments, are found in the essential oils of herbs and spices such as cardamom, pepper, chilli and cloves. They are also in the leaves of eucalyptus and melaleuca trees (known in New Caledonia as niaouli). Niaouli leaves infused with hot water are said to relieve aches and pains. The niaouli oils in the vapours from a hot-water infusion also help to relieve an asthma attack. Other substances found in leaves or flower petals and seeds are pyrethrins, from the pyrethrum daisy, which are used in rapid-acting insecticides, and cineol and terpineol from cardamom, a member of the ginger family.

Readers interested in finding out more about medicinal plants in the Pacific should refer to the two excellent SPC technical papers by Petard (1972) and Holdsworth (1977), details of which are given in the list of references at the end of this booklet.

Protein source and preserved food supply

Processes have been developed, especially in India, to extract protein from leaves. The process involves crushing the leaves, extracting the juice and heating it to coagulate the protein. This is then separated, dried and ground. The resulting green powder is added to baby foods and other foods to increase their protein and carotene content (Fellows, 1987). Many leaves are sun-dried in African countries, ground and then stored to be used later in the year as a food supplement. Some of the more sensitive vitamins will have been lost, but most of the food value will have been retained. More information about leaf protein, its preparation and use, can be found in a handbook produced by the International Biological Programme and edited by Pirie (1971).

Summary

In conclusion, it is stressed that leaves should be used in people's diet as often as possible. The greater the variety of leaves eaten, the more likely it is that daily vitamin and mineral requirements will be satisfied. An interesting and valuable account of the use and nutritional value of green leaves is given by Oomen and Grubben (1977), should additional information be needed.

The next section deals with certain commonly eaten Pacific Island green leafy vegetables which have been analysed by the three PIFCP laboratories.

IV. COMPOSITION OF SOME LEAVES EATEN IN THE PACIFIC ISLANDS

Twenty-two commonly eaten leafy vegetables are described in this section. Each vegetable is illustrated by a colour photograph or line drawing. The chemical composition of these vegetables is presented graphically in Figures 1—17 and in tabular form in Appendix 1.

1. LETTUCE: *Lactuca sativa*

Lettuce is the most widely grown of all the green leaf salad crops. It can also be eaten cooked. It belongs to the Compositae family, one of the largest in the plant kingdom, which contains, sunflower, chicory, endive, pyrethrum and many ornamental flowers. Lettuce is a popular salad vegetable in most parts of the world. The plant probably originated in the Middle East. According to Purseglove (1968), a long-leaved form is depicted on Egyptian tombs dated 4500 BC and there is evidence that lettuce was eaten by the ancient Greeks and Romans.

Lettuce grows best at higher altitudes or in the cooler season in the tropical region. Light, well-drained, well-watered and adequately fertilised soil promotes the most vigorous growth. When water is limited or the temperature is too high, the leaves not only become bitter but there is also a strong tendency for the plant to 'bolt' or go to seed. Several varieties of lettuce exist, including the upright cylindrical cos lettuce, cabbage or head lettuce, curled-leaf lettuce (some with pink tips) and asparagus or stem lettuce from China. Local departments of agriculture can be contacted for the names of recommended varieties.

Lettuce is usually grown from seed and 1 oz or 28 g of seed produces about 3,000 plants. The seeds germinate best at about 20°C within 4—5 days of sowing. Lettuce seeds do not store well in the tropics and if stored, they are best kept in the body of a refrigerator, an air-conditioned room, or a dry, well-sealed container (tin or bottle) in a cool place.

Lettuce must be well washed with clean water, especially if it has been fertilized with animal manure. The leaves should be shaken well to remove water. This enables the oil used for salad dressing to stick to the surface of the leaves. The addition of a little oil helps to extract the fat-soluble carotenes present in the leaves and probably improves their absorption during digestion. About 100 g or 4 oz of lettuce, especially the darker outer leaves, will supply about 30 per cent of a child's daily Vitamin A requirements.

Lettuce (Lactuca sativa)

Lettuce is usually eaten raw as salad after being washed in clean water. The leaves are best eaten with a little oil and vinegar to improve palability and extract vitamins. A Cos type is shown in 1a and a pink-coloured open-headed type in 1b.

2. TARO: *Colocasia esculenta*

(Taro stalks and leaves appear as nos. 2 and 19 in Figures 1—17 and Appendix 1)

The *Colocasia* taro is one of the most important edible aroids in the Araceae family and probably came from India more than 2000 years ago, according to references cited by Bradbury and Holloway (1988). The family includes giant taro (*Alocasia macrorrhiza*), elephant foot yam (*Amorphophallus campanulatus*), giant swamp taro (*Cyrtosperma chamissonis*) and tannia (*Xanthosoma* sp.). These are described by Massal and Barrau (1956), who also give a simple identification key. After cooking, a single taro leaf which weighs about 20 g would supply about 20 per cent of a small child's daily requirement for Vitamin A.

Taro is grown throughout the tropical region, including the Pacific. The major variety eaten is *Colocasia esculenta*, which produces a large edible corm with a few suckers or cormels. Taro lives quite a long time and produces useful food after about eight months in the warmer lowland areas of the Pacific. The leaves are heart-shaped and the leaf veins do not join directly with the petiole or stalk as those of the other common taro, tannia, *Xanthosoma sagittifolium*, do. The plant stands about one metre from the ground and has a normal productive life of about ten months. There are many varieties and each has its particular colouring, taste, yield, disease resistance and vigour (Hale and Williams, 1977).

The leaves and young stems of the non-acrid varieties which do not irritate the mouth are widely used as a green vegetable in salads and many traditional Pacific Island dishes (Standal, 1983; Parkinson, 1984; both cited by Bradbury and Holloway, 1988). The best leaves for eating are said to be the first four produced (Hale and Williams, 1977). The upper parts of larger leaves, especially those varieties with a purplish tinge, and the long white shoots produced by tubers which have been stored in a dark damp place are also eaten (Herklots, 1972). The older leaves are more likely to have sharp, needle-like crystals of calcium oxalate which make them very acrid even after cooking. In the Pacific both leaves and stems are commonly cooked with coconut cream.

Taro needs a deep, fertile soil and plenty of rain — at least 2000 mm per year. It is usually planted in the best areas of newly cleared land. As a Pacific example, the sequence of cropping in Tonga, according to Schröder et al. (1983), usually begins with 'ufi' or sweet yam, (*Discorea esculenta*) followed by 'talo futuna' or kong-kong taro (*Xanthosoma sagittifolium*) and 'talo tonga' or *Colocasia esculenta*, sweet potatoes, cassava and bananas or plantains (cooking bananas).

In the highland areas of Papua New Guinea, on land just out of fallow or newly cleared from forest, the first crops to be planted, at about the same time, are usually the yams and taros, together with a variety of green vegetables. As the soil fertility declines, more sweet potatoes are planted and these are commonly followed by cassava.

Local names for taros and other food plants are given in SPC Information Document No. 35 (1974), *Kulu, kuru, uru*, by Claude Jardin.

***Taro* (Colocasia esculenta)**

Both stalks and leaves can be eaten.

3. PAPAYA SHOOTS: *Carica papaya*

Papaya or pawpaw trees are found in tropical and sub-tropical America and Africa. The species probably originated in southern Mexico and Costa Rica. About 40 species of papaya are cultived in America for their fruit.

The papaya belongs to the small Caricaceae family, which also includes the small egg-shaped mountain papaya and several small shrubs and trees.

The sap or latex of papaya is rich in papain, an enzyme which breaks down protein.

The Spaniards took papaya to Manila in the middle of the sixteenth century, according to Purseglove (1968) and it reached Malacca in Malaysia soon afterwards.

The plant probably spread to the Pacific region during this time.

Papaya is a tropical plant and does not withstand frost. It needs full sun and adequate protection from wind. Low temperatures produce poor-flavoured fruits.

The tree grows best on well-drained and fertile soils, with abundant water, but it cannot tolerate standing water around its roots.

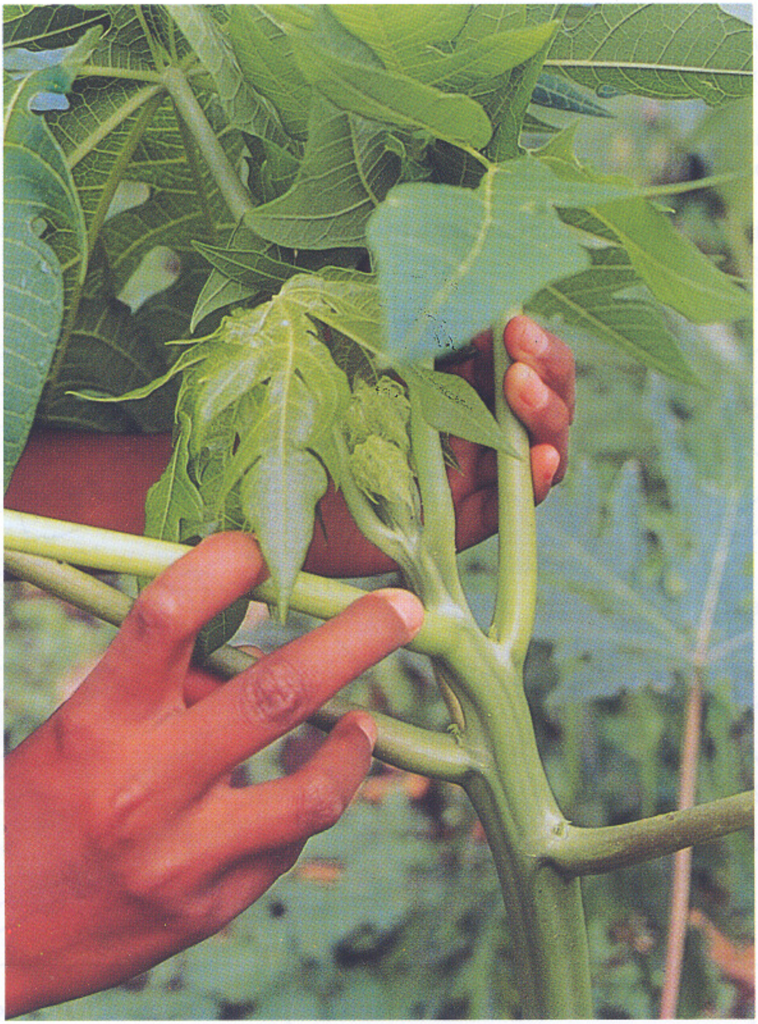
Papaya is a short-lived tree with very soft wood. Young shoots and leaves are eaten as a green vegetable, especially in South-East Asia.

Papaya can be grown from seed but can also be propagated vegetatively by cuttings or grafting. The trees may live as long as twenty-five years.

Fruiting begins after about one year's growth and trees are suitable for latex production for a period of about three years.

Shoots and leaves can be harvested for about the first three years or until the tree grows too high to reach the new young shoots.

More information about husbandry, major pests and diseases and papaya production can be found in Purseglove (1968) or obtained from local departments of agriculture.



Papaya shoots (Carica papaya)

The young shoots and leaves are eaten as a green vegetable, especially in South-East Asia. This vegetable could supply a useful amount of vitamin A and other vitamins to the Pacific diet.

4. CABBAGE: *Brassica oleracea.* var. *capitata*

Cabbage belongs to the plant family Cruciferae, with most of its members having their centre of origin in temperate countries.

The familiar round, compact cabbage has been grown in Europe for about 4500 years and was probably spread to many European countries by the Romans.

The plant is now grown throughout the world, including the Pacific where it has become a very popular vegetable.

Cabbages prefer a well-drained, fertile soil and temperatures between 10° and 25°C but fairly good yields can be obtained with some varieties at temperatures between 25° and 30°C.

Cabbages respond rapidly to the addition of manures containing plenty of nitrogen, which is needed to support the satisfactory development of healthy, dark green leaves. The greener the leaf the more vitamins and minerals it will contain.

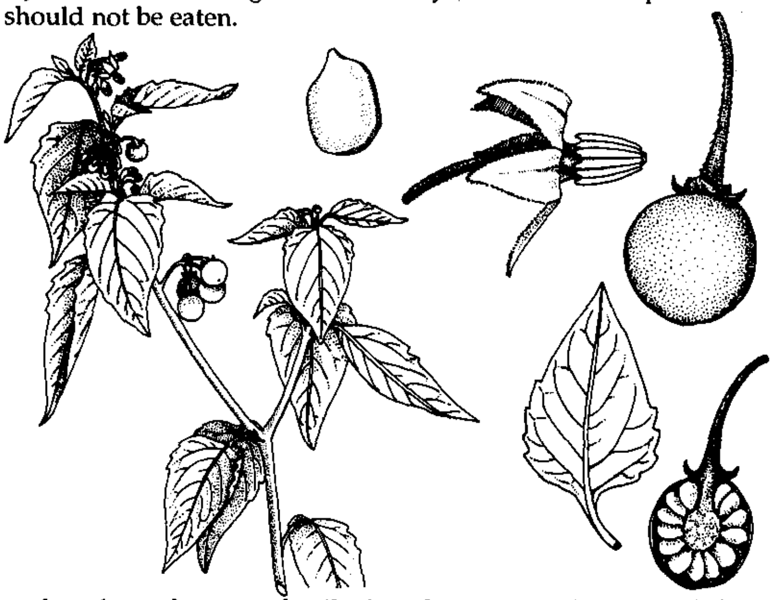
Cabbage (Brassica oleracea, _var._ capitata)

The hard drum-head cabbage keeps well and is a popular vegetable in the Pacific. The pale inside leaves are not as rich in vitamins as the darker outer ones.

5. NIGHTSHADE: *Solanum nigrum*

The Solanaceae family gives us many useful plants such as potatoes, tomatoes, egg-plants, capsicums and chillies, tree tomatoes and tobacco, to name just a few common ones. Tobacco is mentioned here because it contains the substance nicotine which is used as an insecticide on pepper (*Piper nigrum*) and other cash crops suitable for the Pacific.

Nightshade is an annual, known as 'karakap' in Papua New Guinea, which probably grows throughout the Pacific region. It likes cool, wet weather and generally seeds itself, but the seeds can be broadcast. The plant thrives in damp, shady places and among other vegetables and grows like a weed. It rarely reaches a height of one metre and is usually found growing to about 30 cm. The leaves are best eaten young and should be harvested just before flowering and before they harden. The unripe berries are poisonous and should not be eaten.



A similar plant from the same family found in Europe (*Atropa belladonna*) is called 'deadly nightshade' because of its poisonous berries. They contain the alkaloid, atropine — atropine sulphate is used as an antidote for organo-phosphorus insecticide poisoning. Ophthalmologists use atropine to dilate the pupils of their patients' eyes in order to make examination easier. The name 'belladonna' comes from the Italian for 'beautiful woman'; the plant was used by women in some countries to emphasise their eye and make them more attractive.

Nightshade **(Solanum nigrum)**

The tender new leaves from the youngest plants are the best.

6. WINGED BEAN: *Psophocarpus tetragonolobus*

The plant probably originated in tropical Asia but it has been known for a very long time to the Melanesians in Papua New Guinea, where it is called 'arsebean' or 'bin'. Other names for it are Goa Bean, four-angled bean, Manila bean, asparagus pea and princess pea. It belongs to the plant family called Leguminosae, one of the largest of the plant families.

The young leaves, shoots and flowers can be eaten as a vegetable, but the plant is usually grown for its immature pods which are consumed like French beans.

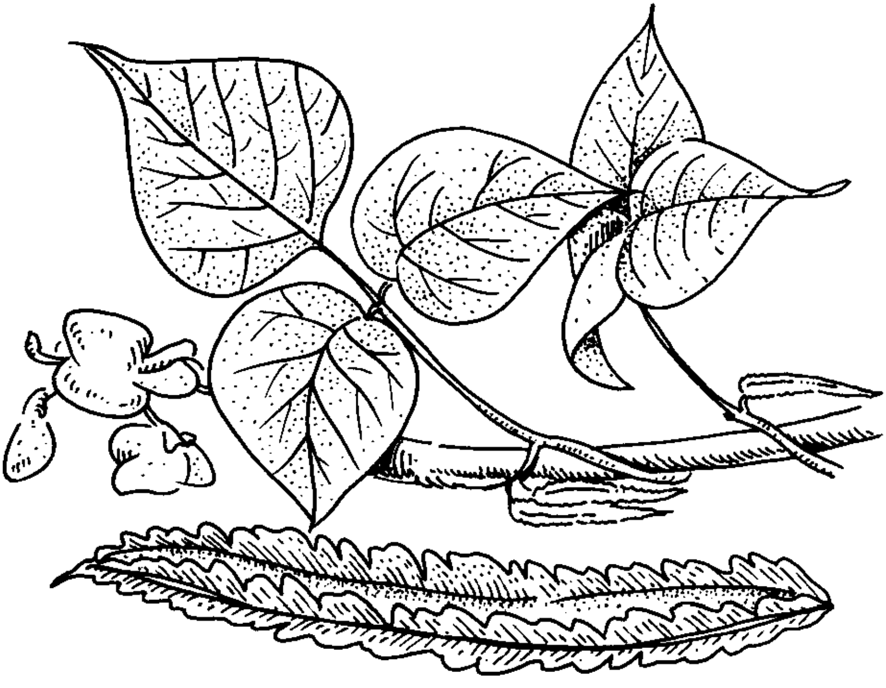
The winged bean also has edible tuberous roots which are eaten, raw or cooked, especially in Burma. Eating the leaves and plant sap is also said to cure tropical yaws (Holdsworth, 1977).

The winged bean grows well in a hot wet climate, although it suffers less from disease in drier weather. The plant does not tolerate waterlogging and prefers a deep, well-drained soil of almost any type.

The plant has the ability to fix atmospheric nitrogen with its exceptionally large nodules or lumps formed on the roots. These lumps of plant tissue contain large colonies of nitrogen-fixing bacteria which live symbiotically with the winged bean. As a result, the winged bean can grow in relatively low fertility soils and is therefore more successful than most other commonly eaten plants of the bean family.

Usually the appropriate bacteria are already present in the soil, but if the plant fails to nodulate special inoculation is needed with the correct rhizobium bacteria.

The nitrogen fixed by the nodules in the roots is left after the plant is harvested and thus improves soil fertility. The yields of any following non-nodulating crops are significantly increased and it is therefore a very valuable crop to include in any form of crop rotation system.

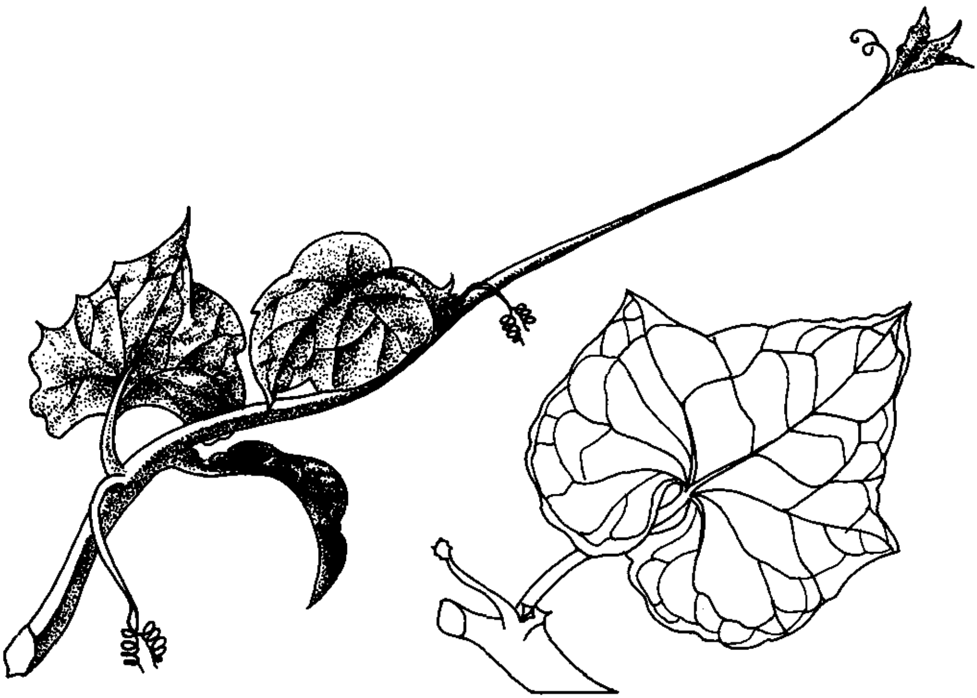


Winged bean (Psophocarpus tetragonolobus)

The drawing shows the pod and leaves. The young leaves, shoots and flowers can be eaten as a vegetable but the plant is usually grown for its young green pods.

7. CHAYOTE: *Sechium edule*

The chayote or choko comes from southern Mexico and Central America and was eaten by the Aztecs long before the Spanish arrived in South America. It has now spread widely throughout the tropics and the Pacific. It is a member of the Cucurbitaceae family which contains gourds, water melons, gherkins, melons, cucumbers, pumpkins, squashes, marrows and loofahs.



Chayote is a strong climbing plant with relatively hairless leaves and stems. The vine is herbaceous and perennial. The young leaves and tender growing points and climbing tendrils are eaten as a vegetable in the Pacific. The fruits are also eaten, usually boiled, as are the large tuberous roots.

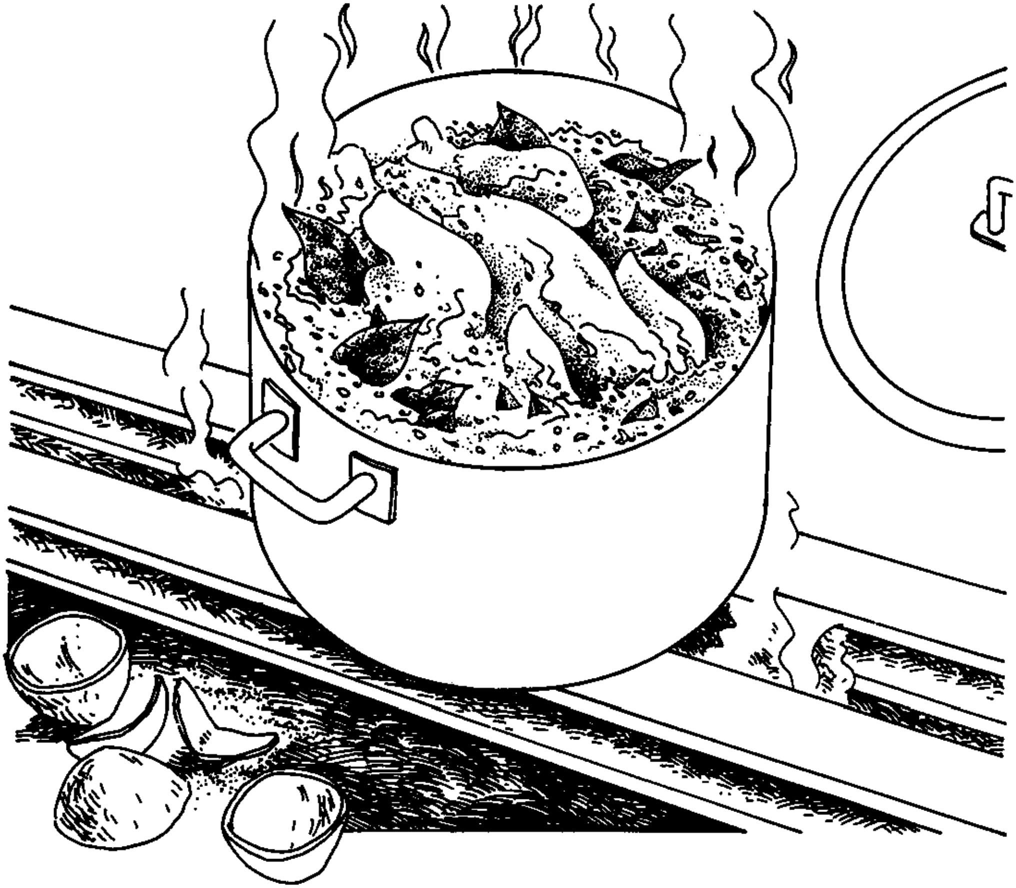
The plant grows best with moderate rainfall and in the slightly cooler areas of the tropics. It is well suited to the Pacific region and prefers the cooler months of the year.

Chayote (Sechium edule)

The young leaves and climbing tendrils are eaten as a vegetable. The wrinkled, often slightly prickly fruits are also eaten after being cooked in stews.

8. JOINTFIR: *Gnetum gnemon*

This is a long-lived, forest tree found in Papua New Guinea, where it is known as 'tulip' or 'two leaves'. It should not be confused with the West African Tulip Tree, *Spathodia campanulata,* which also grows in Pacific countries and is common on old fallow areas or as a decorative tree in urban areas.



The young leaves are eaten as a vegetable or boiled with chicken in coconut cream. The leaves are available in the local markets, especially on the New Guinea side of Papua New Guinea. It is not commonly eaten or found in other Pacific Island countries.

Jointfir **(Gnetum gnemon)**

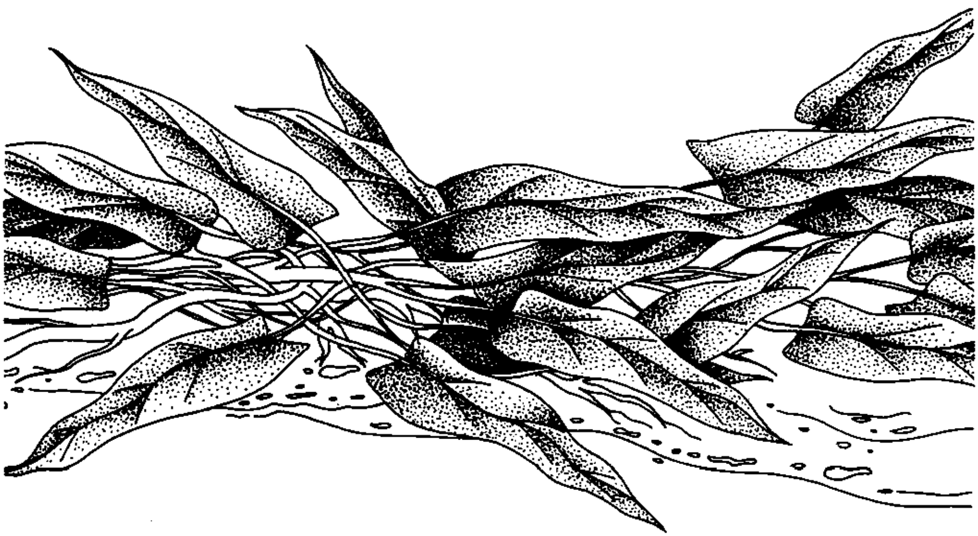
The new young leaves from this forest tree are eaten as a vegetable. It is known as 'tulip' or 'two leaves' in Papua New Guinea because of the distinctive twin-leaf arrangement.

9. WATER SPINACH: *Ipomoea aquatica*

This belongs to the same family, Convolvulaceae, as the sweet potato. It is called 'kangkong' in Asia and the Pacific region. The plant resembles sweet potato, especially in its leaf shapes and twining or creeping habit, but does not produce tubers.

Water spinach, as the name suggests, is an aquatic, floating or trailing herbaceous perennial which is found throughout the tropics and the Pacific region. Dry land types also exist. The young leaves and shoots are usually eaten as a leaf vegetable. The trailing vines can be fed to pigs and cattle.

It is propagated from cuttings or from seed and usually takes about six weeks after planting before enough leaves are available for harvest.



The leaves have a sharp taste and a sticky, glutinous texture, especially if over-cooked. The leaves are best cooked with coconut cream or fried, Chinese style, with different meats. They can also be used fresh in salads.

The plant is easy to grow and lasts a long time in swampy areas or near a plentiful water supply. The flowers are pink or white and have the familiar shape of 'morning glory' flowers (*Ipomoea purpurea*). The dry-land types require very fertile soils which are rich in nitrogen and humus or organic matter.

Water spinach **(Ipomoea aquatica)**

This is a close, water-loving, relative of sweet potato. The young leaves and shoots can be eaten cooked with coconut cream or fried Chinese style with meat or other vegetables.

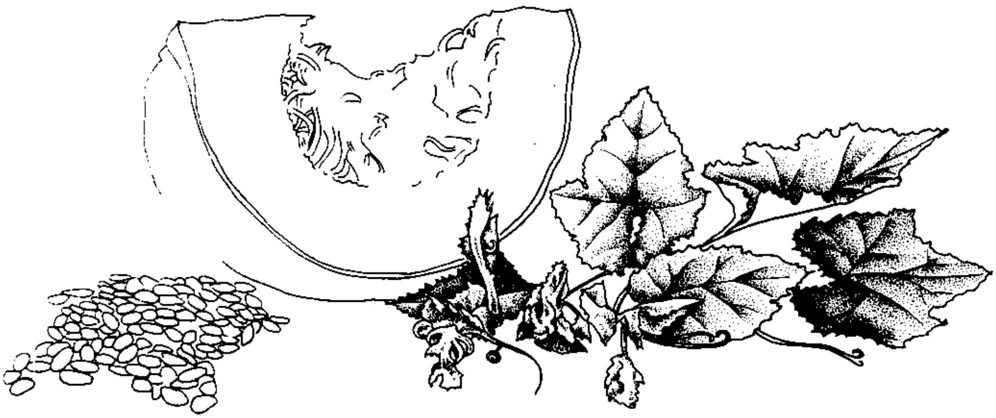
10. PUMPKIN: *Cucurbita pepo*

Pumpkin leaves are known as 'lip pamken' in Papua New Guinea Pidgin and Vanuatu Bislama. In Samoa the shoots are called 'tumutumu maukeni' or green vegetable.

Cucurbita pepo belongs to the family Cucurbitaceae and provides summer squash, winter squash, pumpkin, vegetable marrow and ornamental gourds.

The plant probably originated in North America and the oldest recorded archaeological specimen was growing in Mexico about 9,000 years ago (Purseglove, 1968).

The young leaves, growing points and climbing tendrils are eaten as a green vegetable. The pumpkin tips shown in the photograph weigh about 25 g and would supply about 20 per cent of a child's daily requirement for Vitamin A.



The pumpkin grows throughout the Pacific region and prefers the cooler period of the year. Pumpkins do not do well in the constantly wet and humid tropical areas because of fungal diseases. They grow best on well-drained and highly fertile soils which contain plenty of organic matter.

Pumpkins are usually grown from seed, but they can also be propagated from cuttings because they can produce roots from their nodes.

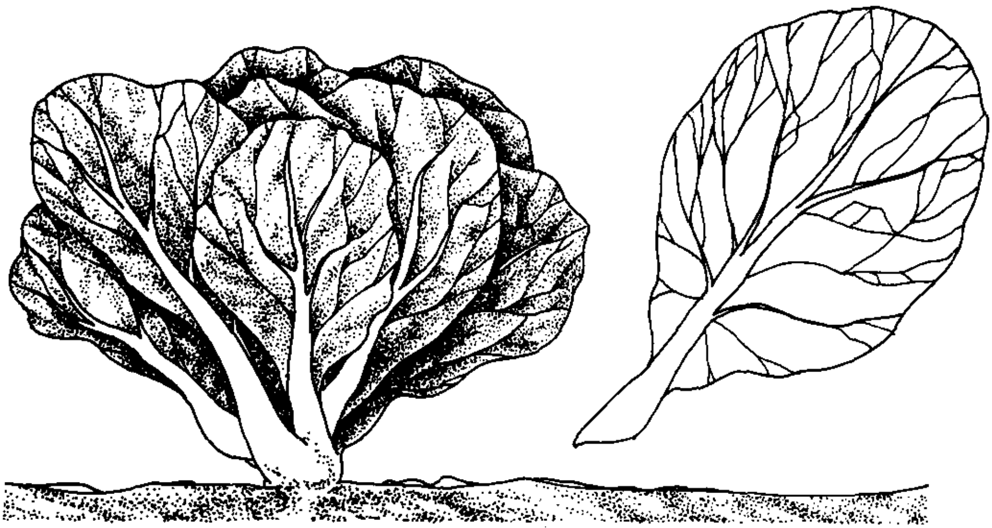
***Pumpkin* (Cucurbita pepo)**

The tender young leaves, growing points and tendrils can be eaten as a green vegetable in many Pacific dishes.

11. CHINESE CABBAGE: *Brassica chinensis* var. *pekinensis cylindrica*

This is a member of the large family called Cruciferae which contains several hundred different groups or genera such as horse-radish, radish, garden cress, watercress, cabbage, turnip, broccoli, cauliflower, brussel sprouts, kohlrabi, kale, rape and mustard.

Chinese cabbage belongs to the *Brassica* group and the variety represented in the photo is *pekinensis cylindrica* or 'pe-tsai' in Chinese. It resembles a giant lettuce and the leaves are eaten either as salad or stir-fried Chinese style with different meats.



It comes from East Asia, is grown extensively in China and Japan and has now spread throughout the tropics and the Pacific. It is a very easy and productive green leafy vegetable to grow and is suitable for all altitudes.

As with all large-leaved fast-growing vegetables, a fertile, well-drained and well-watered soil is needed to produce the best plants. It usually takes about 2—3 months from the seedling stage to reach a size suitable for harvest. It is a biennial plant but is grown as an annual.

Chinese cabbage **(Brassica chinensis *var.* pekinensis cylindrica)**

A tasty vegetable, especially for Chinese stir-fry cooking and stews. As with the head cabbage, the white inner leaves contain fewer vitamins than the darker green outer leaves.

12. DRUMSTICK: *Moringa oleifera*

Also known as 'horse-radish tree' and 'suijan' in Fiji, drumstick is a native of India. Its roots have the same sharp flavour as horse-radish and can be used as a substitute if needed. It belongs to the family Moringaceae.

Drumstick is a small tree which grows throughout the tropics and the Pacific. The young tops, leaves, immature tender pods (which hang down like drumsticks) and the middle of the mature pods can be eaten and even the roots are eaten by Philippinos. The tree is low-growing and can withstand long dry periods. This makes it a convenient standby vegetable for all seasons and conditions. A popular addition to Asian dishes, it is generally propagated from stem cuttings.

***Drumstick* (Moringa oleifera)**

The young tops, leaves and green pods from this small Pacific tree can all be eaten. This makes it a convenient vegetable for all seasons.

13. CASSAVA: *Manihot esculenta*

Also known as manioc, tapioca and tavioka, it belongs to the family Euphorbiaceae, a very large and diverse family which contains many useful plants that give us castor oil, tung oil, rubber, laxatives, fruits and many different ornamental shrubs.

Cassava is not found in the wild state, but it probably originated in Southern Mexico, Guatemala and North-Eastern Brazil. Cassava was probably spread to the Pacific direct from Mexico by the Spanish or from Brazil by Portuguese traders. It would have most likely been introduced to the Philippines by the Spanish in the 16th century.

The sweet cassavas or low cyanide types are more widely distributed in the American tropics than the bitter cassavas. Sweet cassavas usually have softer, whiter flesh and the cyanide content is lower. The cyanide is present just under the skin. Sweet cassavas also mature earlier (six months earlier than the bitter varieties) and do not keep as well in the ground (one year versus over three years for bitter types).

The cassava produces tubers which are an important source of carbohydrate food. The young leaves are eaten as a vegetable. Sweet cassava can be fed to livestock.

Cassava will grow on the poorest soils and can tolerate wide extremes of rainfall, although it is essentially a lowland tropical plant. When there are long periods without rain, cassava sheds its leaves as a survival mechanism. It grows best, however, on light sandy loam soils of low to moderate fertility.

The bush grows to about 1—5 m and there are many varieties with different stem colours and leaf shapes. The leaf stalk or petiole is usually longer than the leaf, which is deeply divided into 3—9 fingers or lobes.

Cassava is propagated from stem cuttings 20—30 cm long, preferably taken from the middle section of the stems. Care is needed to avoid virus diseases, the only serious problem of cassava, which are more likely to be spread if cuttings are used from the base of the stem near soil level. Cassava can be planted on its own or inter-planted with annual food crops, usually with about 1—2 m between plants.

Cassava is very easy to grow in home gardens and a plot measuring about $10m^2$ should produce 1—2 kg of young leaves per week, enough pro-vitamin A for a family of six for a week, depending on the rainfall and general growing conditions. An average-sized cassava leaf, as shown in the photograph, weighs about 5 g and would supply after cooking, about 10 per cent of a child's daily needs of Vitamin A.

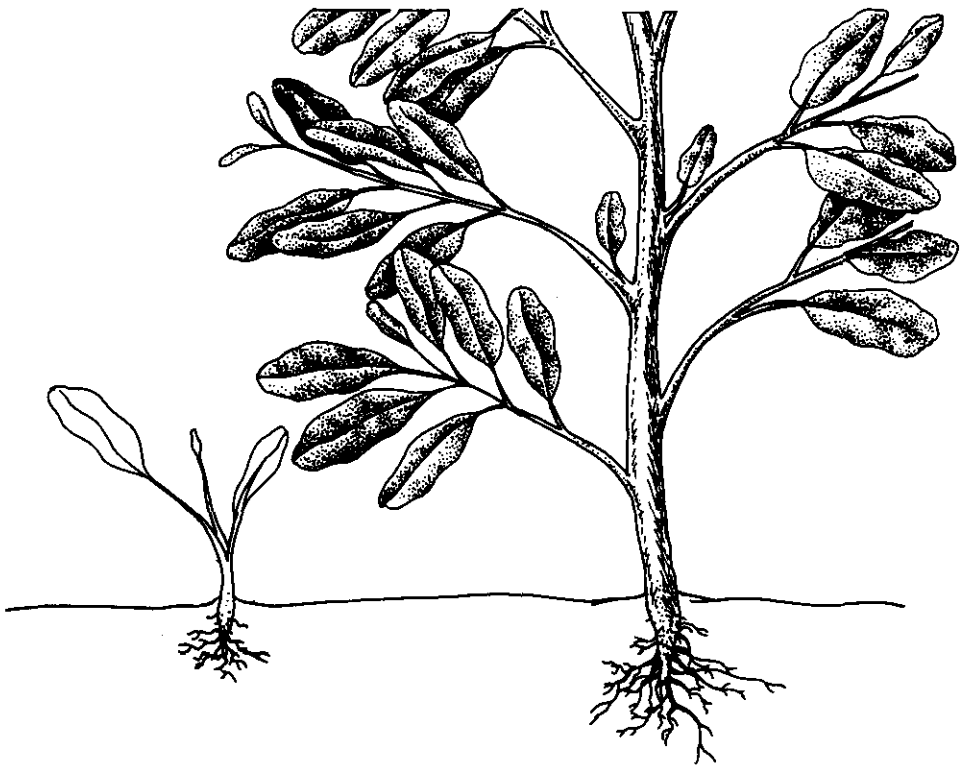
The food value of cassava leaves, especially the iron and pro-vitamin A content, is very high because of the relatively low water content. The average Pacific green leaf contains 86 per cent water, compared with 72 per cent for cassava. The presence of any poisonous cyanide is not a problem because it disappears in the steam during cooking or is poured away in the cooking water. It should be remembered that if too many leaves are harvested from the plant, smaller tubers will be formed.

Cassava **(Manihot esculenta)**

The leaves are very rich in vitamins, especially A and C, but need to be cooked well to get rid of the bitterness. The leaves should be boiled with water for about 10 minutes and the water then poured away. Cook in fresh water until tender.

14. KALE SEEDLINGS: *Brassica oleracea* var. *acephala*

This is in the same family as ordinary round cabbage but does not form a head. It is said by Purseglove (1968) to be closer to the wild species of cabbage which is indigenous to the Mediterranean region, south-western Europe and southern England.



The kale seedlings eaten in Papua New Guinea are immature plants which are harvested a relatively short time after being sown direct from seed in nursery beds. Plants are allowed to grow about ten centimetres or more before harvesting.

Like ordinary cabbages, they prefer a well-drained and highly fertile soil rich in nitrogen with cool to moderate growing temperatures.

Kale seedlings (**Brassica oleracea** *var.* **acephala**)

15. WATER DROPWORT: *Oenanthe javanica*

This is widely eaten in Papua New Guinea. It belongs to the Umbelliferae family together with vegetables and herbs such as parsley, parsnip, carrot, dill, anise, celeriac, celery, caraway, coriander, cumin and fennel.

The leaf shape is very like celery or a large-leaved parsley and the plant grows in clumps quite close to the soil surface. It spreads out to about 1—2 m and roots easily from the nodes.

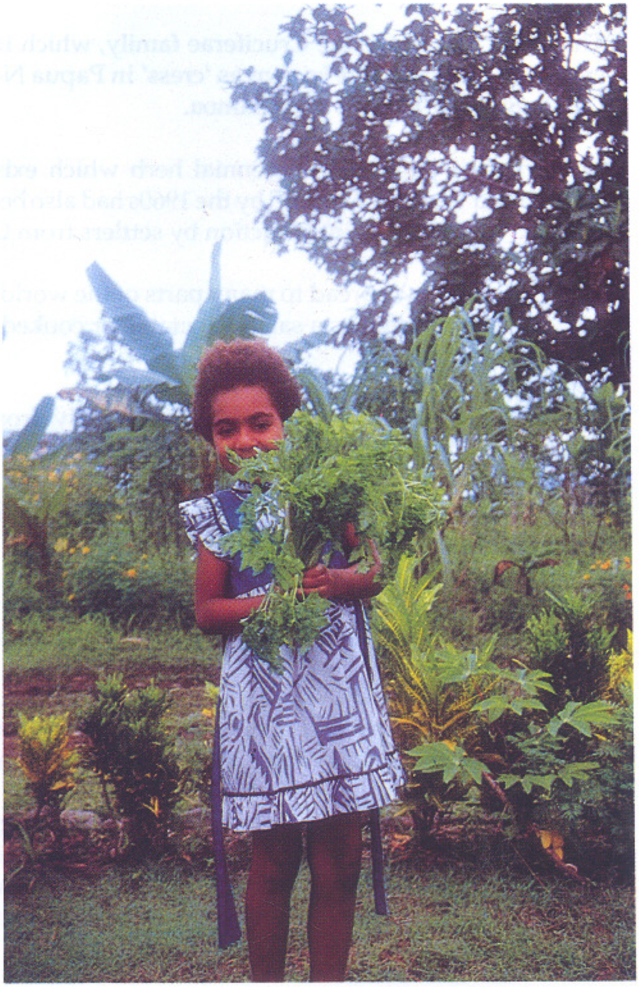
The main stem is hollow and slightly ribbed and has a distinct purplish tinge towards each end of the nodes. It can be propagated from cuttings taken from the middle of the stem.

The plant grows in both wet and dry areas and several varieties exist which vary in colour from purplish-green to yellowish-green.

Water dropwort can be eaten as a salad vegetable or cooked with other foods. The leaves have a slightly sharp but fresh and bitter taste.

In the Southern Highlands of Papua New Guinea it is used as an antidote for poison and to cure headaches and coughs (Holdsworth 1977).

The leaves are ready for harvest about 10 weeks after planting. After a further 10 months or so, the plant stops producing new shoots and fresh cuttings have to be taken to ensure a continuous supply of leaves.



Water dropwort (Oenanthe javanica)

A close relative of parsley and celery which can either be eaten as a salad vegetable or cooked with other foods.

16. WATERCRESS: *Nasturtium officinale*

This plant belongs to the Cruciferae family, which includes radish, turnip, cabbages, cress and mustard. It is known as 'cress' in Papua New Guinea, Fiji, 'cresson' in New Caledonia and 'kapisi vai' in Samoa.

Watercress is an aquatic perennial herb which exists in the wild state throughout Europe and Western Asia and by the 1960s had also become a serious river weed in New Zealand following its introduction by settlers from Great Britain and Europe.

The plant has now spread to many parts of the world including the Pacific region. The leafy stems are eaten as a salad vegetable or cooked with other foods. It has a sharp, fresh and tangy taste.

The stems are hollow and roots grow easily from nodes. Watercress is usually propagated from cuttings but it can also be grown from seed.

Clear running water provides the best growing conditions but it can be grown in well-watered, almost flooded soil.

Regular harvesting encourages the plant to produce more small branches, which in turn provide more leaves and thus a better quality vegetable.

Extra care is needed with watercress when the water it is growing in appears to be dirty or polluted. The leaves and stems should be thoroughly cleaned by washing them carefully several times in clean water, especially if they are to be eaten raw as a salad.

It is worth repeating as often as possible that all green leafy vegetables should be washed very well if they are to be eaten without cooking. This advice is especially relevant when any form of organic manure is used which contains animal excreta or when any form of chemical spray has been used to control pests and diseases.

Watercress **(Nasturtium officinale)**

Can be eaten raw as a salad after careful washing in clean water, or cooked as a vegetable.

17. TROPICAL SPINACH: *Amaranthus viridis*

This is known as in 'tubua' in Fiji, 'aupa' in Papua New Guinea and 'bhaji' (Indian). It belongs to the family Amaranthaceae, most of whose members are grown for grain or as green leafy vegetables. They are herbaceous annuals with single leaves and small densely spiked flowers.

It probably originated in Central and South America and there are now many different types found throughout the tropics including the Pacific region.

Tropical spinach, also known as amaranth, will most likely be found in many Pacific Island gardens growing as a weed, like *nightshade.* It is a relatively short-lived plant and the young leaves and tops are the parts usually eaten, cooked, as a green vegetable.

Tropical spinach is relatively easy to grow directly from seed if it has not already self-seeded. Transplanting seedlings from a nursery is also a good way to produce this plant.

It is a good vegetable to have in any garden crop rotation system because it is not affected by the usual soil problems such as fungal infections or nematode attack. Diseases such as 'damping-off' or pests such as caterpillars and stemborers also do not seem to trouble it.

Tropical spinach needs a lot of water and a well-cultivated soil. It thrives in a garden environment and because it self-seeds it tends to grow all over the place like a weed.

The young shoots and leaves near the growing point can be harvested about one month after sowing and the plant continues to produce new shoots for about two months before developing flowers.

***Tropical spinach* (Amaranthus viridis)**

An easily grown vegetable for a well-watered garden. The young shoots and leaves near the growing point are eaten as a vegetable.

18. SWEET POTATO: *Ipomoea batatas*

Sweet potato is a member of the Convolvulaceae family. This includes many annual and perennial herbaceous twining plants such as kangkong (*Ipomomea aquatica*); morning glory (*Ipomoea purpurea*) a blue flowering creeper, at its best in the mornings; and moonflower (*Ipomoea alba*), a large, white, sweet-scented flower which only blooms at night.

Although sweet potatoes have not been found growing wild, they probably originated in Central America. They were eaten in Mexico before the first European explorers visited America and had found their way to the Pacific at about the same time.

The plant subsequently reached Polynesia and New Zealand. The method of transfer is not exactly known. One idea (suggested by Purseglove, 1968) was that the plant had been carried as seeds by ocean currents from Central America to Hawaii. Another, perhaps more plausible, theory is that they were carried over from South America in sailing canoes as a food supply.

Columbus returned to Spain in 1492 with the sweet potato nearly 80 years before the arrival of the ordinary potato (*Solanum tuberosum*). The name potato comes from the Carib word 'batata' which had been used originally to name *Ipomoea batatas* or the sweet potato. The Spaniards then took sweet potatoes to their settlements in Africa and Asia. The Chinese and Japanese subsequently obtained the plant from the Philippines, in 1594 and 1698 respectively.

By the middle of the nineteenth century, sweet potatoes were commonly grown throughout the tropics and in some countries they were replacing yams and taros as a source of energy food because they were quicker and easier to grow. They are now the main staple root crop in the highlands of Papua New Guinea. The young leaves are eaten as a green vegetable and they also have several medicinal uses. In Papua New Guinea chewed leaves are wrapped around wounds to promote healing (Holdsworth, 1977). The small branch of sweet potato leaves held by the child in the photograph weighs about 5 g and would supply about five per cent of a child's daily requirement for Vitamin A.

Sweet potatoes are usually grown from cuttings and less often from tubers. The plant does not need a highly fertile soil but does need plenty of moisture, without being waterlogged. It cannot tolerate poorly-drained soils. The young leaves and growing tips are eaten as a vegetable. The stalks and older leaves can be fed to pigs.

Sweet potato **(Ipomoea batatas)**

This plant is usually grown for its tuber but the young leaves can also be eaten. The cover picture also shows sweet potato leaves.

19. TARO LEAVES: *Colocasia esculenta*
(Leaves are described in (2), together with stalks)

Taro **(Colocasia esculenta)**

An average taro leaf similar to the one held by the boy in the photo would contain about 20 per cent of the boy's daily requirement for Vitamin A.

20. FERN: *Athyrium esculenta*

This fern is eaten in Fiji ('ota' and 'sukau') and in Papua New Guinea, together with several others, including a tree fern (*Cyathea* sp.) which grows to about 2—4 m in height and of which only the leaflets are eaten; a creeping fern (*Marattia* sp.) which climbs over trees; and a river fern (*Asplenium* sp.), which is found along the edges of rivers growing in clumps up to one metre high.

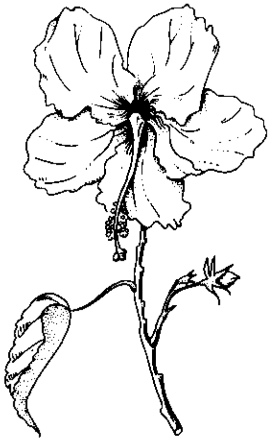
Generally, edible ferns grow wild and are not usually found or planted in gardens. They vary in size, shape and type and are traditionally eaten cooked with pig meat in an earth oven.

Fern **(Athyrium esculenta)**

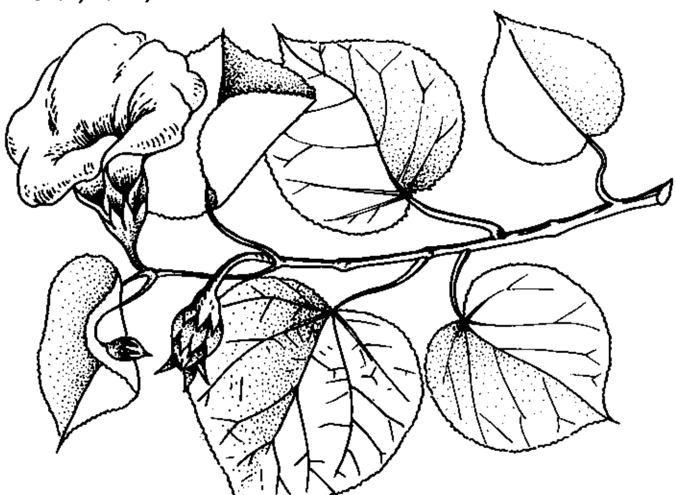
This fern is commonly eaten in Papua New Guinea, Fiji, New Caledonia and Vanuatu.

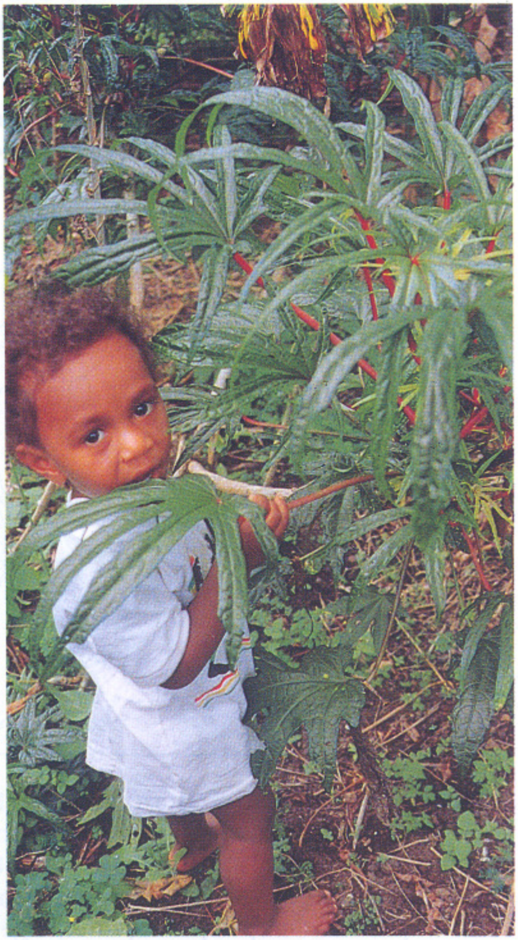
21. EDIBLE HIBISCUS: *Hibiscus manihot*

This is called 'aibika' in Papua New Guinea, 'bele' in Fiji and 'pele' in Samoa. It belongs to the Malvaceae family which also includes cotton, kenaf, okra or 'Lady's Finger', roselle, fibre plants and ornamental shrubs. The familiar hibiscus flower of the Pacific is *Hibiscus rosa-sinensis*. An extract from the leaves of this is said to relieve fever (Holdsworth, 1977).



A small tree, *Hibiscus tiliaceus*, which is found everywhere in the tropics, is used to make mats and ropes and wrap food in the Pacific. It is also used to treat coughs and sore throats (Holdsworth, 1977).



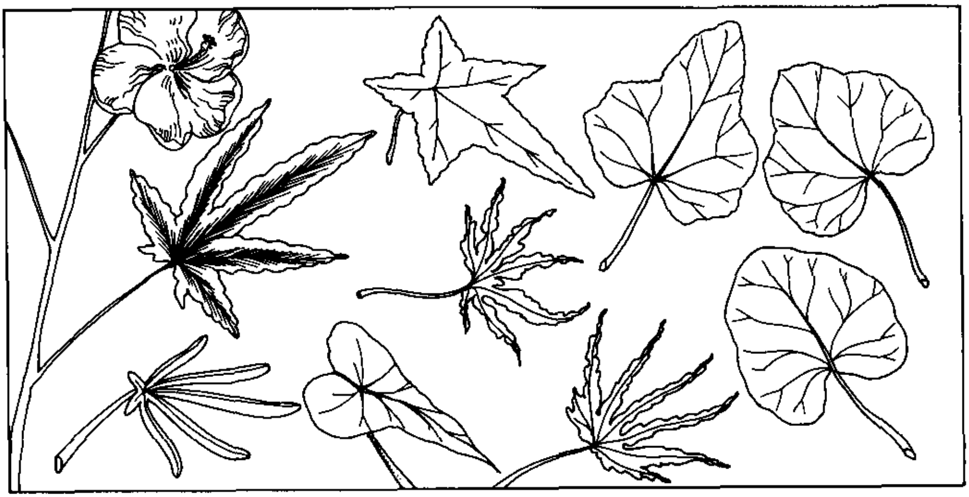


Edible hibiscus (Hibiscus manihot)

This is a very popular leafy vegetable in the Pacific, especially among Melanesians. There are many different types with various leaf shapes, colours and forms. Photos show the full-leaf type and the cassava-leaf type.

The fruits of okra and roselle are edible and the leaves of *Hibiscus manihot* can be cooked as a green vegetable with other foods. The leaves are slightly glutinous or sticky when cut or broken, but are made more appetising by cooking in coconut cream or with a mixture of curry spices.

Edible hibiscus is a small shrub which grows to about one metre in height. Many varieties exist, with very different leaf shapes, colours and flavours. Leaves are usually ready for harvest about four months after planting from a stem cutting — the most common method of propagation.



The plant continues to produce leaves for about two years. The leaves are soft and very attractive to insects, which frequently attack them and cause severe damage. A beetle of the *Nisotra* species, possibly rose beetle, eats many small holes in the leaves, producing the appearance of gun-shot damage, but this is generally not a big problem. A caterpillar of the *Spodoptera* species, together with snails and a stemborer, a form of burrowing grub, also eat into the stems of the plants. In Samoa a white scale insect sometimes causes problems.

Edible hibiscus is an easy plant to grow in the vegetable garden and thrives best on well-drained, well-watered fairly fertile soil which is regularly cultivated. An average leaf as shown in the photograph weighs 5 g and would supply about six per cent of a child's daily requirement for Vitamin A.

22. BASELLA, CEYLON SPINACH: *Basella alba*

Also known as Malabar nightshade or vine spinach, this is a climbing perennial with very dark green, oval or nearly round leaves.

The flesh of the leaves is succulent and sticky. The vines grow to about three metres in length and produce jet-black berries which, when boiled in a little water, will produce an acceptable ink for writing. The plant grows almost anywhere, including poorly drained soils. There are no insect pests and the leaves are ready for harvest about five weeks after the seeds are sown. The usual life-span of a plant in the tropics is about six months. It is a very productive and nutritious leafy vegetable for home gardens in the Pacific. About 100 g of leaves, when cooked, easily supply the daily Vitamin A needs for a child.

Basella is usually grown from seed or stem cuttings and the young leaves and growing tips are most commonly eaten as a cooked vegetable in Chinese-style recipes.

***Basella* (Basella alba)**

This is a popular leafy vegetable in South-East Asia and also for many people in the Pacific. The flesh of the leaves is succulent and slightly sticky. It is a very productive vegetable.

V. NUTRIENT COMPOSITION

Each nutrient is displayed on a separate page in the form of bar graphs (Figures 1—17, Appendix 1) for all the vegetables except for basella leaf (No. 22 in both the text and Appendix 1). This allows each vegetable to be compared within the group for a particular nutrient and also makes it easier to prepare enlargements or overhead projection transparencies for health education purposes.

The average nutrient levels of the green leafy vegetables are given below in Table 1. Vitamin A contents compare favourably with typical values (685 microg Vitamin A retinol equivalent) found for leafy vegetables worldwide (Ball, 1988). Vitamins and minerals are present at very satisfactory levels and show that Pacific leaves are a moderately rich source of pro-vitamin A, Vitamin C, iron, zinc, calcium and potassium. Analytical methods used by the PIFCP laboratories are described in Appendix 2.

Table 1: Average nutrient composition of some green leafy vegetables eaten in the Pacific (Values are per 100 g edible portion, raw)

	Average	Range
Water (g)	87.00	72 — 96
Energy (kcal)	35.00	10 — 91
Protein (g)	3.70	0.3 — 7.0
Fat (g)	0.60	0.1 — 1.8
Carbohydrate (g)	3.40	Tr — 18
Fibre (g)	3.00	0.5 — 8.5
Ash (g)	1.80	0.5 — 3.0
Sodium (mg)	8.00	1 — 50
Potassium (mg)	342.00	23 — 843
Calcium (mg)	152.00	13 — 465
Iron (mg)	5.40	0.6 — 19.0
Zinc (mg)	0.80	0.2 — 2.8
Vitamin A (μg)	568.00	63 — 1963
Thiamine (mg)	0.07	Tr — 0.27
Riboflavin (mg)	0.19	0.05 — 0.72
Niacin (mg)	0.78	0.3 — 4.3
Vitamin C (mg)	64.00	5 — 311

The values given in Appendix 1 are for vegetables **in the raw state**, with the exception of taro leaves where the Vitamin A figure has also been determined after cooking. Cassava leaves have a very high content of pro-vitamin A carotenoids, but it needs to be emphasised that cassava **leaves contain poisonous cyanide compounds** and therefore should never be eaten raw. **Taro leaves also need to be cooked because they contain** oxalate, another unpleasant and poisonous substance.

Cooking unfortunately destroys some vitamins and reduces others. Minerals and water-soluble vitamins are also dissolved out of the leaves and lost in the cooking water when it is poured away. Losses of over 30 per cent were found for pro-vitamin A carotenoids of taro leaves after cooking, according to one PIFCP laboratory (INR, Fiji).

Cooking and nutrient value

If one assumes that about 30 per cent of the pro-vitamin A carotenoids are lost after boiling, cassava leaves still contain the highest concentration of pro-vitamin A carotenoids of the entire group of green leafy vegetables. Vitamin C is very susceptible to oxidation and most cooking methods reduce the level significantly.

It should be remembered that green leafy vegetables should be cooked for the shortest time possible and in the smallest volume of water to ensure maximum retention of nutrients. The cooking time depends on individual tastes and preferences but, generally speaking, green vegetables should only be cooked until just tender enough to make them easily digestible.

Most green leafy vegetables eaten in the Pacific are eaten as tasty side dishes or used as wrappings and additions to the main food items such as sweet potatoes, yams and fish. Vegetables are rarely eaten separately in large quantities as is the custom in Western countries. The Pacific custom of wrapping foods in a leafy vegetable during cooking means the leaf is kept at a higher temperature longer than necessary because the main food needs more cooking.

Minerals probably go from the leaf to the other food, but the levels of Vitamins A, C and E and possibly other vitamins in the B group, such as folacin, are substantially reduced after prolonged cooking (Tver and Russell 1989). According to Souci and colleagues (1989), the maximum losses of vitamins due to cooking are estimated to be:

Vitamin A 40%, carotene 30%, Vitamin D 40%, Vitamin E 55%, Vitamin K 5%, thiamine 80%, riboflavin 75%, niacin 70%, pantothenic acid 50%, Vitamin B6 50%, biotin 60%, folic acid 100%, Vitamin B12 50%, Vitamin C 100%.

The Chinese cooking method of rapid stir-frying in a little oil probably retains more nutrients than most other methods. Boiling cabbage leaves in a large volume of water for a long time and then discarding the cooking water is very wasteful, not only because minerals and vitamins are lost but also because it produces unpleasant-smelling sulphur compounds.

Cooking losses are probably the most serious form of nutrient loss, especially for the green leaves which are eaten in the Pacific. If few green leafy vegetables and fruit are eaten, these losses have even more serious health consequences, because about half of the human dietary intake of Vitamin A is usually derived from fruit and vegetable carotenoids (Hsieh and Karel, 1983). Infants are certainly the most vulnerable group because they are entirely dependent on the food they are given. Vegetables cooked in coconut milk or included in stews retain most of the water-soluble nutrients.

Differences in leaf composition

Green leafy vegetables are an important source of minerals and vitamins and differences in their levels are therefore of some significance. Unfortunately, these components show the largest variations in quantities present.

The concentrations of minerals found in leafy vegetables are particularly variable because they depend on the interactions of many factors, the main ones being environmental and genetic. These include the type of soil the plants are growing in, the quality of available water, nearness to the sea, plant variety or species and other factors. Crops grown immediately following a long-duration fallow or after the clearing of primary forest will contain a much higher concentration of most minerals, especially the soluble forms such as potassium and nitrate-nitrogen. Some plants can take up more nutrients than they need — 'luxury uptake'. This is true for potassium and nitrate-nitrogen, especially in green leafy vegetables.

Vitamin levels also vary more than those of the major components mentioned earlier because they are closely linked to variety and the general vigour of plant growth. Healthy, pest-free, fast-growing, dark green leafy vegetables will contain far more active substances such as pro-vitamin A carotenoids, Vitamin C, Vitamin E and folacin than pale green, slow-growing, diseased or deficient plants. There are 30- to 50- fold differences between the vitamin and mineral contents of pale inner leaves of lettuce and cabbage and dark outer leaves, as mentioned earlier in the section on composition.

Green leafy vegetables should preferably be considered as a group and not each on its own as a potential 'super vegetable'. There is generally too much overlap in nutrient contents, due to the many variables present, to be able to say with certainty that a particular leafy vegetable will always be the best nutritionally. The best way to ensure a satisfactory intake of minerals and vitamins is to ensure that as wide a variety of leafy vegetables as possible is eaten, within the limits of the environment or income of the people concerned.

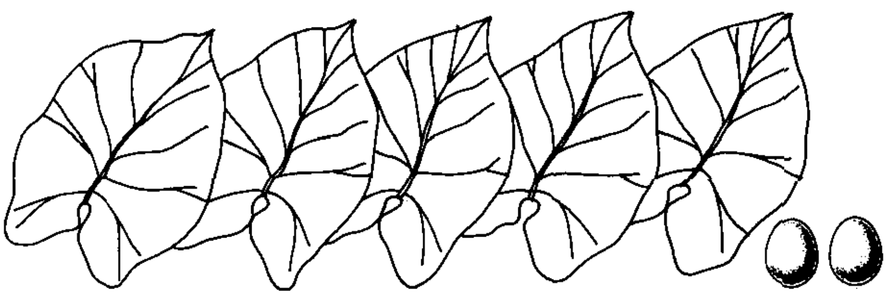
Eating a wide variety of green leaves evens out some of the differences and compensates for deficiencies in a particular nutrient or the presence of anti-nutritional factors which may be present in some leaves.

Improving nutrient value

The nutritional value of leafy vegetables can be improved by ensuring the plants receive adequate nutrients, water and light in their growing environments. Protection from wind or animal damage, such as fences and wind breaks, may also be needed. Nutrients can be supplied by some form of manure made from compost, animal droppings and urine, wood ash, plant refuse, seaweed, fish and animal waste or, if money is available, from a small quantity of a balanced compound fertilizer which contains nitrogen, phosphorus and potassium in available forms. The quantity of fertilizer material to apply depends on the type of material and the age or stage of development of the vegetable. In general, large-leaved, fast-growing vegetables will require more than seedlings. Great care is needed with concentrated manures because they can easily burn young plants if too much is used. The best thing to do is obtain advice from an experienced manure user before applying anything. Well-rotted compost which has been prepared for at least three months can be used freelv on all green leafy vegetables at any time.

Comparison of nutrient composition of leaves

The values shown in the bar graphs are the weights of nutrient present in 100 g of fresh, uncooked leaves. In terms of everyday quantities, 100 g is the weight of two average hen's eggs or about the weight of one third of a tin of 'Coca-Cola' drink. About 100 leaves of 'bele' or 'aibika' — edible hibiscus —— would give 100 g but this of course depends on the size of the leaves. An average-sized taro leaf weighs about 20 g. Good kitchen scales or a simple scientific balance are needed to obtain accurate weights. In practical terms, a good estimate is all that is needed. Some of the leaves in the colour *photographs were weighed and the figures are given where available.*



The 'average leaf', as shown in Table 1, contains 87 per cent 'water' and 11.2 per cent 'dry matter' with ranges of 72—96 per cent and 4—28 per cent respectively. This so-called 'dry matter' is made up of 3.4 g protein, 0.6 g fat, 3.4 g carbohydrate, 3.0 g fibre and about 0.5 g minerals and vitamins. For comparison lettuce contains 95 per cent 'water' and 4.8 per cent 'dry matter' made up of 1.25 g protein, 0.22 g fat, 1.1 g carbohydrate, 1.52 g fibre and about 0.7 g minerals, vitamins and other substances.

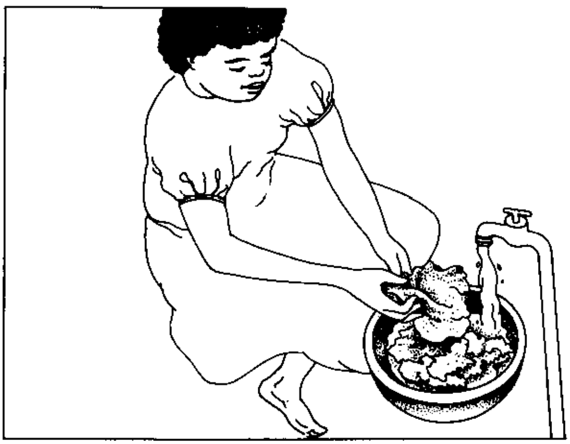
VI. COMPOSITION OF LETTUCE LEAVES

The average green leafy vegetable also contains many other substances which have or may have significant nutritional or health-related properties. In order to illustrate this, some additional nutrient composition data of lettuce leaves, from the German Food Tables produced by Souci et al. (1989), are presented below in Table 2.

— Why lettuce?

The reader will no doubt immediately ask why lettuce has been chosen to illustrate the point. The main reason is that lettuce has been analysed in laboratories all over the world and in great detail. Most of the Pacific green leaves in this booklet have never been analysed before or, if they have, not in any great detail.

Another reason for choosing lettuce is that it probably contains the least amounts of all the nutrients and therefore it is safe to assume that most Pacific green leaves will contain more of everything. Lettuce is usually eaten raw, although it can be eaten cooked or made into soups, and therefore it is a healthy vegetable to eat. The only problem with eating lettuce or any other raw salad vegetables such as watercress is that they have to be washed very carefully in clean water before being eaten. This is extremely important because raw salad can carry the cysts of parasites and bacterial spores, especiallv if animal manures have been used as fertilizers or polluted water for irrigation.



Many of the health problems in Pacific Island countries are associated with poor sanitation and poor food safety habits. Young children suffer the most from these food- and water-borne diseases and they are the ones who would benefit most from eating more green leafy vegetables.

Table 2: Nutrient composition of lettuce leaves

A. Major nutrients

(Values given are per 100 g edible portion.)

Constituent	Average	Range
Water (g)	95.00	93 — 96
Energy (kCal)	11.00	—
Protein (g)	1.25	0.80 — 1.63
Arginine (mg)	62.00	56 — 69
Histidine* (mg)	21.00	20 — 23
Isoleucine* (mg)	70.00	48 — 83
Leucine* (mg)	77.00	75 — 79
Lysine* (mg)	70.00	48 — 81
Methionine* (mg)	12.00	4 — 22
Phenylalanine* (mg)	54.00	46 — 64
Threonine* (mg)	56.00	51 — 59
Tryptophan* (mg)	11.00	9 — 13
Tyrosine (mg)	34.00	—
Valine* (mg)	66.00	60 — 68
Fat (g)	0.22	0.17 — 0.25
Palmitic acid (mg)	34.00	—
Stearic acid (mg)	3.90	—
Palmitoleic acid (mg)	1.00	—
Oleic acid (mg)	5.20	—
Linoleic acid (mg)	52.00	—
Linolenic acid (mg)	71.00	—
Carbohydrate (g)	1.10	—
Starch (g)	0.019	0.013 — 0.027
Glucose (g)	0.41	0.25 — 1.11
Fructose (g)	0.56	0.38 — 1.38
Sucrose (g)	0.10	0.04 — 0.13
Dietary fibre (g) Total	1.52	—
Dietary fibre (g), water-soluble	0.15	—
Dietary fibre (g), water-insoluble	1.37	—
Pentosan (g), water-soluble	0.18	—
Hexosan (g), water-insoluble	0.16	—
Cellulose (g), water-insoluble	0.76	—
Polyuronic acid (g), water-insoluble	0.42	—

* Essential amino-acids

B. Mineral elements
(Values given are per 100 g edible portion)

Constituent	Average	Range
Sodium (mg)	10.00	5 — 14
Potassium (mg)	224.00	140 — 313
Magnesium (mg)	11.00	6 — 13
Calcium (mg)	37.00	17 — 51
Manganese (mg)	0.35	0.12 — 0.53
Iron (mg)	1.10	0.50 — 2.00
Cobalt (µg)	5.40	1.8 — 12.0
Copper (µg)	54.00	30 — 78
Zinc (mg)	0.22	0.16 — 0.35
Nickel (µg)	11.50	5.0 — 14.0
Chromium (µg)	14.00	7.0 — 21.0
Molybdenum (µg)	6.00	2.0 — 11.0
Phosphorus (mg)	33.00	19 — 57
Chloride (mg)	57.00	39 — 74
Fluoride (µg)	32.00	28 — 38
Iodide (µg)	3.30	2.6 — 4.0
Boron (µg)	82.00	30 — 90
Selenium (µg)	0.75	0.40 — 10.00
Silicon (mg)	2.00	1.0 — 4.0
Nitrate (mg)	262.00	23 — 661

C. Vitamins and other health-related substances

(Values given are per 100 g edible portion)

Constituent	Average	Range
Carotene (µg)	790.00	160 — 1600
Vitamin A equivalents (µg)	131.00	26 — 260
Vitamin E activity (µg)	440.00	—
Vitamin K (µg)	200.00	—
Vitamin B1, thiamin (µg)	62.00	40 — 80
Vitamin B2, riboflavin (µg)	78.00	60 — 100
Niacin (µg)	320.00	200 — 500
Pantothenic acid (µg)	110.00	—
Vitamin B6, pyridoxine (µg)	55.00	36 — 75
Biotin (µg)	1.90	0.7 — 3.1
Folic acid (µg)	37.00	—
Vitamin B12 (µg)	0.00	—
Vitamin C (mg)	13.00	8 — 22
Citric acid (mg)	13.00	—
Oxalic acid Total (mg)	0.00	—
Ferulic acid (µg)	50.00	0 — 100
Caffeic acid (mg)	38.00	16 — 60
Sterols total (mg)	10.00	—
Campesterol (mg)	1.00	—
Beta-Sitosterol (mg)	5.00	—
Stigmasterol (mg)	4.00	—
Purines total (mg) (as uric acid)	20.00	10 — 30

Protein

In Table 2A, protein has been analysed into the component amino acids. All eight 'essential' amino acids are present and although they are only present in small amounts, the resultant protein in lettuce leaves can make a contribution to the protein supply. Other green leafy vegetables would most likely contain at least the same range of amino acids as lettuce and some probably contain larger quantities.

Fat

The fat content of lettuce leaves is well below the average level found for the group of green leaves analysed by the PIFCP laboratories. It is, however, of excellent quality when the constituent fatty acids are examined. Mono- and polyunsaturated fatty acids, oleic, linoleic and linolenic acids make up more than 70 per cent of the total fat content. The last two mentioned are also known as Omega 6 and Omega 3 fatty acids because of their special chemical structure. They could be considered as 'vitamins' because they are needed in small amounts and are thought to be involved in many wide-ranging biochemical activities in cell walls and blood-clotting mechanisms (Nettleton, 1987). Omega 3 fatty acids from plants can be converted in the body to the type of Omega 3 fatty acids found in fish and seafood.

Carbohydrate

Carbohydrate, especially starch, is very low in the lettuce shown in the table. The main carbohydrates are soluble sugars, with glucose and fructose being dominant. This level of carbohydrate is well below that found for Pacific green leaves such as cassava and amaranth.

Fibre

Dietary fibre is much lower in lettuce than in the other Pacific green leaves and is mainly in the form of water-insoluble fibre. This is made up of cellulose, hexosan and polyuronic acids.

Minerals

Some of the many different mineral elements in lettuce are given in Table 2B. The major components are potassium, calcium, chloride, phosphorus and nitrogen.

Potassium is present in relatively high amounts in lettuce. Levels of over two per cent are possible in some plants. Green leaves are generally rich in potassium. It occurs in the soluble or ionic form and plays an important role, with sodium, in balancing the water content of cells and cellular fluids. Potassium also plays a similar role in animals and an adequate supply helps to regulate blood pressure.

Potassium and especially nitrate-nitrogen can vary tremendously with changes in soil fertility. The large increase in soil potassium following forest burning and clearing, or the flush of nutrients made available in soil after opening up land after a long fallow period, are two examples of the dramatic changes in soil fertility which can occur. Plants respond quickly to this release of nutrients and healthy, fast-growing, green leafy vegetables will take up more of everything. The nutrient levels of the leaves generally decrease each year as the level of soil nutrients goes down. When the leaves begin to show deficiency signs, or preferably before, it is time for another period of fallow and for the weeds, shrubs and young forest trees to regenerate once again.

Where there is severe population pressure and the land shortage, the land is farmed many times before returning to fallow. When the time allowed for fallow is too short, the vegetable gardens become impoverished and the green leaves grown in them are consequently of lower nutritional quality. Nutrient composition in the leaves can vary from three to thirty times due to this change in soil fertility.

Vitamins

Table 2C shows the vitamins and some other substances found in lettuce leaves which have been shown to have important roles in nutrition and health. Lettuce, in common with all green leafy vegetables, is a good source of carotene or Vitamin A, Vitamin E, Vitamin C and some of the B group vitamins. Folic acid is also present in lettuce and other green leafy vegetables. It represents a number of related chemical substances which help prevent certain forms of anemia. The nutritional, biochemical and clinical aspects of the vitamins listed are discussed in detail by Machlin (1984).

Other substances

Constituents such as ferulic and caffeic acids decrease the availability of thiamine or Vitamin B1. Oxalic acid reacts with calcium to make it less available to the body. The sterols are similar chemically to cholesterol but do not have the same capacity to form deposits or plaque on the sides of the blood vessels in the body. Purines are low in lettuce and green leaves generally compared with other foods such as liver and kidney which contain up to 40 times as much.

Lettuce, like all green leafy vegetables, contains a wide variety of nutrients. The levels found in lettuce as usually consumed are, however, probably among the lowest of all green leaves. This is mainly due to the way lettuce is prepared. The outside leaves are probably thrown away or fed to animals because they are damaged or too dirty. The outer, dark green leaves are known to contain up to 40 or 50 times as much carotene as the pale inner leaves. Other nutrients also will be present in these outer leaves in many times the concentration of the inner leaves.

VII. FUTURE FOR LEAVES

The known links between good health and eating plenty of green leafy vegetables and fruit every day grow stronger as time passes and our knowledge is increased.

The orange colour in fruits and root vegetables such as sweet potatoes and carrots has long been known to be due to beta-carotene, a molecule which gives us about half of our daily requirement of Vitamin A. This substance is also present in green leaves, although its colour is masked by the green pigment chlorophyll.

Recent research has shown that certain forms of cancer are significantly reduced or prevented by eating a diet rich in green leafy vegetables and fruit. It has now been proved that beta-carotene is not the only molecule associated with these cancer-protective effects, and that a very large number of other substances found in leaves and fruits are also involved. Many of these substances are natural anti-oxidants and are known to inhibit certain reactions which can damage animal cells (Frankel, 1989).

The building bricks of the leaf are microscopic cells which contain many tens of thousands of different organic molecules, all taking part in a complex chain of chemical reactions which enable them to use the energy received at the surface of the leaf to create organic matter from carbon dioxide gas in the air and absorbed water (that miraculous process of photosynthesis once again).

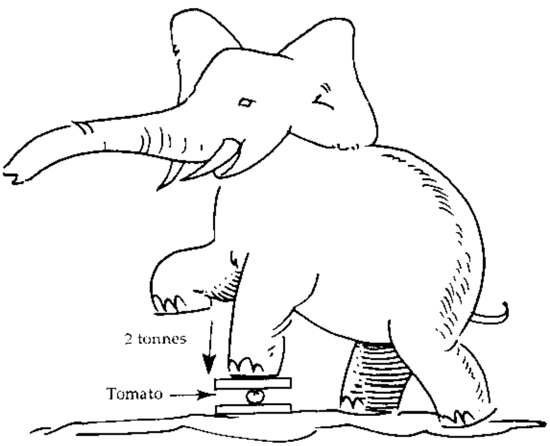
Some of these chemicals are also toxic to animals and help protect the leaf against pests and diseases (Beier, 1990). These 'magic molecules' have many and varied properties and when we eat a leaf, some of these special molecules pass into our blood relatively unchanged. A common feature of these molecules is their ability to scavenge or react with oxygen in some way (natural anti-oxidants). Some mineral elements such as selenium and Vitamins C and E and many of the very large group of carotenoids found in green leaves all have the capacity in varying degrees to react rapidly and easily with any spare potentially dangerous active substances, or 'free radicals', as they are known. Anti-oxidants are used as additives in many processed foods to prevent nutrient loss and spoilage. Anti-oxidants are probably one class of chemical additives for which the advantages of their use to protect natural antioxidants may outweigh the disadvantages of not using them in food processing.

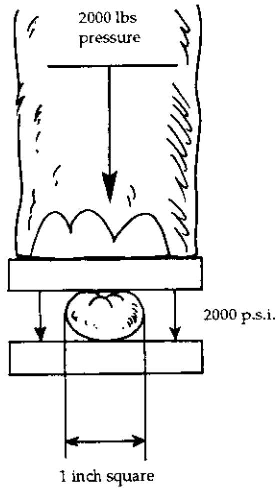
As you would expect from the name, 'free radicals' are highly reactive. Recent research strongly suggests that free radical reactions involving lipid peroxides present in human tissues are part of the cause of skin cancer following long or excessive exposure to sunshine (Mergens and Bhagavan, 1989).

Green leaves lose their nutrient quality very quickly once they are removed from the plant. Poor handling, storage and overcooking all result in huge losses of the most active substances as mentioned in an earlier section. Natural anti-oxidants such as Vitamins C and E and many carotenoids are among these active substances.

A new analytical technique known as High Pressure Liquid Chromatography is already being used to separate some of the many different active substances in leaves.

It involves the use of extremely high pressures to force a leaf extract, in a special solvent, through a small stainless steel column containing a uniformly packed material such as aluminium oxide or fine silica beads. The pressure applied (2000 p.s.i.) would be about the same as that produced when an elephant stamps on a tomato! The different molecules in the leaf extract travel through the tube or column of powder at different speeds depending on their size and chemical nature. Most complete separations take about half an hour.





As each different substance leaves the column it is measured by special detector cells and a series of peaks is produced on a recorder. The size of the peak indicates the quantity of the substance coming off the column at that precise time. Substances of known composition are also introduced onto the column and their peak positions and sizes are used as standard references to identify the unknown substances in the extract.

Future research into the health-giving and protective properties of green leaves will certainly continue to be directed at the identification of all the different highly active chemical substances found in their cells and the determination of their relationship to the different environmental diseases. These include cancer, heart disease, diabetes, hypertension and gout — the so-called non-communicable or 'life style' diseases which are now becoming a serious problem among Pacific peoples.

The effect of cooking, processing and storing could also be studied by analysing leaves by HPLC before and after the leaves have been treated. Changes in the levels of the different active substances would be indicated by the presence or absence of their specific peaks on the chromatograms.

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APPENDIX 1

NUTRIENT COMPOSITION OF SOME GREEN LEAFY VEGETABLES EATEN IN THE PACIFIC

(value per 100 g edible portion, raw)

	1 Lettuce *Lactuca sativa*	2 Taro (stalks) *Colocasia esculenta*	3 Papaya shoots *Carica papaya*	4 Cabbage *Brassica capitata*	5 Nightshade *Solanum nigrum*	6 Winged bean *Psophocarpus tetragonolobus*	7 Chayote *Sechium edule*	8 Jointfir *Gnetum gnemon*	9 Water spinach *Ipomoea aquatica*	10 Pumpkin *Cucurbita pepo*	11 Chinese cabbage *Brassica chinensis*
Water (g)	95 M	93 M	83 M	95	88	93	91	77	91	90	96
Energy (Kcal)	17 M	25 M	59 M	22 UK	29	25	41	40	16	25	15
Protein (g)	1.2 M	0.3 M	5.6 M	1.6	5.0	3.5	4.4	5.3	1.5	4.3	2.3
Fat (g)	0.1 M	0.2 M	0.4 M	0.1	0.8	1.1	0.3	1.8	1.0	0.1	0.1
Total CHO (g)	2.8 M	5.5 M	8.2 M	3.8 UK	Tr	Tr	Tr	Tr	Tr	Tr	1.2 M
Fibre (g)	0.5 M	0.7 M	1.0 M	2.7 UK	8.5	4.0	0.7	4.5	4.8	3.3	0.7 M
Ash (g)	0.7 M	0.5 M	1.5 M	0.5	2.5	1.1	2.1	1.9	1.3	1.5	1.0
Sodium (mg)	10 M	1 M	3 M	2	4	6	3	7	50	4	3
Potassium (mg)	139 M	85 M	629 M	63	346	328	359	682	443	509	92
Calcium (mg)	50 M	116 M	290 M	51	225	44	71	29	13	108	90
Magnesium (mg)	8 UK	-	-	13	83	57	41	70	29	40	16
Iron (mg)	1.5 M	1.9 M	6.4 M	0.6	19.0	2.8	7.3	3.7	3.1	2.7	1.9
Zinc (mg)	0.2 UK	-	-	0.4	0.6	0.9	0.8	1.3	0.5	0.8	1.3
Vitamin A (micro-g)	304 M	16 M	612 M	Tr UK	-	-	-	350 IMR 85	793 M	981	186 M
Thiamine (mg)	0.08 M	0 M	0.09 M	0.06 UK	-	-	-	0.10 IMR 85	0.10 M	-	0.06 M
Riboflavin (mg)	0.22 M	0.06 M	0.37 M	0.05 UK	-	-	-	0.14 IMR 85	0.55 M	-	0.05 M
Niacin (mg)	0.30 M	0.3 M	1.3 M	0.3 UK	-	-	-	0.9 IMR 85	0.60 M	-	0.50 M
Vitamin C (mg)	28 M	5 M	124 M	40 UK	-	-	-	66 IMR 85	49 M	4	39 M

	12 **Drumstick** *Moringa oleifera*	13 **Cassava** *Manihot esculenta*	14 **Kale seedling** *Brassica oleracea*	15 **Water dropwort** *Oenantha javanica*	16 **Watercress** *Nasturtium officinale*	17 **Tropical spinach** *Amaranthus viridis*	18 **Sweet potato** *Ipomoea batatas*	19 **Taro (leaves)** *Colocasia esculenta*	20 **Fern** *Athyrium esculenta*	21 **Edible hibiscus** *H. manihot*	22 **Ceylon spinach** *Basella alba*
Water (g)	76 M	72 F	89	91	92	86	83 F	83	85	80	93 M
Energy (Kcal)	89 M	91 F	22 M	26 M	10	42 F	49 F	31	36	35	23 M
Protein (g)	5.8 M	7.0 F	3.1	2.4	2.0	3.2	4.6 F	4.8	4.7	4.6	1.6 M
Fat (g)	1.1 M	1.0 F	0.1	0.1	0.2	0.1	0.2 F	0.8	1.7	1.8	0.1 M
Total CHO (g)	14 M	18 F	3.4 M	4.4 M	Tr	8.3 F	0.2 F	0.7	Tr	Tr	3.8 M
Fibre (g)	1.2 M	4.0 F	0.9 M	1.0 M	4.5	1.8 F	2.4 F	6.0	8.0	1.5	0.3 M
Ash (g)	2.4 M	2.0 F	2.0	1.6	2.6	3.0	2.0 F	2.0	3.0	2.8	1.3 M
Sodium (mg)	9 M	17 M	3	1	4	2	16 M	3	5	7	15 M
Potassium (mg)	444 M	23 M	180	156	399	259	252 M	843	535	418	233 M
Calcium (mg)	261 M	303	90	134	119	309	158 F	216	59	465	115 M
Magnesium (mg)	-	-	33	38	45	119	-	192	40	382	-
Iron (mg)	3.0 M	7.6 F	4.9	1.8	3.0	8.7	6.2 F	2.7	14.7	9.5	1.3 M
Zinc (mg)	-	-	2.8	1.1	0.4	0.8	-	1.0	0.5	0.7	-
Vitamin A (micro-g)	489 M	1963 F	310 US	533 M	500 UK	953 F	978 F	744 (506)*	263	915	661 M
Thiamine (mg)	0.27 M	0.25 F	0.07 US	0.10 M	0.10 UK	0.05 F	0.10 F	-	-	-	0.08 M
Riboflavin (mg)	0.72 M	0.60 US	0.06 US	0.31 M	0.10 UK	0.42 F	0.28 F	-	-	-	0.11 M
Niacin (mg)	4.3 M	2.40 F	1.30 US	0.60 M	1.10 UK	1.20 F	0.90 F	-	-	-	0.60 M
Vitamin C (mg)	106 M	311 F	130 US	60 M	60 UK	64 F	70 F	90 (Tr)*	7	24	59 M

Vitamin A is given as micro-g retinol *derived from beta-carotene using* the WHO approximation of bio-availability given in WHO Technical Report Series No. 362; 1967. The conversion of beta-carotene to retinol by animals is physiologically inefficient with only about 50 per cent of the beta-carotene eaten actually absorbed - retinol from animal sources is assumed to be completely absorbed. The overall utilisation of beta-carotene is therefore estimated to be one-sixth that of retinol (Hathcock, J.N. et al. 'Evaluation of Vitamin A toxicity'. Am J. Clin. Nutr. 1990, 52:183-202).

The nutrient composition figures come from the PIFCP laboratories (NACL and NAL, PNG and INR, USP, Fiji) supplemented with data from Siong et al. 'Nutrient composition of Malaysian foods', denoted by M. 'The composition of foods'. HMSO, UK (1985), denoted by UK; 'Composition of foods' by *USDA, revised 1979, denoted* by US; FAO Food and Nutrition paper 47/7, 'Utilisation of tropical foods; fruits and leaves', 1990, denoted by F; Institute of Medical Research, Papua New Guinea, 1985, denoted by IMR 85.

* After cooking.

Compiled by Food Composition Co-ordinator, *South Pacific Commission*, B.P. *D5 Noumea* Cedex, New Caledonia.

APPENDIX 2

ANALYTICAL METHODS

The three PIFCP laboratories, Institute of Natural Resources (INR), University of the South Pacific, Suva, Fiji; National Agricultural Chemistry Laboratory (NACL), Department of Agriculture and Livestock, Papua New Guinea; and National Analytical Laboratory (NAL) used the *Laboratory instruction manual for food composition studies* compiled by Wills and Greenfield (1988) as a guide for the analysis of their green leaf samples. For some components, however, different methods were used or modifications were made by the individual laboratories. The methods used are outlined below for each component determined.

Sample preparation

Immediately upon reaching the laboratory, the sample bunch of leaves was washed well with tap water, rinsed with distilled or deionised water to remove dust and soil particles and then drained and shaken to eliminate excess water. The edible parts of the plants were separated and weighed. The inedible portions were also weighed and then discarded. The sample selected for analysis was quickly homogenised in a blender to the consistency of a pulp. The samples were finally stored in strong plastic bags in the deep freeze until needed for subsequent analysis.

All analyses were duplicated and standard reference materials were run at the same time.

Moisture

In the NACL the leaves were weighed and then dried to constant weight in a vacuum oven set at 80°C. The NAL dried the leaves in a fan oven set at 135°C for 2 hours before cooling in a dessicator. The weight loss was then determined (Association of Official Analytical Chemists, Official Methods of Analysis, 1990, Method 930.15).

Protein

The standard kjeldahl digestion method with selenium catalyst was used by all three laboratories. The NAL measured the total ammoniacal nitrogen, using an automated 'Büchi' 322/342 Kjeldahl Apparatus, according to the British Standard 5766, Part 4,1981. INR and NACL used manual and 'Tecator' equipment respectively for the measurement of total ammoniacal nitrogen. The standard factor 6.25 was used to convert total nitrogen to 'crude protein'.

Fat

INR and NACL used the acid hydrolysis method. A weighed leaf sample was boiled with dilute hydrochloric acid to free the bound lipids. These were extracted with a mixture of petroleum ether and diethyl ether. Fat was determined gravimetrically after the complete evaporation of the ethers.

NAL extracted a 5—10 g sample with hexane using a 'Tecator Soxtec' Apparatus. The fat remaining after evaporation of the solvent was determined gravimetrically (Association of Official Analytical Chemists, Official Methods of Analysis 1990, Method 920.39 B).

Ash

INR and NACL followed the Wills and Greenfield method using a muffle furnace set at 530°C. NAL ashed a 2 g sample for 2 hours at 500°C in a muffle furnace (Association of Official Analytical Chemists, Official Methods of Analysis, 1990, Method 942.05).

Minerals (Sodium, Potassium, Calcium, Magnesium, Iron and Zinc)

The ash was digested with hot, dilute hydrochloric acid and the solution analysed using the atomic absorption technique. NACL added caesium chloride to prevent ionisation of sodium and potassium and strontium as a releasing agent for calcium and magnesium. NAL used lanthanum at 0.1 per cent as specified in the British Standard 5766 par. 4.1984, and Australian Analytical Chemists Committee Method 40—70, 27.10.82.

Available carbohydrates

NACL extracted sugars with ethanol and after removal of the ethanol separated them by HPLC (High Pressure Liquid Chromatography). NAL and INR did not determine available carbohydrates.

Dietary fibre

Only NACL determined 'dietary fibre'. The residue left from the determination of available carbohydrates was hydrolysed with the enzyme, amyloglucosidase and the resulting glucose measured by HPLC. The final glucose-free residue following this step, after allowing for ash and protein, was considered to be 'dietary fibre'.

Vitamin C

Only INR determined Vitamin C. The Association of Official Analytical Chemists, Official Method of Analysis, 1990, Method 43.069—43.073, was employed.

Carotenes

These precursors of Vitamin A were only determined by INR. The carotenes were separated by column chromatography into three main fractions consisting of alpha-carotene, beta-carotene and cryptoxanthin. Each fraction was measured by a visible absorption method as described by Wills and Greenfield (1988).

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The nutrient data for lettuce were used with permission from the German *Food composition and nutrition tables* 1989/90 by Souci et al. (1989). Most additional supplementary data for the nutrient tables in Appendix 1 were taken with permission from the *Nutrient composition of Malaysia foods* (1988) by Siong et al. of the ASEAN Food Habits Project, National Sub-committee on Protein, Malaysia.

I thank Jean-Paul Gaudechoux for figures 1—17 and Jean-Pierre Le Bars for most of the colour photographs and illustrations. The vital parts played by the 'models' Lilette and Joelie Maseng and Siutaisa Fuavao are gratefully acknowledged. I would also like to thank 'Chez Marin', Paul Trinh Ngoc Bon and Feldah Maseng for allowing us to photograph their vegetable gardens.

I have supplemented my own knowledge of the botany and agronomy of the different plants with much valuable information from Purseglove (1968) and Hale and Williams (1977). Mc Gee (1984) also supplied me with fascinating background information about the effects of cooking on the nutritional quality of green leafy vegetables.

I very much appreciated the support and patience of all the SPC typists who helped prepare this booklet for publication, especially Yvana Routier, Evelyne Gras, Marielle Georget, Maria Lourenco, Heather Jackson and Odile Rolland and Elise Kamisan. I thank the Publications Officer, Caroline Nalo, for interesting discussions about leaves, for her helpful comments and for editing the work. For the layout I thank Martial Dosdane.

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John M. Bailey

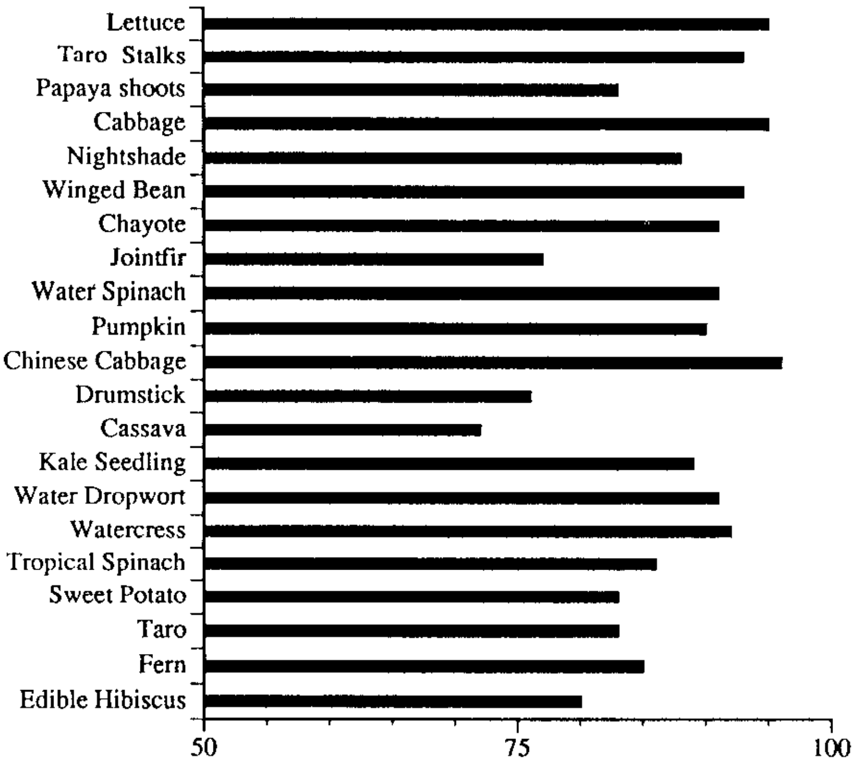

Figure 1: Weight of water, in grams, in 100 g edible portion, raw.

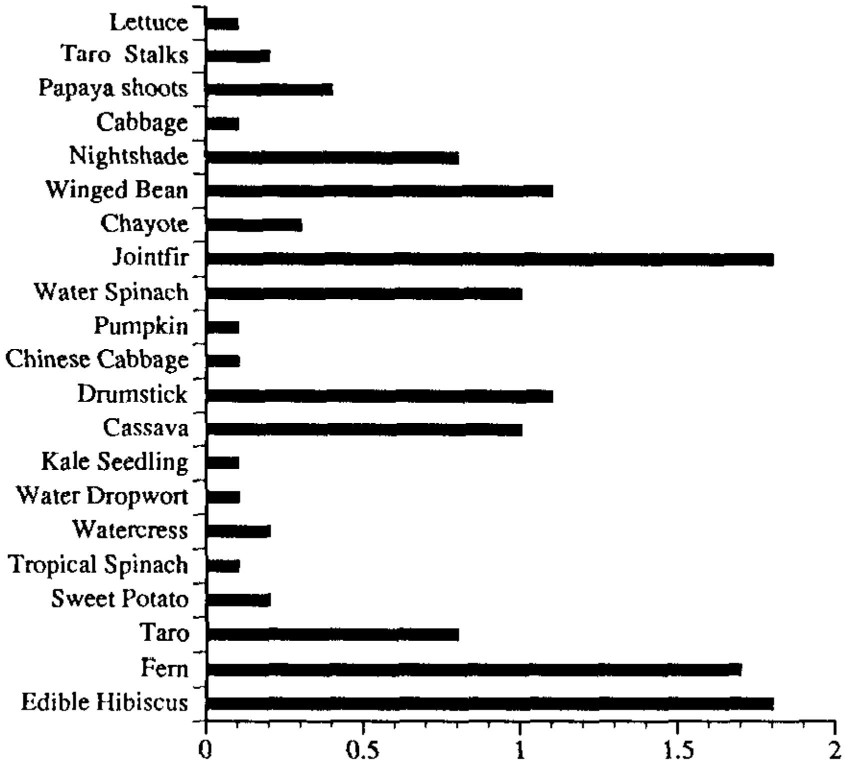

Figure 2: Weight of fat, in grams, in 100 g edible portion, raw.

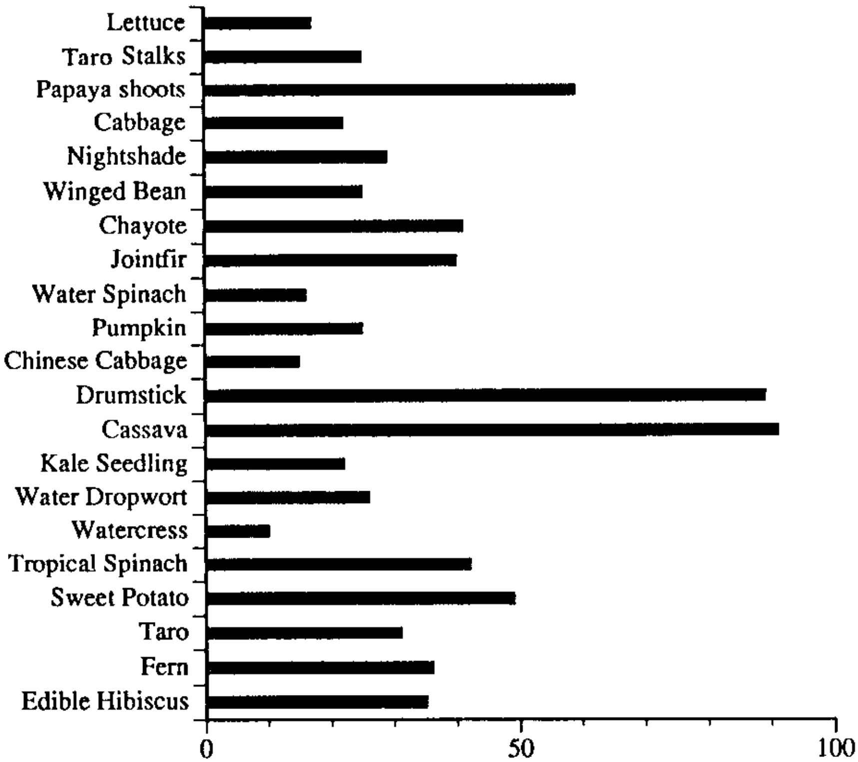

Figure 3: Energy content, in kCals, in 100 g edible portion, raw.

Multiply by 4.184 to convert to kilojoules

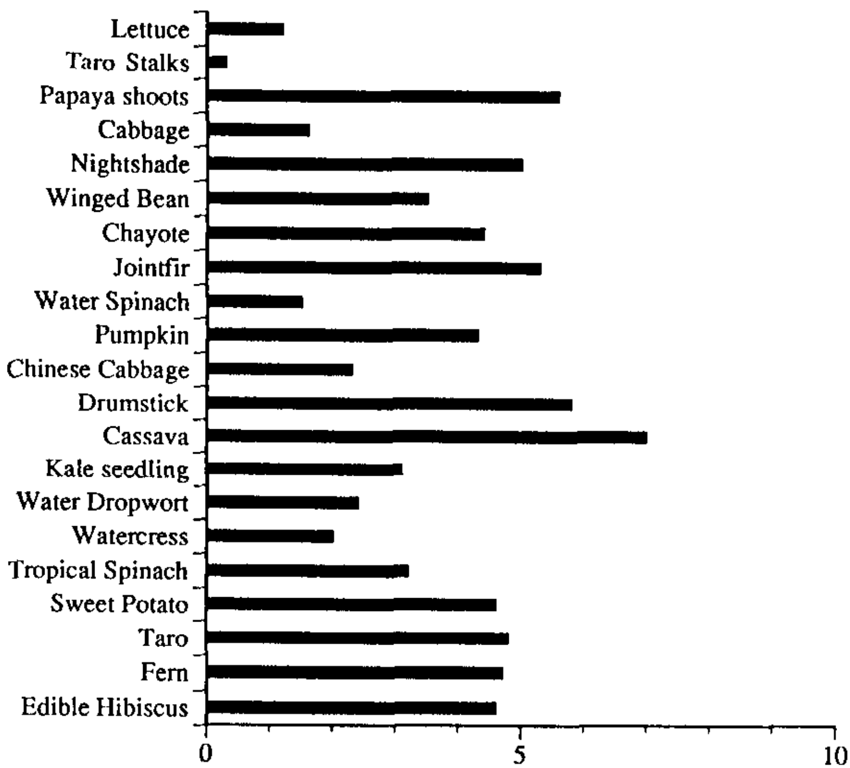

Figure 4: Weight of protein, in grams, in 100 g edible portion, raw.

Protein was calculated by using the factor 6.25 x total nitrogen.

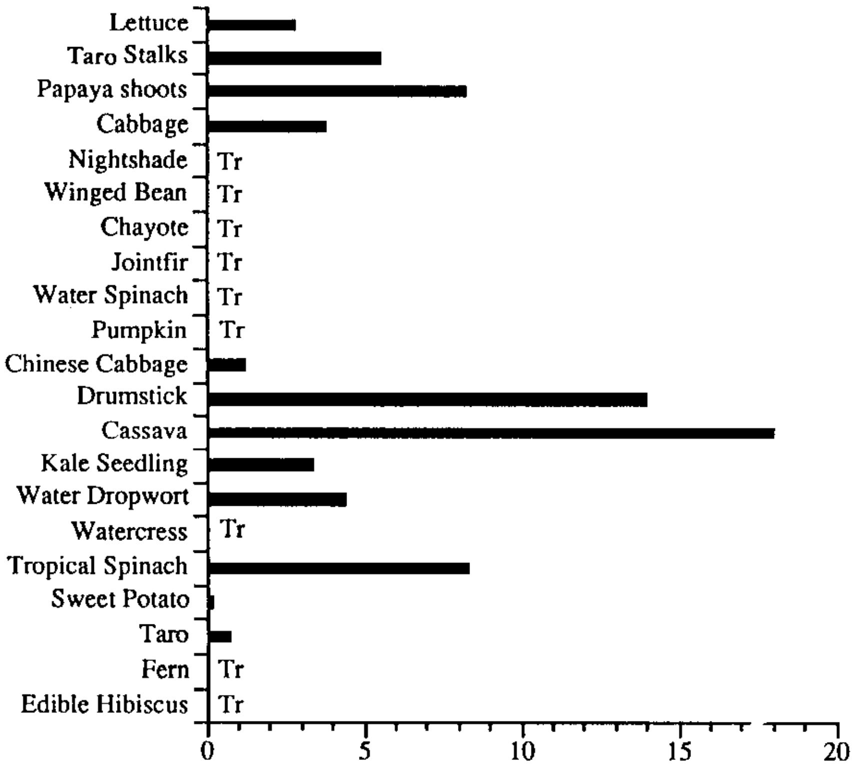

Figure 5: Weight of carbohydrate (CHO), in grams, in 100 g edible portion, raw.

Tr indicates that the quantity of carbohydrate present is below the detection limit of the analytical method used.

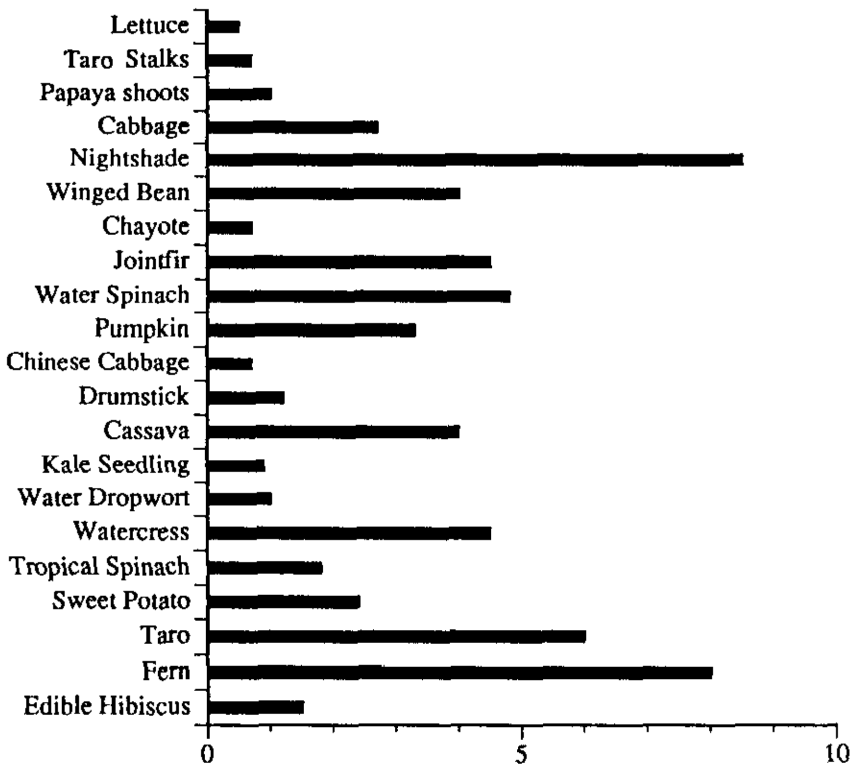

Figure 6: Weight of dietary fibre, in grams, in 100 g edible portion, raw.

The data for 5, 6, 7, 8, 9, 10, 16, 19, 20, and 21 are from the National Agricultural Chemistry Laboratory, PNG (See Appendix 1).

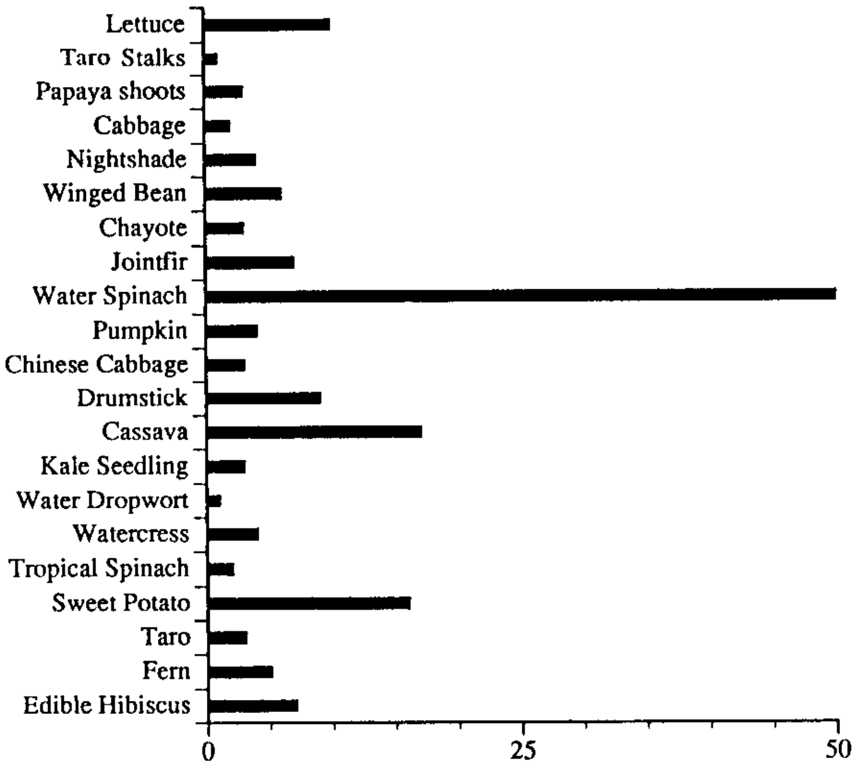

Figure 7: Weight of sodium, in milligrams, in 100 g edible portion, raw.

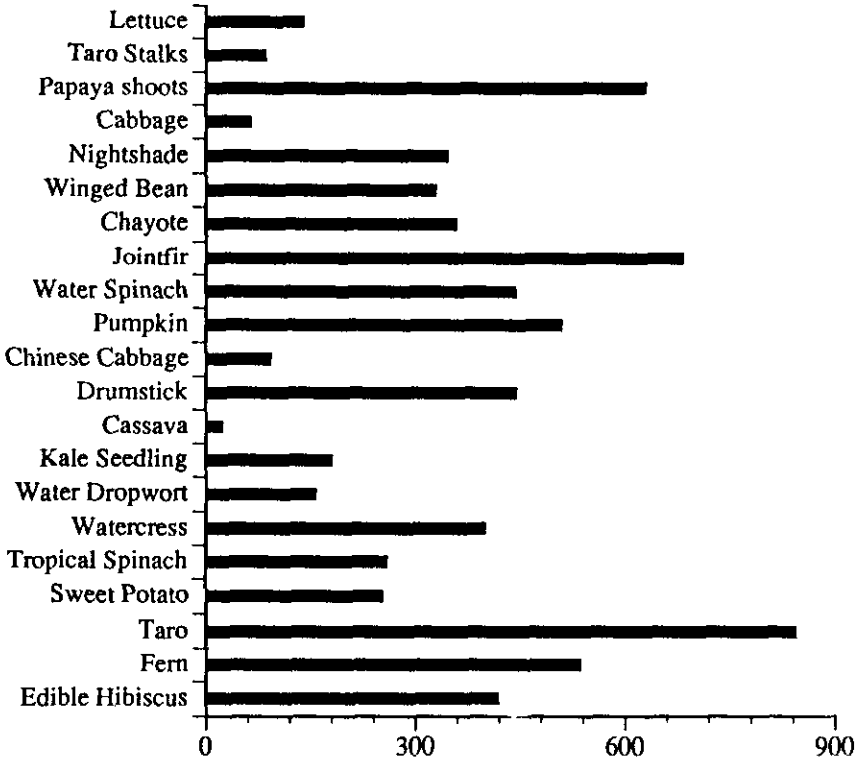

Figure 8: Weight of potassium, in milligrams, in 100 g edible portion, raw.

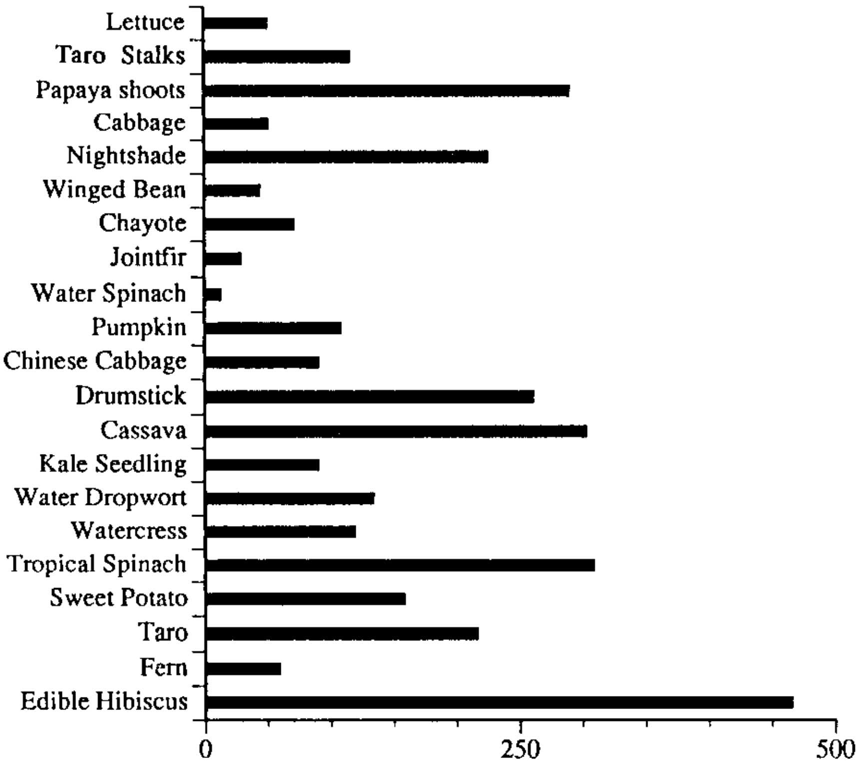

Figure 9: Weight of calcium, in milligrams, in 100 g edible portion, raw.

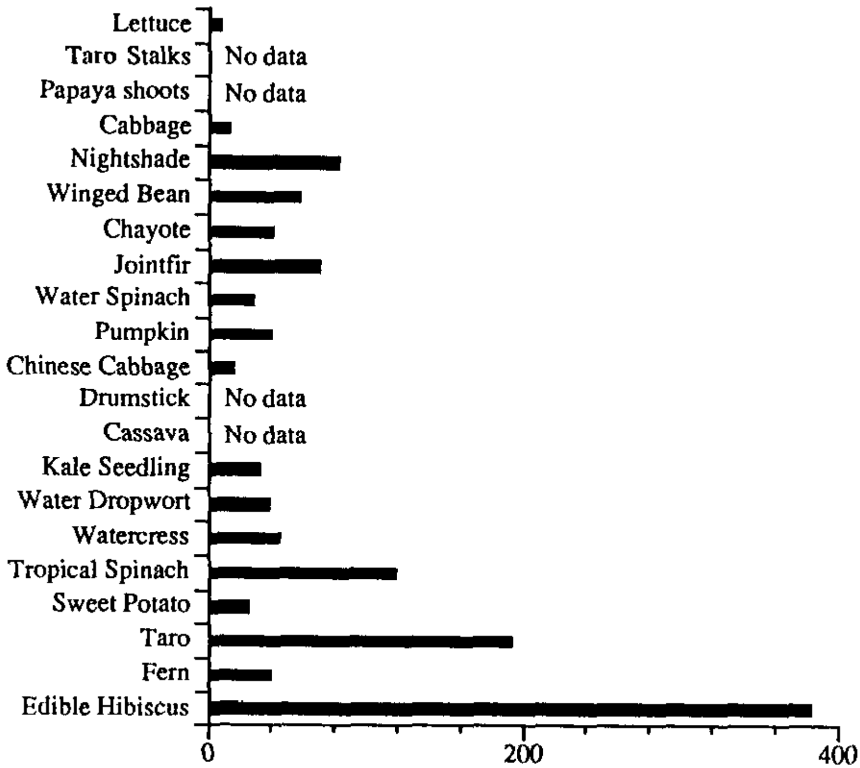

Figure 10: Weight of magnesium, in milligrams, in 100 g edible portion, raw.

'No data' indicates that magnesium was not determined in the PIFCP laboratories and that a suitable literature source could not be found.

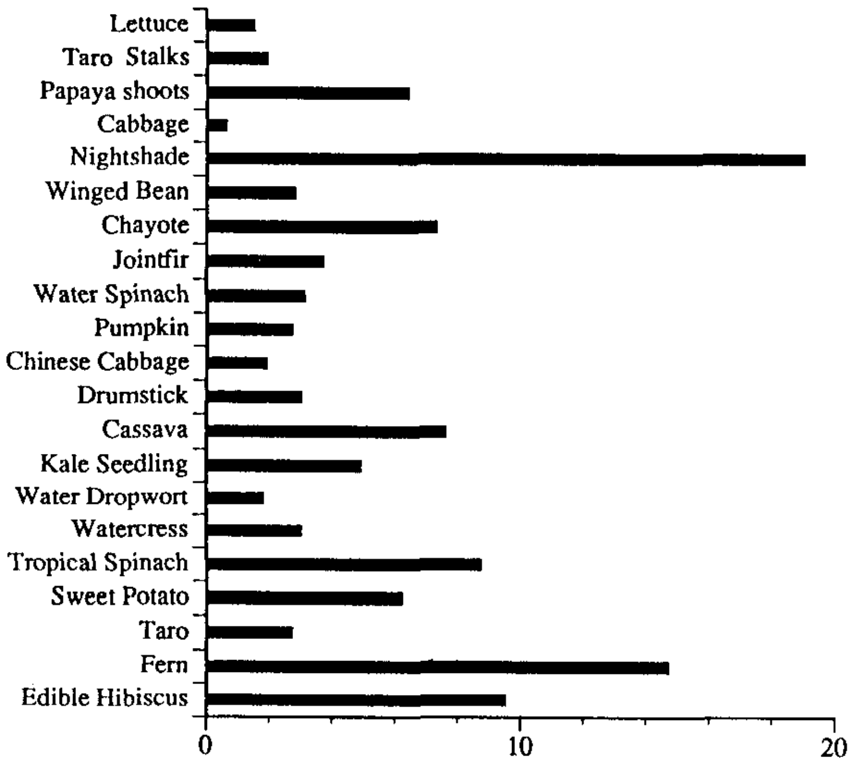

Figure 11: Weight of iron, in micrograms, in 100 g edible portion, raw.

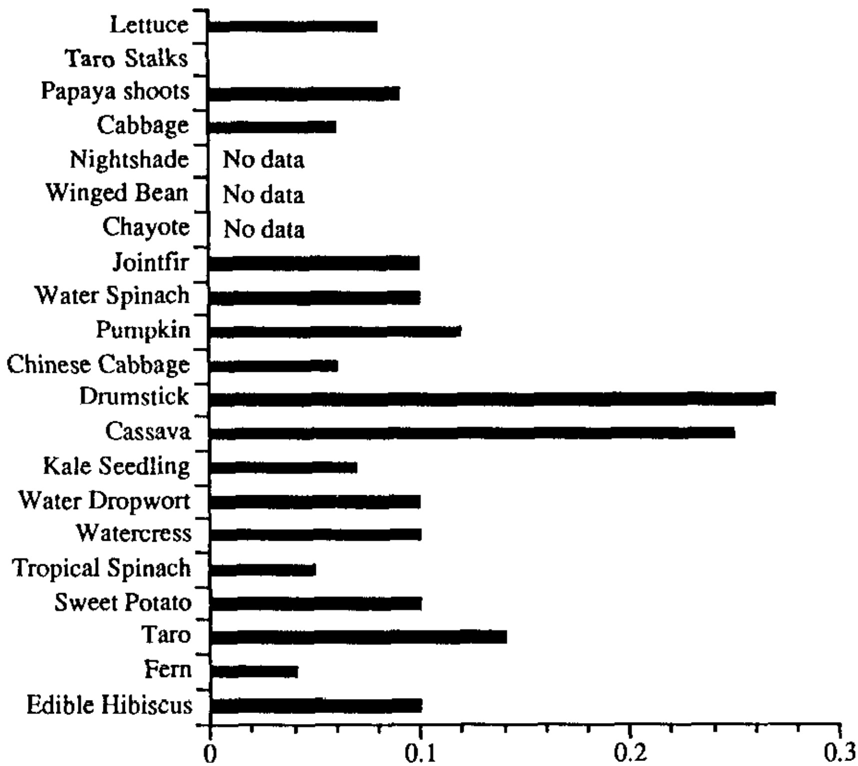

Figure 12: Weight of zinc, in micrograms, in 100 g edible portion, raw.

'No data' indicates that zinc was not determined in the PIFCP laboratories and that a suitable literature source could not be found.

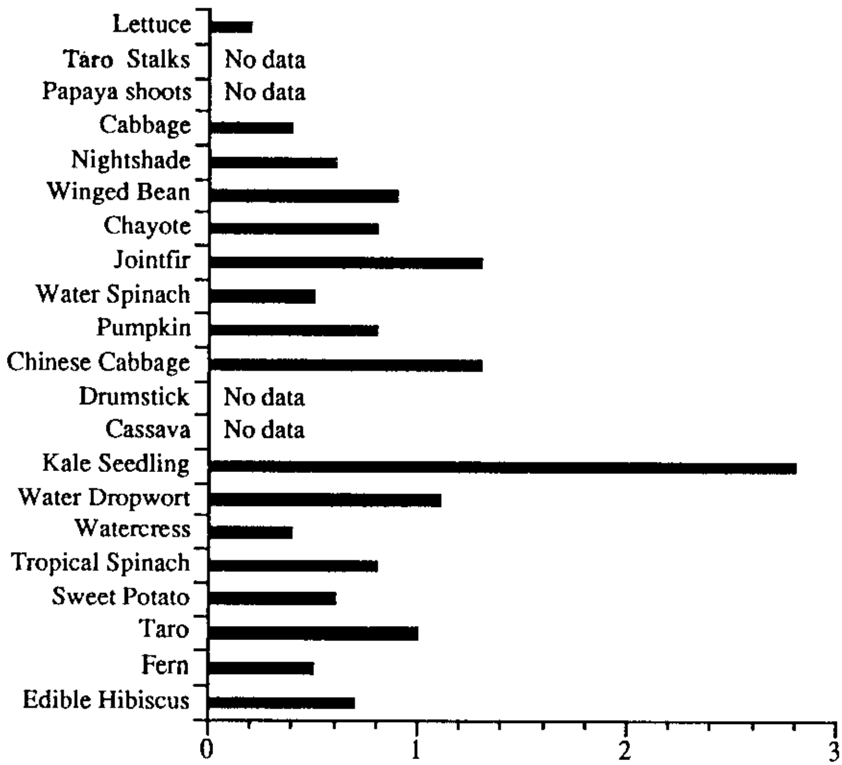

Figure 13: Weight of thiamine, in milligrams, in 100 g edible portion, raw.

'No data' indicates that thiamine was not determined in the PIFCP laboratories and that a suitable literature source could not be found.

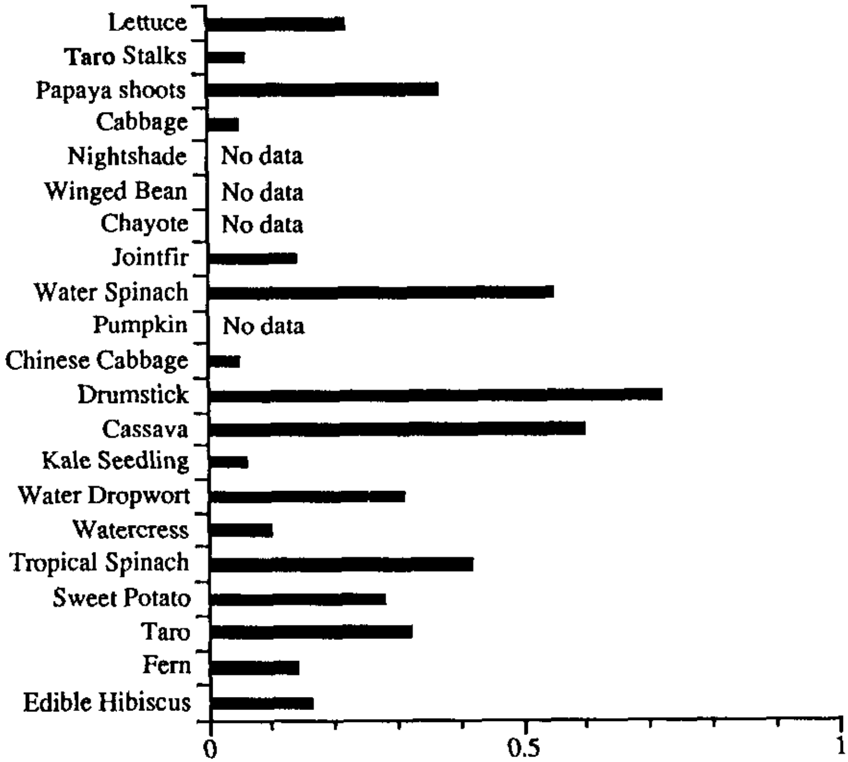

Figure 14: Weight of riboflavin, in milligrams, in 100 g edible portion, raw.

'No data' indicates that riboflavin was not determined in the PIFCP laboratories and that a suitable literature source could not be found.

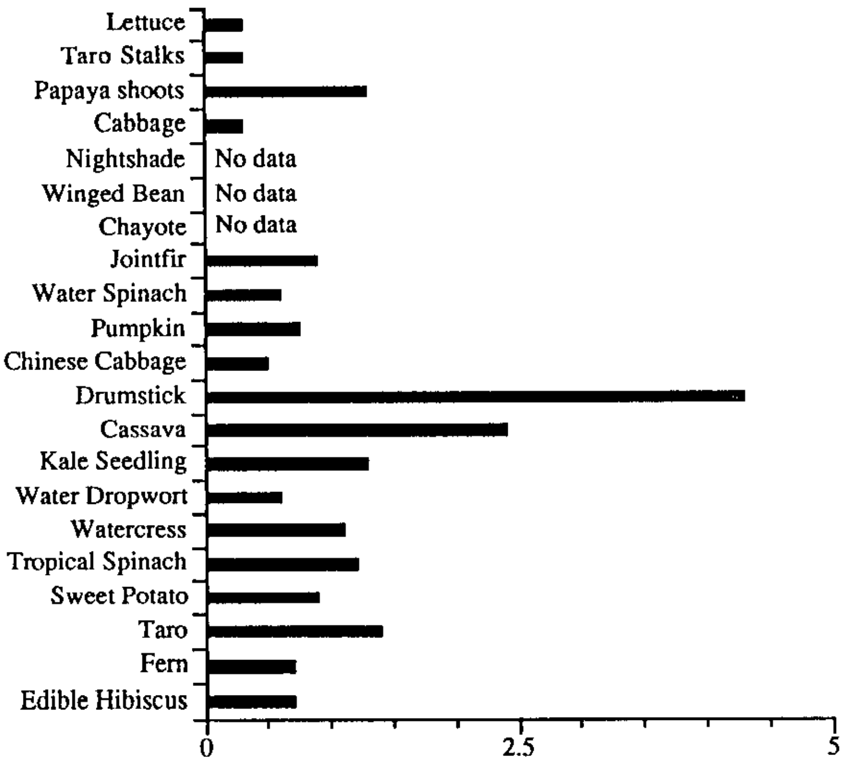

Figure 15: Weight of niacin, in milligrams, in 100 g edible portion, raw.

'No data' indicates that niacin was not determined in the PIFCP laboratories and that a suitable literature source could not be found.

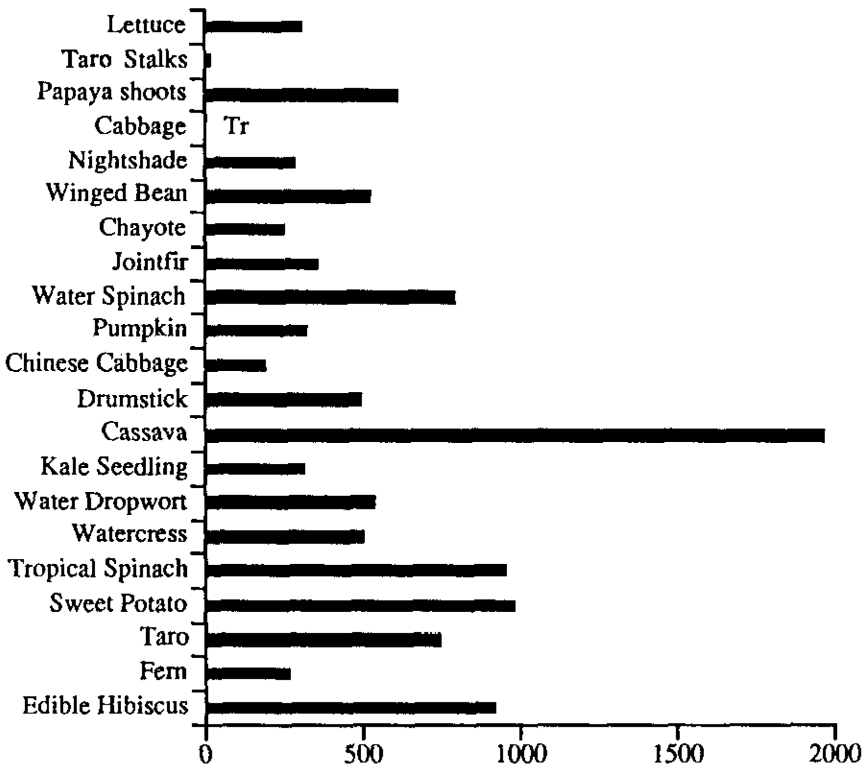

Figure 16: Weight of Vitamin A, in micrograms retinol equivalents, calculated from the weight of carotene divided by six, in 100 g edible portion, raw.

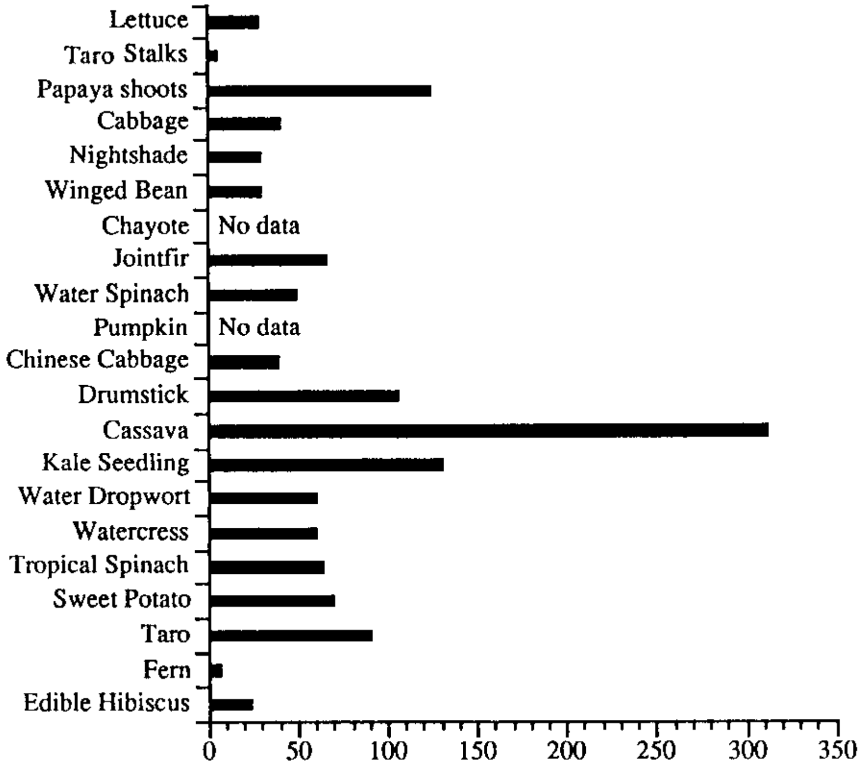

Figure 17: Weight of Vitamin C, in milligrams, in 100 g edible portion, raw.

'No data' indicates that Vitamin C was not determined in the PIFCP laboratories and that a suitable literature source could not be found.