NEW ZEALAND ARCHAEOLOGICAL ASSOCIATION MONOGRAPH 17:
Douglas Sutton (ed.), ***Saying So Doesn't Make It So: Essays in Honour of B. Foss Leach***

SAYING SO DOESN'T MAKE IT SO

PAPERS IN HONOUR OF B. FOSS LEACH

Edited by
Douglas G. Sutton

New Zealand Archaeological Association
Monograph 17

The Nutritive Value and Cooking of *Cordyline australis* (Tī Kouka)

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INTRODUCTION

Cordyline australis, referred to as the cabbage tree, is the most common of the five endemic species of *Cordyline* in New Zealand. The pre-European Maori used four of these for food along with the introduced *C. terminalis*. The Maori collective name for all species is *tī* with *C. australis* having the names *tī kōuka* (or *tī kāuka*) and *tī whanake* (Best 1976: 263; Williams 1971). I use the terms *Cordyline*, *tī*, and cabbage tree interchangeably with *tī kōuka* referring specifically to *C. australis*. *Tī kōuka* was the most widely eaten species in the South Island. This chapter reports part of my doctoral research (Fankhauser 1986) which was directed towards answering several questions on the use of *Cordyline* as a food.

Harvesting and cooking *Cordyline* in New Zealand was an important activity according to historical accounts. For example, Teone Tikao, a Maori from the South Island, commenting on the use of *C. australis* in the South Island states, "The preparation of *kauru* from cabbage trees was a strenuous work of great importance in our food supplies" (Beattie 1939: 140). An investigation of this activity led to the major problem posed in this research—proximate analysis of *C. australis* to determine its nutritive value. Was *C. australis* worth eating?

I collected *C. australis* plants monthly for a year to determine the extent of nutrient variation with emphasis on the carbohydrate level. Seasonal collection gives a clearer picture of maximum and minimum nutrient levels. The ethnographic literature indicates *tī* harvesting was a seasonal activity for Maori (Kauru n.d.). Shortland describes this activity:

> Just as we were leaving the place Te Rehe brought us a basket of "kauru", or baked root of the "ti" for which Waiateruati is celebrated. This root is in shape like a carrot, but from two to three feet long, and requires a deep and rich soil for its growth. The natives have learned to dig it at the season when it contains the greatest quantity of saccharine matter; that is, just before the flowering of the plant. They then bake, or rather steam it in their ovens. (Shortland 1851: 234)

In addition, he recorded on 19 January 1844, "This was also the season for digging the root of the *ti* or *whanake* ..." (Shortland 1851: 230). This brings up the second question

investigated. Did this seasonal activity correspond with the maximum nutrient levels, especially carbohydrate, in *C. australis*? If so, the Maori must have been aware of changes in nutrition level in the plant.

In general, nonstructural carbohydrate reserves reach a maximum in the monocotyledons at flowering and decrease thereafter as seeds form (Archbold 1940; Whistler and Smart 1953). Levitt (1980) and Smith (1973) also discuss seasonal changes in plant constituents. Archbold (1940) deals only with D-fructose polymers in monocotyledons, but Levitt and Smith discuss all plant constituents especially as related to cold-hardiness. Given this background, it was expected that *C. australis* would show a seasonal change in nutrition level.

The problems above were investigated with the chemical analysis of *C. australis* plants employing standard techniques for food analysis (e.g., Egan *et al.* 1981; Lees 1975; Osborne and Voogt 1978). Carbohydrate values were determined using high performance liquid chromatography (HPLC).

A common carbohydrate, starch, is the chief energy reserve of many plants. It is abundant in cereal grains such as rice and maize, and in tubers such as potatoes, cassava, and yams. Glucose is the only monosaccharide obtained on hydrolysis of starch. Instead of starch, some plants (e.g., Jerusalem artichoke (*Helianthus tuberosus*), iris (*I. foetidissima*), and rye (*Secale cereale*)) have energy reserve polysaccharides composed of fructose units rather than glucose (Archbold 1940; Lewis 1984; Meier and Reid 1982). Tanimoto (1939) also found *C. terminalis* contains a polysaccharide made up of mainly fructose. Research on *C. terminalis* by Boggs and Smith (1956) indicates its roots contain a water soluble polysaccharide built up of D-fructofuranosyl and D-glucosyl residues in a ratio of about 14 : 1. A similar polysaccharide was expected in *C. australis* because, as well as being a member of the same genus, its use as a food paralleled that of *C. terminalis*. This previous research on *C. terminalis* formed the basis for the chemical investigations on *C. australis* presented below.

Most of the carbohydrate research presented here was done with HPLC using a Sugar Pak I column (Ivie 1982). HPLC with recently available columns allows one to rapidly quantitate and identify multiple sugars directly in a single analysis. This resulted in extracted and hydrolysed *C. australis* samples being successfully analysed.

With the results from chemical analyses, I was able to assess the quality of *C. australis* as a food and consequently its importance in the Maori diet. The proximate analysis of *C. australis* provided a nutritional comparison to common starchy plants. It would have been as good a source of carbohydrate as common starchy plants while providing more fat but less protein.

Another problem presented in this research is the question of the effect of cooking on *C. australis*. *Cordyline* was traditionally cooked for long periods of time. In New Zealand, cooking times vary from 12 hours to "days" with most accounts giving one to two days as the time required (Best 1976; Brunner 1952). I carried out cooking studies to specifically answer two questions: Does it need to be cooked for several days, and what are the results of cooking?

Cooking may simply be defined as the heat treatment of foods carried out to improve their palatability, digestibility and safety (Fox and Cameron 1982). Cooking of vegetable foods softens and partially breaks down the cellulose framework of the plant walls to release starch, mineral elements and vitamins. A popular method of cooking amongst Polynesians was steaming using an earth oven (Best 1924; Leach 1982). This was the method used

by Polynesians for cooking *tī* and the ovens are called *umu tī*. Remains of *umu tī* are common in South Canterbury (Fankhauser 1986, 1987) (Figure 1), Otago (Knight 1966), and Southland.

Figure 1: The remains of a raised rim *umu tī* (4 m diameter) located near Timaru, South Canterbury. The pit in the left foreground probably furnished soil to cover the oven when it was reused.

In moist heat cooking, nutrients may be lost by the leaching of water soluble nutrients. However, steaming results in a smaller loss of soluble matter than boiling, and steam under pressure reduces the cooking time because of the higher temperatures reached. Steaming has the advantage over dry heat in not destroying nutrients to the same extent.

Food is necessary for life as a source of energy and for the growth and replacement of tissue (see Potter 1978; Wilson *et al.* 1979). The six groups of essential nutrients are carbohydrates, fats, proteins, water, vitamins and minerals. The latter two were not determined in this study.

The energy value of foods is measured in terms of calories (cal) or joules (J) where 1 cal = 4.19 joule (note, small calorie). It is most convenient to express the energy values in kilocalories (kcal) and kilojoules (kJ) or megajoules (MJ). Because much of the literature on food energy still uses kcal, both means of expressing energy will be used here.

Energy is required by the body for basal metabolism, i.e., for maintaining basic body processes. Also, energy is used by the body for physical activity. The body gets its energy from carbohydrates, proteins, and lipids. Although the calculations of energy values for these nutrients are not straightforward and do vary, generally accepted values are presented in Table 1 (from FAO 1967; USDA 1978: 6).

Carbohydrates supply the bulk of energy in diets worldwide. Most people have a staple food which is a cheap source of carbohydrates. These include starchy foods such as rice,

TABLE 1
ENERGY VALUE OF NUTRIENTS

Nutrient	Energy, kcal/g	kJ/g
Carbohydrate	3.8	16
Lipid	9.0	38
Protein	4.0	17

maize, wheat or potatoes. The total energy supplied by carbohydrates in the diet can vary from 20–80%, depending on ecological and economic factors, and still be consistent with normal health. However, it is now generally agreed carbohydrates should supply 50–65% of the total energy requirements (Osborne and Voogt 1978).

Protein requirements have been a subject of research since the beginning of the 19th century. The value of protein food is based on its protein content, protein digestibility and the number and amounts of essential amino acids which it provides. The primary function of food proteins is to provide amino acids for the production and maintenance of body proteins, but they are ultimately broken down to urea and provide energy (Fox and Cameron 1982). The recommended protein requirement in various countries is about 1 g/kg of body weight per day for adults (Osborne and Voogt 1978: 56–69). However, this amount is dependent upon such factors as climate extremes and physical exercise.

Lipids supply a concentrated portion of human energy supplies, having more than twice as much energy per unit weight as carbohydrates and proteins. There is no set figure for recommended fat intake, but it is necessary to consume a small amount to supply the essential fatty acids. Gaman and Sherrington (1981: 69) suggest a minimum of 1–2% of the energy intake of an individual should be supplied in the form of fat. Current opinion favours a lipid level in the diet of 25–35% of the total energy requirement (Osborne and Voogt 1978). Eating fat reduces the bulk of food which must be eaten since it has more than twice the available energy of carbohydrates.

MATERIALS AND METHODS

SAMPLE COLLECTION AND PREPARATION

Cordyline australis trees were collected from the Otago Coast Forest in south-east Otago at a rate of one per month, for a year beginning in mid-November. Trees complete with roots (underground stems) were dug at midday and as close to midmonth as possible. I selected young trees of 6–8 cm diameter and 1.2–1.8 m stem height because this size was used by Maori for food.

Within two hours of uprooting, the trees were cut into sections: two pieces each of 0.5–1 kg from the stem and root. In some specimens, the undeveloped leaves referred to as top were sampled. The samples were split into small pieces and dried in a forced air oven at 70°C for a minimum of two days. Samples were further processed by homogenizing along with dry ice and then ground either in a Tema mill or a Wiley mill for 5–15 sec.

PROXIMATE ANALYSIS

Water: Approximately 35 g fresh samples were taken in triplicate, dried in a forced air oven as stated above, cooled in a dessicator and weighed. I measured the residual moisture (1–6%) in the samples at the time of analysis by further drying at 40°C for 16 hours in a vacuum oven equipped with a liquid nitrogen trap.

Fibre: This was determined using the neutral detergent method (Van Soest and Wine 1967: 50–5).

Protein: Nitrogen content was determined by the micro-Kjeldahl method (Lakin 1978) using K_2SO_4 + Se tablets and H_2SO_4 for digestion. The protein level was obtained by multiplying the total nitrogen by 6.25 (Jones 1931).

Total ash: Ash content was determined using the method described by Egan *et al.* (1981).

Lipid: The lipid content was estimated by Soxhlet extraction using chloroform:methanol (2 : 1 v/v). Extraction was done for 10–16 hours (Osborne and Voogt 1978).

CARBOHYDRATE ANALYSIS

Instrumentation: I did HPLC analyses using a Varian Model 500 Liquid Chromatograph, Model U6K Waters Associates injector, Waters Associates Sugar Pak I column (30 cm × 6.5 mm id) maintained at 90°C, precolumn filter and model R-401 differential refractometer detector (Waters Associates). The detector signal was recorded on a Varian model 9176 recorder with a chart speed of either 1 or 2.5 cm per min. In some analyses the detector signal was simultaneously recorded on a Hewlett Packard 3390A integrator.

Sample preparation: (Extraction) I weighed each sample of 0.20 g into a glass vial and added 2.00 g of 50.0 mg/g of mannitol solution as an internal standard. This was diluted with Milli-Q water up to a total mass of 15.00 g. The vial was capped and agitated on a Gallenkamp flask shaker for 30 min. The solution was vacuum filtered through a sintered glass filter. (Hydrolysis) 0.1 ml of 0.5 M tetrafluoroacetic acid (TFA) was added to 10 ml of each extracted solution above. The solution was transferred to a 50 ml round bottom flask and refluxed for 30 min.

Analysis: All samples were filtered through a Millipore HA (0.045 µm) membrane. I injected 10 µl of each hydrolysed sample into the instrument. The mobile phase was 100% Milli-Q water filtered through a Millipore HA (0.045 µm) membrane and degassed under vacuum while immersed in an ultrasonic bath. The flow rate was 0.5 ml/min.

Identification and quantification of individual constituents were based on comparisons to standard solutions (2.5 and 5.0 mg/g) of fructose, glucose, sucrose, *C. australis* polysaccharide prepared according to Boggs and Smith (1956), and the internal standard mannitol. The results reported are based on peak areas.

COOKING METHODS

I selected the January *tī kōuka* root sample for this study because this specimen would correspond to the traditional harvest time indicated in the ethnographic literature. Powdered samples of 0.200 g were weighed into 20 ml glass vials and 0.100 g of mannitol standard

added. The glass vials were spaced around the inside of a 25 cm diameter camp cooker and a pressure cooker, both equipped with screens to keep the samples above the water level. I also cut a *tī kōuka* root from February into small pieces to be cooked at atmospheric pressure along with the powdered samples.

The lids were placed on the vessels when the water was boiling. The solid samples and glass vials containing the 0.200 g samples were withdrawn at 1, 2, 4, 8, 12, 18, 24 and 36 hours. The vials were immediately capped and frozen as were the solid samples. Before analysis, the samples were dried overnight at 40°C in a vacuum oven equipped with a liquid nitrogen trap. The solid samples were ground in a Wiley mill and 0.200 g weighed into vials along with mannitol. All samples were then diluted with Milli-Q water up to a total nett mass of 15.00 g. Carbohydrate analysis was done by HPLC as described above.

RESULTS AND DISCUSSION

CARBOHYDRATE

The proximate compositions on a dry weight basis are presented in Table 2. The water percentage is given in this table to allow conversion to fresh weight percentage. Note that top refers to the undeveloped leaves.

The main constituent of *C. australis* is nonstructural carbohydrate with a variable content throughout the year. As in all plants, the amount of carbohydrate varies from plant to plant at any one time. Since the carbohydrate content (and other constituents) for each month was determined from a single plant, a method of smoothing the results was necessary to look for any seasonal variations. The samples were collected for only a period of a year, but it may be assumed seasonal trends are cyclic. Note however, that seasonal polysaccharide concentration is certainly affected to some extent by environmental conditions.

Seasonal trends are often described using a cubic equation (Stewart and Wallis 1981):

$$y = B_0 + B_1x + B_2x^2 + B_3x^3, \tag{1}$$

where, in this case, y = carbohydrate content, B_0 to B_3 = constants, and x = months.

If analyses have been done for only a one year period and not for over a period of say three years, and it is assumed seasonal variations are cyclic, then over a twelve month period the twelfth month value will correspond with the previous year's value, month 0, (Manly pers. comm.; Stewart and Wallis 1981) or

$$y_0 = y_{12}. \tag{2}$$

Then

$$12B_1 + 12^2B_2 + 12^3B_3 = 0, \tag{3}$$

leading to:

$$y = B_0 + B_1(x - x^3/144) + B_2(x^2 - x^3/12). \tag{4}$$

Regression of y in equation (4) on 2 predictors, $(x - x^3/144)$ and $(x^2 - x^3/12)$, will give a regression equation for predicating y from x. A statistical computing system, Minitab, was used to solve the regression equations. Besides the regression equation, Minitab gives the predicated monthly y values with their standard deviations and other values to assess the significance of the regression equation. I assumed that if the regression equation was significant then a cyclic relationship exists.

TABLE 2
PROXIMATE COMPOSITION OF *Cordyline australis* (% DRY WT)

Month	Sample	Water(%)	Protein	Fat	Carbohydrate	Fibre	Ash
Nov	Root	70.0	1.2	1.9	74.6	23.9	2.6
	Stem	72.4	1.2	2.9	43.2	46.3	3.1
Dec	Root	51.0	0.9	4.2	64.1	31.3	2.2
	Stem	65.0	0.9	3.3	74.7	25.2	1.0
	Top	80.5	7.2	16.0	49.0	25.0	9.1
Jan	Root	71.7	1.9	5.5	57.4	32.2	2.9
	Stem	68.4	2.0	6.4	38.8	47.4	2.3
Feb	Root	63.2	1.0	3.8	66.0	26.4	2.0
	Stem	67.4	1.4	6.1	30.4	55.3	3.1
Mar	Root	73.6	2.2	5.8	59.5	30.8	n.d.
	Stem	69.0	1.9	4.6	33.6	49.0	n.d.
Apr	Root	61.1	1.9	8.7	47.0	37.4	n.d.
	Stem	71.5	2.3	6.8	28.6	57.2	n.d.
May	Root	62.9	0.9	3.1	56.3	35.0	n.d.
	Stem	81.6	1.5	9.1	23.8	60.2	n.d.
June	Root	67.3	1.0	10.3	63.6	29.1	n.d.
	Stem	71.8	1.3	12.4	32.9	47.5	n.d.
July	Root	67.7	1.0	7.6	58.1	32.1	n.d.
	Stem	84.0	1.4	9.2	21.1	63.2	n.d.
Aug	Root	65.2	3.1	5.3	51.1	40.6	n.d.
	Stem	72.4	1.9	8.0	15.1	69.4	n.d.
Sept	Root	72.8	1.7	5.4	48.4	43.0	n.d.
	Stem	75.9	1.8	10.8	31.3	54.1	n.d.
	Top	82.6	6.6	16.8	46.8	28.1	n.d.
Oct	Root	64.1	1.4	3.7	33.2	58.5	n.d.
	Stem	67.4	1.2	6.5	47.4	44.0	n.d.
	Top	82.5	7.2	18.1	47.6	23.5	9.4

Notes:
1. Protein = $N(\%) \times 6.25$; n.d. = not determined.
2. Percent water of fresh samples is given to allow conversion of data to fresh weight values.

I did regression analyses on the dry weight and calculated fresh weight monthly carbohydrate values for both the stems and roots. There was no significant cyclic relationship for the root carbohydrate data where Fisher's (F) = 1.55 and 1.34 for dry and fresh weights, respectively. (However, note the highest values for root carbohydrate were in the months of November, December, and February).

Regression analysis for the stem carbohydrate data resulted in equations significant at the 2.5% level. The stem seasonal carbohydrate variation is shown in Figure 2 where the monthly carbohydrate results and cyclic regression equations are plotted for dry and fresh weights. The stems with the highest polysaccharide content are found in spring through summer (Figure 2) which is typical for monocotyledons. The root serves as the main carbohydrate store with the stem storing a highly variable amount of reserve carbohydrates. There were not enough data to assess the top variability, but presumably this would follow the trend of stems.

There was a significant seasonal cyclic variation above for the stem carbohydrate levels. Since only one plant per month was sampled, further comparison was made between the means of summer and winter plants to determine if a significant difference exists. Using tests by Lord (1947) and Tukey (1959) for two small sample sizes, the means of stem

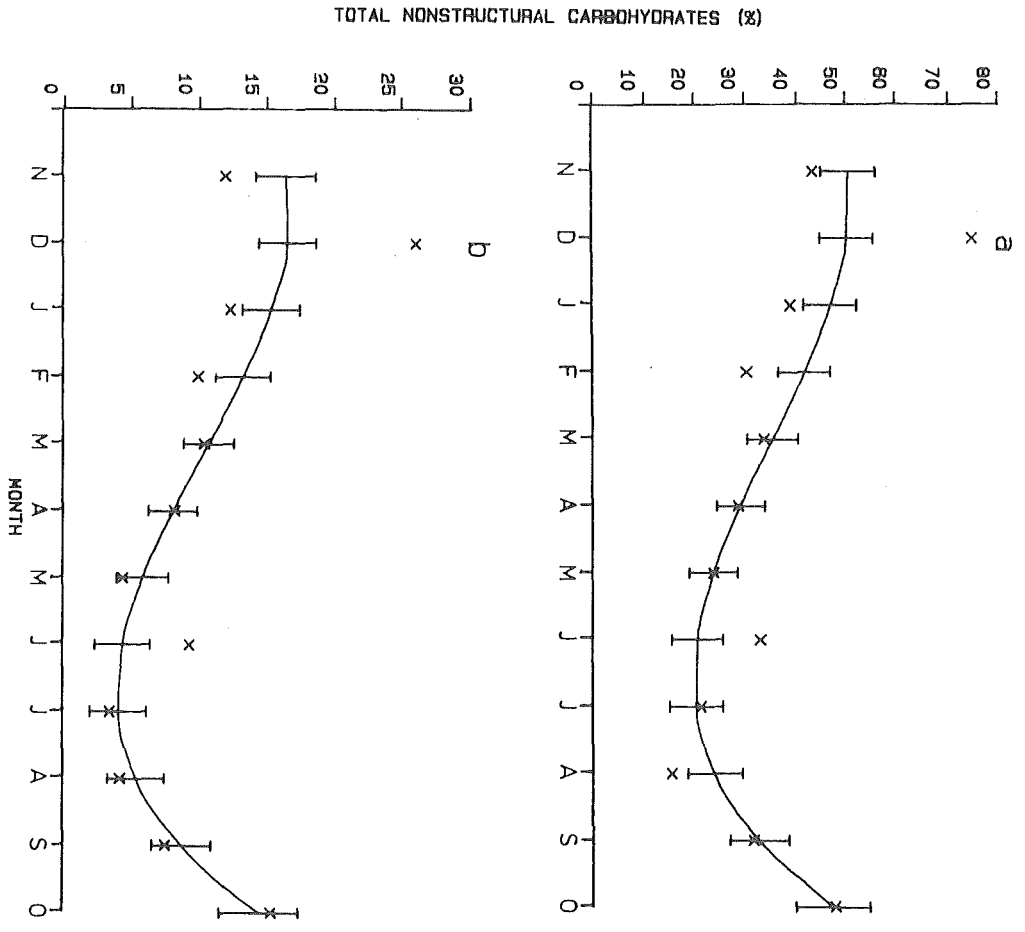


Figure 2: Monthly total non-structural carbohydrate analyses of *C. australis* stems. a. % dry wt; b. % fresh wt. From results in Tables 2 and 3. Curves are cyclic cubic regression fits to the results with errors of one standard deviation.

carbohydrate values, dry or fresh weights, for November through February compared with those of May through August were found to be statistically different at the 5% level. The same conclusions were reached if November through January samples were compared with those of June through August.

My results indicate the recorded time of harvesting by Maori corresponded with the maximum carbohydrate content. This coincidence could have been fortuitous in that the most convenient time of the year weatherwise for harvesting would have been in the spring-summer period. The rainy winter season would have caused problems in drying *tī* after cooking. Also, the summer season corresponded with other traditional excursions for food

gathering as discussed by Anderson (1982, 1983). However, most likely, experience dictated the best time of the year for gathering and cooking *C. australis*. This seasonal knowledge for *Cordyline* cooking would not have been brought to New Zealand because *C. terminalis* used traditionally in other parts of Polynesia probably was harvested and cooked at all times of the year. *C. terminalis* has been recorded as flowering at all times of the year in the tropics (Smith 1979: 149–51) and this flowering is preceded by an increase in the carbohydrate content. Only in a temperate climate like New Zealand would the carbohydrate content vary seasonally to any extent.

Seasonal harvesting of *Cordyline* may have applied only to the roots and stems. Tikao (cited in Best 1976: 269–70), referring to *C. australis*, indicates the tops (undeveloped leaves) were eaten at all times of the year by cooking with eels, birds, etc. He also states the tap roots were cooked at all times, but goes on to say stems were only prepared during the summer. It is possible the roots could have been cooked in the winter, but this seems to be a waste of time considering both the lower amount of carbohydrate in the roots and throwing the stem away.

Various references (see Best 1976) point out Maori were aware of the season for the highest polysaccharide content in *Cordyline*. It seems that Maori were also aware of methods to increase the carbohydrate content by either ligaturing the plant (Hector 1897; White 1898: 116) or cutting off the top (Best 1976: 264) some time before harvest. I do not know whether mutilation was successful, but Archbold (1940: 215) found there was an immediate increase of total sugar and fructan in all parts of barley plants when he removed some tillers from one group of plants and from another group both tillers and ears at the time of ear emergence. Mutilation indicates Maori were trying to get maximum yields. This points to the strong possibility that knowledge of the best time to harvest was acquired through experience. Hydrolysis experiments conducted as a part of my research (discussed below) reveal a further reason for harvesting during the warmer months of the year.

The carbohydrate trends presented in Table 2 and Figure 2 are similar to those expected for a monocotyledon with the exception of the root data which should show a cyclic seasonal variation. A more thorough investigation sampling several plants per month by repeated coring would probably be the best way to define seasonal variations.

The carbohydrate results in Table 2 are from the HPLC analyses on hydrolysed samples. A breakdown of these HPLC results is shown in Table 3.

These results indicate the water soluble polysaccharide is composed of fructose and glucose. Unhydrolysed disaccharides and polysaccharides are present in all hydrolysates. These components are most likely composed of condensation and reversion products from the hydrolysis (Fankhauser and Brasch 1985).

Nuclear magnetic resonance (NMR) research on the polysaccharide from *C. australis* and *C. terminalis* show that the polysaccharides from both are virtually identical and are composed of fructose and glucose in a ratio of 15:1 (Brasch *et al.* 1988, Fankhauser and Brasch 1985).

McDonald (1985) using NMR and methylation analyses, determined *C. australis, banksii*, and *indivisa* glucofructans contain mainly 2,1-linked fructo-furanose residues, with branching occurring at the 6-position of some fructose residues, and a small proportion of fructose residues which were linked through the 2 and 6 positions only. The polysaccharide chains were terminated by an α-D-glucosyl group. McDonald (1985: 106) presents structures of some glucofructans from his NMR and methylation results (Figure 3). HPLC analyses indicate the polysaccharide levels in the roots of *C. australis* and *C. terminalis*

TABLE 3
NONSTRUCTURAL CARBOHYDRATE COMPOSITION OF HYDROLYSED *C. australis* SAMPLES (% DRY WT)

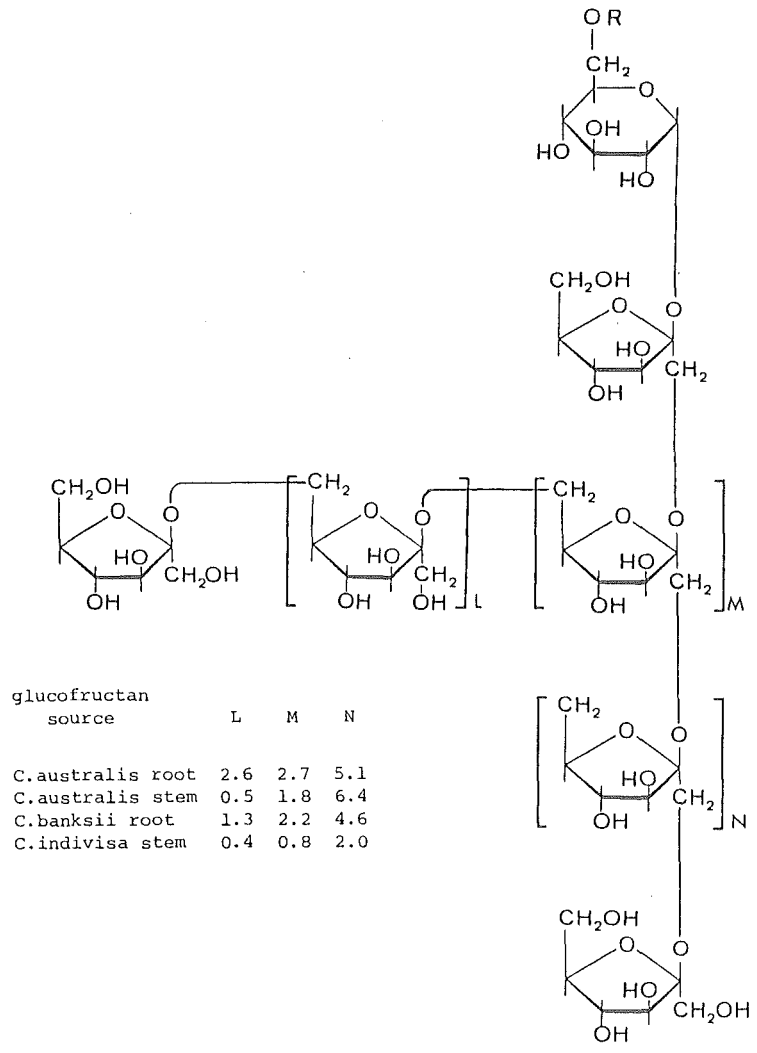
Month	Sample	Fructose	Glucose	Disacc.	Polysacc.	Total
Nov	Root	61.9	5.3	4.4	3.0	74.6
	Stem	35.1	3.3	1.7	3.1	43.2
Dec	Root	55.2	3.9	2.9	2.0	64.1
	Stem	67.2	2.9	4.0	0.6	74.7
	Top	13.1	4.9	12.6	18.4	49.0
Jan	Root	45.8	4.9	3.3	3.4	57.4
	Stem	29.2	2.9	2.6	4.1	38.8
Feb	Root	56.0	4.4	3.6	2.1	66.0
	Stem	22.6	2.8	1.2	3.8	30.4
Mar	Root	47.9	4.7	3.8	3.1	59.5
	Stem	24.4	2.6	1.8	4.8	33.6
Apr	Root	36.4	2.8	3.3	4.5	47.0
	Stem	17.0	2.5	2.0	7.0	28.6
May	Root	46.4	4.7	2.7	2.5	56.3
	Stem	13.5	3.5	0.9	5.9	23.8
June	Root	44.8	5.0	8.8	5.0	63.6
	Stem	16.9	2.9	5.4	7.7	32.9
July	Root	46.1	3.9	4.5	3.6	58.1
	Stem	7.1	3.1	1.5	9.4	21.1
Aug	Root	42.6	3.2	2.8	2.5	51.1
	Stem	7.2	2.3	0.7	5.0	15.1
Sept	Root	38.4	4.1	2.4	3.4	48.4
	Stem	19.8	4.7	1.2	5.6	31.3
	Top	21.6	7.2	9.4	8.6	46.8
Oct	Root	24.3	3.7	1.9	3.3	33.2
	Stem	35.3	4.2	3.8	4.1	47.4
	Top	19.3	5.6	9.3	13.4	47.6

are similar (Fankhauser and Brasch 1985). Furthermore, I found the levels in *C. banksii* and *C. indivisa* to be similar as did McDonald (1985). These similarities indicate that all *Cordylines* may be alike chemically, and the results presented here for *C. australis* are probably indicative of the genus *Cordyline* as a whole.

Best (1976) indicates Maori cooked all species of *Cordyline* and my results confirm they would supply similar amounts of carbohydrate. However, Best notes certain species were preferred. I think this may be due to taste preferences and not to total carbohydrate produced.

An HPLC chromatogram (Figure 4) shows the individual peaks are well resolved at a flow rate of 0.5 ml per minute with retention times in minutes of: polysaccharide = 4.7; TFA = 5.0; disaccharide = 6.7; glucose = 8.3; fructose = 10.3, and the internal standard mannitol = 13.4.

Duplicate runs on hydrolysis samples had a difference varying from 0.7–6.8% of each other with a mean precision of 3.3%. A "perfect" proximate analysis would have all the components, i.e., protein, fat, carbohydrate, fibre and ash adding to 100%. In reality, this is seldom the case. The average of the total of all monthly proximate analyses in Table 2, assuming a value of 2.5 for the undetermined ash samples, is 99.9% indicating there were no systematic errors involved.



glucofructan source	L	M	N
C.australis root	2.6	2.7	5.1
C.australis stem	0.5	1.8	6.4
C.banksii root	1.3	2.2	4.6
C.indivisa stem	0.4	0.8	2.0

Figure 3: Structures of glucofructans from indicated species of *Cordyline*. L, M, and N are mole ratios of given monomer linkages; R = H or 2 linked β-D-fructofuranosyl residue. From McDonald (1985: 106).

The ease with which samples were hydrolysed varied throughout the year. The extent of polysaccharide hydrolysis, i.e., (total carbohydrate – polysaccharide) × 100 / (total carbohydrate), for the root samples throughout the year was greater than 90% (see Table 3). However, this extent of hydrolysis was found only for the stem polysaccharide in late spring and early summer. The ease of hydrolysis reached a low with the July stem. I do not have an explanation for this, but it must be connected with the breakdown of large polysaccharide molecules into lower moleculer weight molecules in winter (cf. Halmer and Bewley 1982; Meier and Reid 1982).

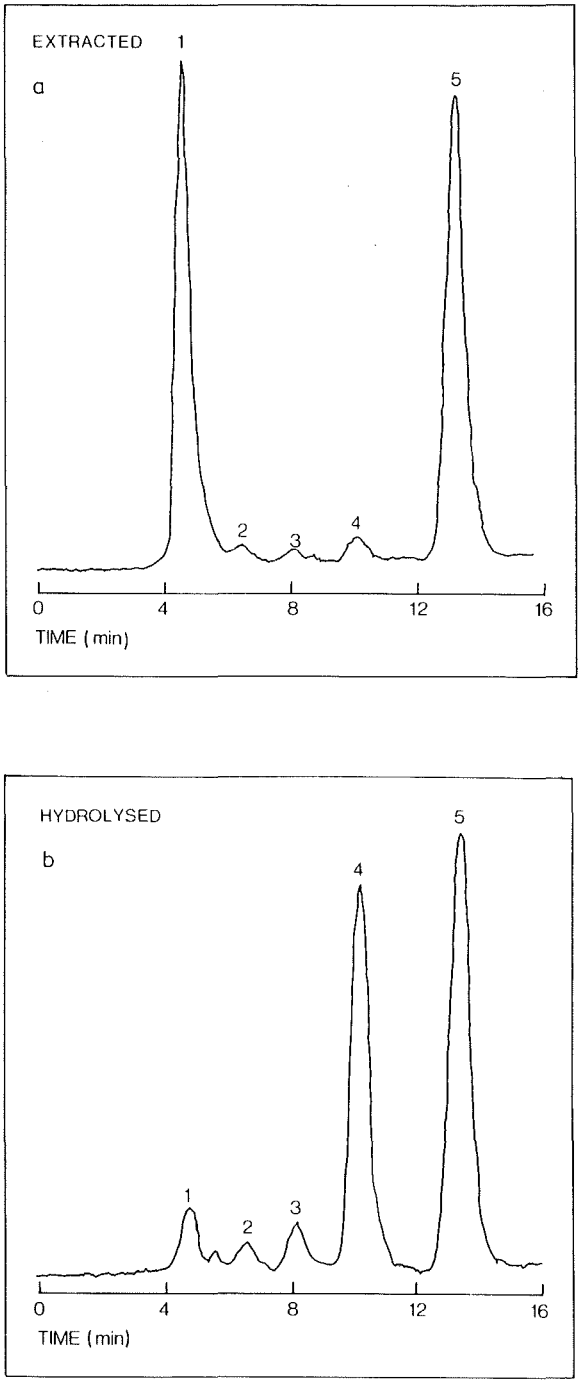


Figure 4: HPLC carbohydrate chromatograms of typical (a) extracted and (b) hydrolysed samples of *C. australis*. Peak identifications are (1) glucofructofuranan in (a) plus TFA in (b), (2) disaccharides, (3) glucose, (4) fructose, (5) mannitol (internal reference).

Not only is the polysaccharide content of cabbage trees lower in the winter, but the stem polysaccharide does not hydrolyse to the same extent as that of summer plants. Stems collected and cooked in the autumn and winter would not be very sweet. If *Cordyline* was ever harvested and cooked at this time of the year, it would not have taken long for Maori to realize the sweetness was not present in the stems. So once again, the results of chemical analysis reveal the rationality of the traditional harvesting season of spring and summer.

PROTEIN

The proximate compositions in Table 2 indicate there is little variation in the amount of protein throughout the year. It is evident protein is only a minor constituent of the root and stem of *C. australis*. The protein levels are comparable to those found in fruit such as apricots, cherries, grapes, oranges, etc. (Osborne and Voogt 1978: 84). The top contains about four times this amount of protein.

LIPIDS

Monthly lipid values for *C. australis* are given in Table 2. The roots and stems contain values comparable to wheat bran and millet grains. The top has about four times this amount. Lipid values are higher than those found in most foods of plant origin with the exception of nuts and seeds (Altman and Dittmer 1968: 82, 85).

There is a significant cyclic seasonal variation of lipids for both stems and roots. I determined this by using equation 4 above and the method described for carbohydrates. The lipid contents reached a maximum during late autumn and winter. This was expected because it has been well established that there is an increase in lipids during plant hardening (Alden and Hermann 1971: 96–102; Levitt 1980: 193–6).

COOKING STUDIES

An indication of the extent of cooking can be obtained by the amount of fructose produced as this is the main hydrolysis product. The fructose results plotted in Figure 5 are relative to the amount of fructose which was obtained by TFA hydrolysis (value = 100%) on an uncooked portion of the same sample. The polysaccharide content was calculated by dividing the polysaccharide amount by the total carbohydrate content and then multiplying by 100.

It required about 24 hours at 100 °C (atmospheric pressure) and 12 hours at 118 °C (pressure cooker) for complete cooking of the January *tī kōuka* root (Figure 5). Free fructose (plus glucose and disaccharide) was found in the uncooked sample (0 hours), and consequently there is less than 100% of the polysaccharides at the start of cooking. Some representative chromatograms upon which these calculations are based are shown in Figure 6. Note the decrease in the polysaccharide peak area and an increase in the glucose and fructose peaks with cooking time.

The above results suggest the cooking time in an earth oven should be between 12 and 24 hours, but added to this is the time required to develop a temperature over 100 °C after the closing of the oven. I found this to be about six hours in the case of an experimental oven (Fankhauser 1982). Given the variables involved in the cooking process, e.g., initial firing temperature, amount of water and effectiveness of sealing the oven, it would take approximately 24 hours to cook cabbage tree stems and roots. This is the time most often indicated in the ethnographic literature. It appears that times mentioned beyond 24

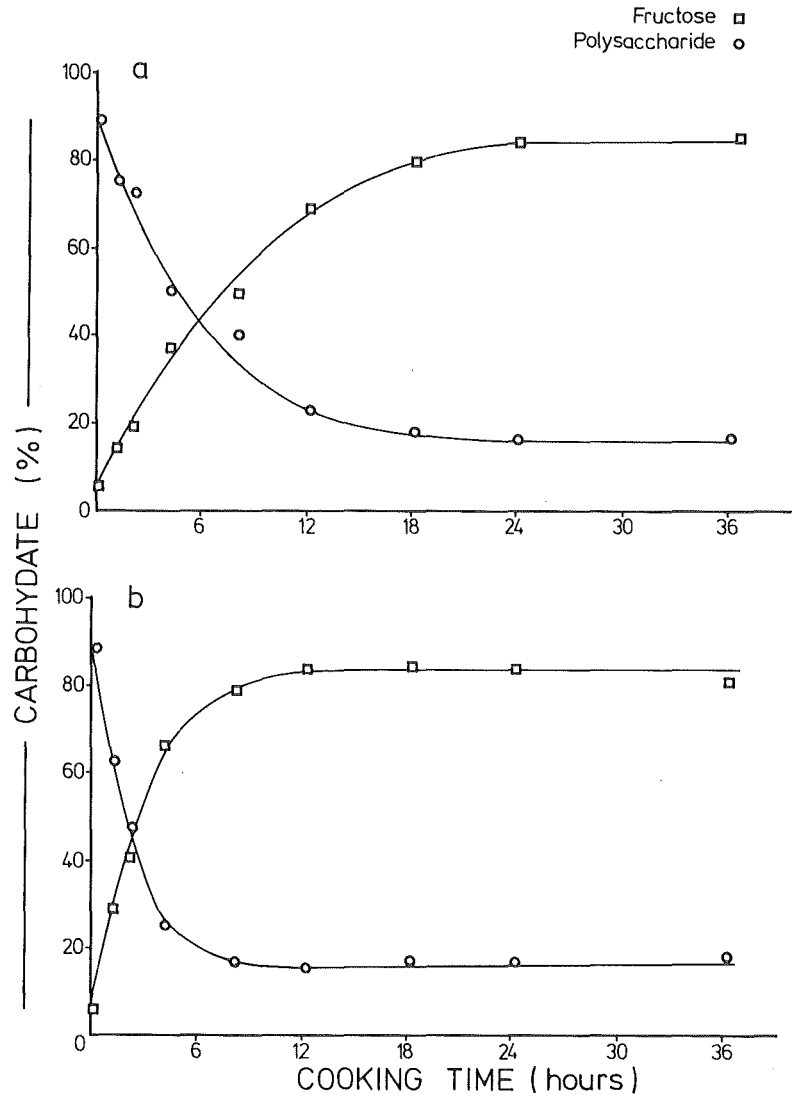


Figure 5: Cooking results for the non-structural polysaccharide from *C. australis* root. Cooked for indicated times at (a) 100°C and (b) 118°C.

hours may be either observers' exaggerations or an effort to be on the "safe side". Best (1976: 271) commenting on James Hay's accounts of cooking *Cordyline* states, "The remark that the ti was left in the oven for many days seems to be an exaggeration."

The results in Figure 5 indicate cooking was not as efficient as dilute acids at completely hydrolysing the glucofructofuranan. This was the case although the medium was acidic (the pH varied from 4.87 to 4.44 for uncooked and 36 hour cooked samples respectively). The effect of incomplete hydrolysis upon cooking would result in a lower nutritive value than that calculated from acid hydrolysed samples. This is because the polysaccharide probably

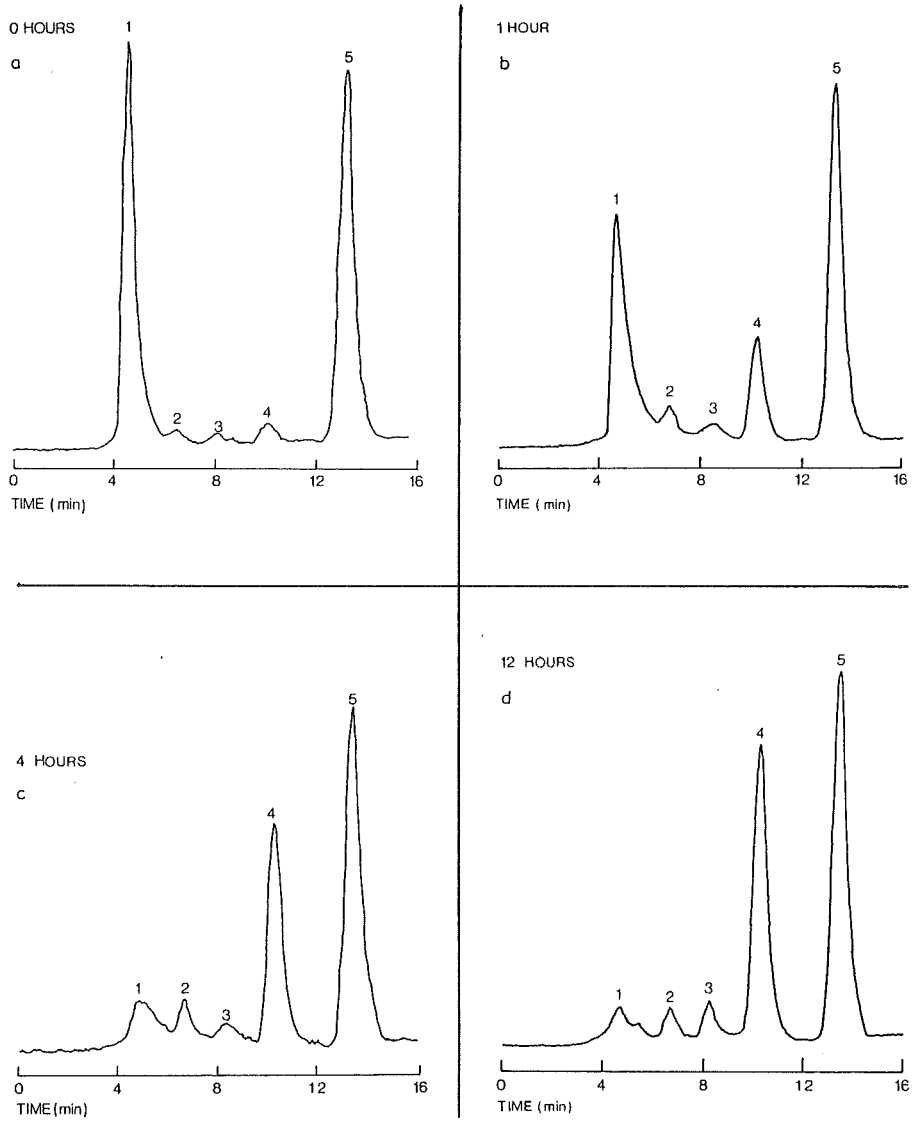


Figure 6: HPLC carbohydrate chromatograms for *C. australis* samples cooked at 118 °C for (a) 0 hours (uncooked), (b) 1 hour, (c) 4 hours and (d) 12 hours. Peak identifications are (1) glucofructofuranan, (2) disaccharides, (3) glucose, (4) fructose and (5) mannitol (internal reference). Note the decrease in peak 1 and the increase in peaks 2, 3 and 4 with cooking time.

cannot be further hydrolysed with available enzymes or HCl in the digestive system. Glucofructofuranans are resistent to hydrolysis by ptyalin and mixtures of α- and β-amylase (Whistler and Smart 1953). The pH of gastric juice in man varies from 1.5–8.4 (Altman and Dittmer 1968: 247) and is unlikely to effect hydrolysis at body temperature (37 °C). I found a solution of 0.05 M HCl at 35 °C resulted in no detectable hydrolysis of *C. australis*

glucofructofuranan after three hours, and the same concentration of HCl took three hours at 55 °C to completely hydrolyse the January polysaccharide.

Therefore, uncooked *Cordyline* would supply no carbohydrate nutrients (except a small amount of free sugars) and would be bland because the polysaccharide itself is not sweet. The sweetness comes mainly from fructose. Fructose in the β-D-fructopyranose form is the sweetest of all sugars. The relative sweetness of selected sugars is shown in Table 4 with sucrose equal to 100. It should be noted the perceived sweetness of fructose is related to its mutarotational behaviour and is therefore dependent upon temperature, concentration, and acidity (Hyvonen and Koivistoinen 1982).

TABLE 4
RELATIVE SWEETNESS OF SOME COMMON SUGARS

Sugar	Relative Sweetness
Fructose	173
Invert sugar	130
Sucrose	100
Glucose	74
Lactose	16

Source: Gaman and Sherrington (1981: 51)

Since the gluctofructofuranan in *C. australis* consists of more than 90% fructose, the cooked (hydrolysed) soluble extract should be very sweet. Brunner (1952: 25–6) commented on this fact in 1847 when he "... found the ti excellent, but rather too sweet for a diet...." Fructose is sweetest in a cold slightly acidic solution. This sweet solution would correspond to dissolving the soluble extract (pH $\approx$ 4.5) from *C. australis* in water; this is one of the ways in which it was prepared by Maori. Besides its greater sweetness, fructose has several other advantages over sucrose as a sweetener including greater water solubility, and a partly insulin-independent metabolism (Pawan 1973).

A syrup made from the root of *C. australis* was found to be extremely sweet and the uses for high fructose syrups and fructose as sweeteners are becoming increasingly more important today (Fankhauser and Brasch 1985). In the mid-1800s cane-sugar replaced *Cordyline* in the Maori diet. It is interesting to see that after more than a century of non-use, sweeteners based on fructose are now important. In fact, 50% of the sugar at present used in the United States is in the form of high-fructose corn syrups (Layman 1987). *Cordyline* has the potential to provide a natural sweetener superior to both sugar-cane and sugar-beet.

As noted in the introduction, moist heat cooking can result in the loss of nutrients through leaching. I investigated this problem by steaming solid pieces of *C. australis* root at 100 °C and then grinding the pieces to give a meal for carbohydrate analysis. The loss of total soluble carbohydrates (mainly polysaccharide) occurred within the first hour of cooking with no change in total carbohydrate for samples cooked for 4 and 12 hours. The carbohydrate loss was 23.8%, but this would certainly represent an upper limit because the experimental samples were small with a large surface area per unit mass as compared to pieces of 60 cm length, which have been recorded as being cooked in earth ovens (Best 1931: 16). Since carbohydrate loss occurred within the first hour, it would not make any difference how long *Cordyline* was cooked for the retention of this nutrient. Micronutrients, vitamins and minerals, are also lost by leaching.

Some ethnographic accounts of *tī* cooking indicate the sugar was caramelized. This caramelization could be interpreted to indicate *Cordyline* was cooked by methods other than steaming because high temperatures generally associated with caramelization could not be reached in a steam oven. In fact, there are occasional references to *Cordyline* being baked (e.g., Brunner 1952: 125; Colenso 1869: 347, 1881: 17). Was *Cordyline* cooked by either steaming or baking or a combination of these methods? There is also the possibility of an earth oven accidentally running out of steam. Would this be detrimental to cooked *tī* and, furthermore, is there any possibility the most successful cooking would have a long steaming time with a baking finish? Answers to these questions can be explored by looking at caramelization and comparisons of cooking *tī* with dry and steam heat.

Caramelization occurs most readily in the absence of water, but sugar solutions (syrups) will caramelize if heated strongly enough to form a sweet brown substance of carbohydrate-like compounds (Gaman and Sherrington 1981). Glucose has been found to form glucosan (1,2-anhydro- α-D-glucose) and levoglucosan (1,6-anhydro- β-D-glucose). Fructose gives levulosan (2,3-anhydro- β-D-fructofuranose). Other products would also be formed (Lee 1975: 179–81). An answer to the caramelization question can be found by looking at the melting points of glucose and fructose which are 146 and 103–105 °C respectively. This compares with a melting point of 170–186 °C for sucrose—high temperatures which we usually associate with caramelization. Caramelized *Cordyline* can be produced since fructose is the main sugar in cooked *Cordyline*, and a temperature well over its melting point can be attained near the ovenstone-matting interface (Fankhauser 1982). An experimental *umu tī* (steam oven) built by Cox (1982) produced cooked roots covered with a brown molasses-like syrup. He found that only roots with a diameter less than 2 cm caramelized. Roots of this diameter have little fibre with a gelatinous substance in them which is presumably rich in carbohydrate and would caramelize easily.

I attempted to bake *C. australis* using dry heat with no success. The pieces of root and stem dried quickly and subsequently charred. This was long before any cooking would have occurred. Similar results were obtained by Cox (1982) who tried to cook *C. terminalis* roots in a propane oven at 200 °C. Even if steam was used initially for cooking, *Cordyline* would be spoiled by the charring effect of dry heat. This is noted by Tikao (Best 1976: 269) in his discussion of *tī* cooking where

> Burned contents of an oven were entirely lost, but the *puna* [oven] of underdone contents were rekindled, though the *kauru* would not be very palatable but would be *puia* [unpalatable, having a smoky taste].

Since dry heat is detrimental to cooking, and caramelization could occur in a steam oven, I conclude that, at least in New Zealand, *tī* was cooked by steaming even though there are occasional references to baking.

NUTRITION

I will now present the nutritive value of *C. australis*. The results in Tables 2 and 3 indicate *Cordyline* contains a high percentage of sugars—more than sugar-cane (average 13%) or sugar-beet (16%). However, before looking at the energy food, the nutrition provided by protein and fat will be presented.

The protein analysis results are presented in Table 2. The protein levels in the cabbage tree root and stem are comparable with those found in fruit and the top contains protein equal to many vegetables (Osborne and Voogt 1978: 84, 87).

The quality of the protein for *C. australis* based on its amino acid composition is slightly higher than that of potatoes and wheat (Fankhauser 1986: 211–4). However, the total protein on a fresh weight basis is only about one-fifth of that in potatoes and cooked wheat as shown in Table 5.

TABLE 5
NUTRITIVE VALUES OF SOME COMMON STARCHY FOODS AND *C. australis* (% OF EDIBLE PORTION)

Food	Water	Ash	Fat	Carbo-hydrate	Fibre	Protein	kcal/ 100g	kJ/ 100g
Sweet Potato (*Ipomoea batatas*) [1]	71.1	0.7	0.2	22.5	1.6	1.4	93	386
Taro (*Colocasia esculenta*) [1]	69.1	0.9	0.1	25.5	1.5	1.1	102	428
Yam (*Dioscorea esculenta*) [1]	74.2	0.8	0.1	19.8	1.2	2.1	84	353
Potato (*Solanum tuberosum*) [2]	79.8	0.9	0.1	17.1	0.5	2.1	76	318
Wheat-cooked (*Triticum aestivum*) [2]	87.7	0.8	0.3	9.4	0.3	1.8	45	188
Cordyline australis [3]								
Root	64.0	0.9	1.4	23.6	10.3	0.4	103	431
Stem	68.3	0.7	1.5	14.9	13.6	0.4	71	297
Top	81.5	1.7	3.2	8.8	4.5	1.4	68	283

Note: Energy calculated from values in Table 1.
1. Values from Bradbury and Holloway (n.d.).
2. Values from Watt and Merrill (1950).
3. Average of November through February analyses.

The top has about four times as much protein as the stem and root. The *C. australis* values in Table 5 are the averages of the November through February proximate analyses on a fresh weight basis. I averaged the analyses from these months because they would most closely represent values of *tī kōuka* as cooked by southern Maori. All values in this table represent the raw foods, i.e., no losses in nutrients from preparation and cooking have been considered. I also present the total kcal and kJ per 100 g of these foods.

It is evident from Table 5 that *Cordyline* is not a good source of protein. To supply a 70 kg adult male with the recommended daily amount of protein, 56 g (Health and Welfare Canada 1976), would require a person to eat an amount of fresh cabbage tree equal to 18.8 kg taking the quality of protein into consideration (assuming no cooking losses). This amount of *tī kōuka* would certainly supply enough fat in the diet ($\approx$ 260 g), but would also supply a total of 19,400 kcal (80.9 MJ) which is more than six times the recommended energy requirement—definitely a calorie overdose!

According to Table 5, the fat content of *C. australis* is several times that of other starchy foods presented. To supply a person with a minimum recommended amount of fat in the diet (1–2% of a 3000 kcal daily requirement) would require about 100–200 g of fresh top or an equal amount of dried root or stem. About half of this amount of winter root would be required because of the higher seasonal amount of lipid. This fat would contain the essential linoleic acid plus other nutritionally important fatty acids. The seeds would be an

even better source of linoleic acid (Morice 1965), but it appears they were not eaten by the Maori.

The total available carbohydrate from the root of *C. australis* (Table 5) is similar to that found in starchy foods commonly forming a basis of nutrition. Of the 103 kcal/100 g (431 J/100 g) for the root, the carbohydrate supplies 86% of the food enery (see Table 1 for energy values). This indicates *tī kōuka* could serve as an important carbohydrate (energy) supply which it most certainly did in southern New Zealand. The only other important available carbohydrate source would have been fern root (Anderson 1982: 50, 63, 1983: 1; Leach 1969: 35; Shawcross 1967).

A more realistic picture of the amount of *C. australis* which would actually furnish energy can be presented by looking at the dry weights. This is due to the fact *Cordyline* must be and was stored dry. Table 6 gives the same cabbage tree analyses as Table 5, but on a dry weight basis.

TABLE 6
NUTRITIVE VALUES OF *C. australis* (% DRY WT)

Part	Ash	Fat	Carbo-hydrate	Fibre	Protein	kcal/ 100 g	kJ/ 100 g
Root	2.4	3.9	65.6	28.4	1.3	286	1197
Stem	2.4	4.7	46.8	43.6	1.4	223	932
Top	9.3	17.0	47.8	24.2	7.2	361	1509

Eating about a kilogram of cooked dry root and stem would supply an adult with the daily requirement of food energy. This would also supply enough fat in the diet. However, this would not supply the minimum amount of protein and this would have to come from other sources such as meat and marine species. Meat from moa was available to southern hunters up until about AD 1500, and marine species were readily available at all times to southern Maori (Anderson 1982, 1983). Houghton (1980) has confirmed that the diet of prehistoric Maori was "generally adequate".

CONCLUSIONS

The main constituent of *C. australis* is nonstructural carbohydrate with a maximum content occurring in the stem during late-spring and summer. I found this maximum to be coincident with the time for harvesting and cooking by Maori as recorded in the ethnographic accounts.

My hydrolysis research indicates the stem could be successfully cooked only during the warmer months. This fact also points to a seasonal harvesting activity.

The polysaccharide consists of fructose and glucose units in a ratio of approximately 15 to 1. The high fructose content made *tī* an excellent sweetener.

C. australis would not be a good protein source, but would help supplement fats in the diet. This is especially true of the top which contains about four times the fat of roots or stems.

All parts of the plant except the developed leaves would have been cooked by steaming for at least 24 hours, and during this time some nutrients would have been lost.

Tī in cooked dry form would have been ideal as a carry-along food for activities such as hunting and travelling where it would have furnished a high energy easily transported food source. There can be little doubt *tī kōuka* served as an important energy source to southern Maori who knew when to harvest and cook it for its maximum food value.

ACKNOWLEDGEMENTS

I thank Foss Leach who was my Ph.d. supervisor for his encouragement and help in this research. He originally conceived this multidisciplinary research project. I also thank Donald Brasch and Patricia Croad for their interest and help in the chemical analysis of *C. australis*.

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