Transforming the inedible to the edible:

An analysis of the nutritional returns from Aboriginal nut processing in Queensland's Wet Tropics

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Abstract

In ethnohistorical records, tree nuts are frequently referred to as important food sources for Aboriginal people in the tropical rainforest region of northeast Queensland. Experimental processing and chemical analyses were undertaken of nuts from yellow walnut (Beilschmiedia bancroftii)*, black walnut* (Endiandra palmerstonii)*, black pine nut* (Sundacarpus amara) *and black bean* (Castanospermum australe)*. Their energy values and potential dietary benefits were analysed through replication experiments that followed traditional Aboriginal processing techniques. Results indicate these species were all high energy-high return food sources. We propose that, despite the relatively intense preparation required, they would have provided an important and reliable source of starchy food within a varied rainforest diet. Findings support the proposal that processed toxic and noxious rainforest nuts may have played a significant role in the late Holocene permanent settlement of the rainforest region and in the development of a unique Aboriginal rainforest culture.*

Introduction

The Aboriginal people of the far northeast Queensland (Qld) rainforest are one of several Australian Indigenous groups known to have incorporated toxic plant species into their diet (Asmussen 2009, 2010; Beck 1985; Beck et al. 1988; Smith 1982). These people developed a complex processing technology to remove bitter and toxic compounds. Indeed, the archaeological record demonstrates that their use of toxic plants extends back at least 1500 years (Cosgrove et al. 2007; Ferrier and Cosgrove 2012) and possibly to 2500 ya (Ferrier 2009; Horsfall and Hall 1990). Historical records and oral traditions further demonstrate that plant foods comprised a significant proportion of the Aboriginal diet at the time of European arrival (Coyyan 1918; Roth 1901; Savage 1989). Rainforest subsistence strategies included the collection, processing and consumption of a large number of toxic rainforest tree nuts, as well as other rainforest plants and animals (Pedley 1993). Complex processing and consumption of such nuts are often described in the ethnohistorical literature and, from this evidence, it has been suggested that toxic tree nuts may have formed a food staple for Aboriginal rainforest people (Harris 1975; Pedley 1993).

Previous studies of the nutritional values of unprocessed tree nuts from four species used historically by Aboriginal people by Harris (1987:365) demonstrated that these substances were rich in starch and protein. However, in an unprocessed state, a high proportion of this starch is resistant to digestion; Aboriginal rainforest people invested considerable energy to increase the amount of digestible carbohydrates in their diet. In order to understand the potential energy costs involved to make these nuts edible, as well as to evaluate their dietary benefits, experimental work was undertaken on modern samples of four species of tree nuts, and chemical analyses undertaken to examine the effectiveness of processing. In the first part of the paper, we present the background, botanical descriptions and methodology used to measure the carbohydrates available at different stages of processing these four nut species.

Most plant food resources require lengthy handling times and have therefore been considered a high cost-low return food option in hunter-gatherer diets (Bright et al. 2002). It is worth considering the reasons behind this notion, particularly as it relates to theories about prey selection and return rates. The optimal foraging model is designed to rank food resources on their optimality, i.e. an optimal resource maximises the energy return of a captured food item (Bird and O'Connell 2006). If the selection of high-energy-return foods by humans can be assumed directly to affect an individual's fitness and reproductive success, foods that produce either an equal or higher return than the energy spent on search and handling time would be a more optimal source of food. Given that toxic plant foods generally involve complex processing, i.e. techniques that require a minimum of half a day to complete (Beck 1985), their preparation time directly impacts upon the energy spent on acquiring them, as well as delays their consumption. As a result, it has been argued that, in order for toxic plants to be a food option, they must provide at least equal or higher energy returns to offset the energy spent in their preparation (Bird and O'Connell 2006). This is examined further below.

Study Area and Environmental Setting

The Wet Tropics Bioregion in far north Qld comprises the largest continuous expanse of tropical rainforest in Australia (Hopkins et al. 1993), covering approximately 12,000 km² (Figure 1). The research presented here focuses on the Atherton and Evelyn Tablelands, ca 900 metres above sea level (m asl), 32 km from the present coastline (Birtles 1997) and separated from the coastal plains by the highest mountains in Qld. Rainfall is seasonal, with most rain falling between January and April.

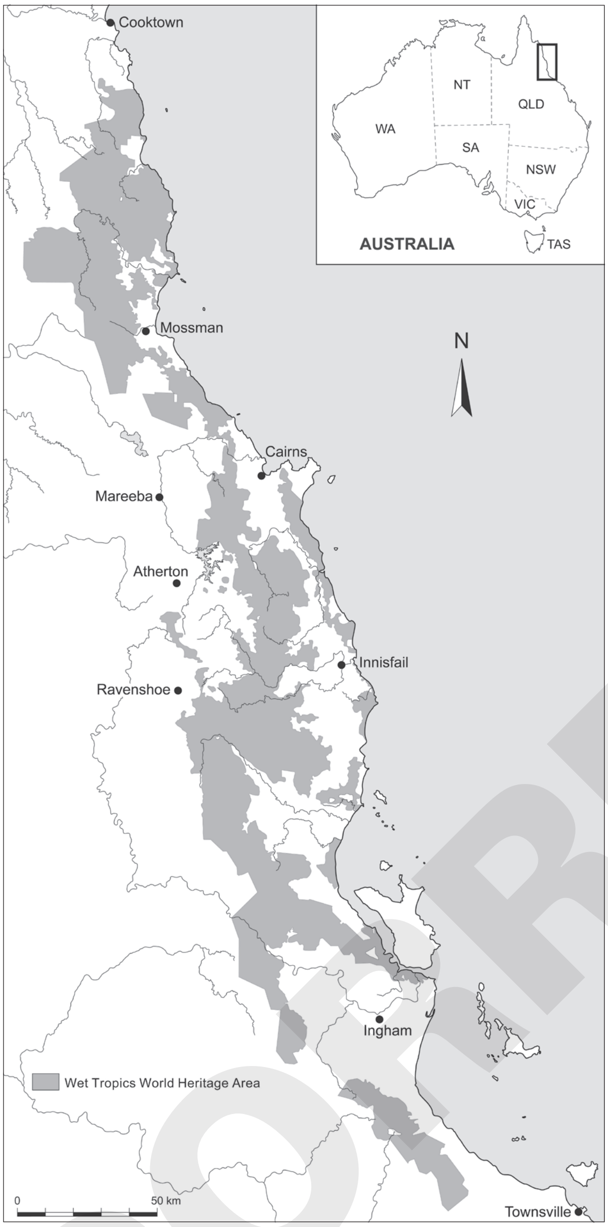

Figure 1 The Wet Tropics World Heritage Area in far north Qld.

There are 13 sub-formations of rainforest and ten types of rainforest with emergent sclerophylls in the Wet Tropics Bioregion. Prior to European settlement, the Tablelands were essentially covered in two types of rainforest: complex mesophyll vine forest in the east and southeast, and complex notophyll vine forests in the west and north (Tracey 1982; Tracey and Webb 1975).

The distribution of yellow and black walnut trees, *Beilschmiedia bancroftii* and *Endiandra palmerstonii*, and black pine trees, *Sundacarpus amara*, are limited to areas of rainforest (Cooper and Cooper 2004; Horsfall 1987). The two walnut trees grow from 0–1300 and 0–1100 m asl, respectively (Cooper and Cooper 2004).

The fruiting period for the yellow walnut tree is approximately August through March, whilst the black walnut tree fruits from September until April. Both the yellow and black walnuts' fruit is a globular-shaped drupe. A hard shell (the endocarp) encapsulates a single seed, ca 34–52 mm diameter for the yellow walnut and ca 30–45 mm diameter for the black walnut, which is enclosed inside the fruit (Cooper and Cooper 2004). The apex and base of the yellow walnut endocarp both have sharp protrusions, while the black walnut endocarp has a single pointed apex at one end.

The black bean tree, *Castanospermum australe*, has a much wider distribution and grows from 0–840 m asl (Cooper and Cooper 2004). It produces large characteristic pods containing 1–5 beans approximately 30–50 mm in length, each one encased in a thin brown skin; these are usually available from March to November.

The black pine tree fruits from December to February and is restricted to altitudes of 600–1200 m asl. The fruit is also drupe-shaped and contains a single spherical seed, ca 20–25 mm in diameter (Cooper and Cooper 2004).

The fruit of the black walnut is eaten by feral pigs and giant white-tailed rats (Cooper and Cooper 2004), while that of the yellow walnut is a favoured food source of cassowaries and bush rats, and sulphur crested cockatoos enjoy the black bean. The black pine nut is also a food source for cassowaries, bush rats and giant white-tailed rats, as well as the fawn-footed melomys (Cooper and Cooper 2004). Nuts that have fallen to the ground are commonly preyed upon by these animals, sometimes leaving only a brief opportunity for people to collect them from the ground intact (Cooper and Cooper 2004).

Previous Research on Aboriginal Rainforest Diets

Mjöberg (1918) described the wide variety of plant foods available within tropical Australian rainforests:

> What adds, more than anything else, to the autumn[1] feeling, is that this is the time of the year when the rainforest fruits fall down from the trees. The ground looks like an orchard after an autumn storm. All sorts of delicious to look at fruit are found – but bitter to taste, competing in numbers and in wonderful colours of yellow, red, green, and blue. Bright red cherries, an inch across, as bitter as gall; plums, which are not plums at all; false apples, oranges, walnuts and chestnuts, which, now and then, drops down through the foliage. This is harvest time for the blacks [sic] who eagerly search out and find the walnut-like fruits of *Cryptocaria bancroftii*. The old women act as beasts of burden. One can see them constantly passing by, carrying their cane baskets, filled with nuts, to be stored and later to be crushed, roasted and thoroughly washed in water, before being eaten.

Jirrbal elder Maisie Barlow (pers. comm. 2004) described the traditional processing techniques as follows:

> When you cook the yellow walnut, they used to bake it, they dig a pit in the ground, put a lot of wet ginger leaves in it, and they put the nuts in that. Then they put a lot of leaves on top and make a fire on top of it. They had to be cooked twice that way. Then a dilly-bag was put in water, you put some fern leaves underneath, make a little funnel so the water goes in to the middle of the dilly-bag and gets all the poisonous sap out of it. The black bean was cooked in a pit as well. Sometimes they lay stones in the bottom first, and

[1] An apparent confusion with the Southern Hemisphere spring.

> they make the fire on top. They open it up and put all the black beans in and cover them over, and lit a small fire on top. The old people used a lot of ginger leaves and paper bark to cook them properly. The nuts give you lots of energy you know, you feel like you are full of beans after eating them. About two dozen nuts would make up a meal for a family of four. Goaj (black walnut) you can grate and mix in a bowl, they used to mix it on a sheet of bark, and then make like a damper out of it. But goaj you can throw straight on the coals and you can eat it straight away.

Historical accounts include descriptions of toxic and non-toxic plants collected and processed, and primarily refer to the use of rainforest tree nuts, which are available for long periods and in large quantities (Horsfall 1987; Pedley 1993). In addition, the high seasonal abundance of nuts was further prolonged by underground storage for use later in the seasonal calendar (Pedley 1992). Ethnohistorical accounts also demonstrate that some of the Aboriginal men were excellent tree climbers (Coyyan 1918; Mjöberg 1913, 1918), a strategy employed to collect new season nuts and fruits directly from the tree canopy, thereby avoiding competition with the cassowary, bush rat and giant white-tailed rat for fallen nuts.

Previous investigations into the Aboriginal rainforest diet have described toxic and noxious rainforest nuts as a staple food source. Harris (1987) argued that fruits and nuts were an important source of carbohydrates, ranking the yellow and black walnuts as primary staples and the black bean and black pine nut as supplementary sources of starchy food. He suggested that Aboriginal rainforest subsistence consisted of a 'specialised, intensive exploitation of high yielding nut-bearing trees supplemented by other plant foods and by fish, birds and a few terrestrial mammals' (Harris 1975:60).

Pedley (1993) attempted to produce a complete nutritional content for plant foods of the southern part of the rainforest region, suggesting a seasonal pattern for the use of some. The black walnut provided a food source from the middle of the cool, dry winter to the end of the wet season. Black beans were collected during the cool, dry winter months, while the yellow walnut was collected and processed during the hot, dry storm season. In the following wet season the much sought after black pine nut was collected.

In the late 1800s, a number of Europeans visiting the rainforest region observed large ceremonial gatherings taking place on the Tablelands in the wet summer months. The historical records describe how many tribes would gather for several weeks in large rainforest clearings and participate in elaborate ceremonies whilst consuming huge quantities of processed tree nuts (Ferrier 2009), many of which had been stored for some period of time (see Pedley 1993).

Overall, previous research into the dietary composition of rainforest tree nuts has demonstrated that, once processed, they provided an important source of carbohydrates, protein and fat (Harris 1975, 1987; Pedley 1993). Studies into the energetic significance of cooking food demonstrate that this process significantly increases the digestibility of foods, further suggesting the value of certain processing techniques (Carmody and Wrangham 2009). Based on these previous studies and historical observations, experimental processing was undertaken on modern samples of the four nut species to identify the quantities of starch and carbohydrates available to Aboriginal rainforest people.

Experimental Processing Methodology

The methodology aimed to replicate, as far as possible, pre-European processing techniques for yellow walnut, black walnut, black pine nut and black bean. The processing techniques were derived from previous studies (Pedley 1992, 1993), as well as from ethnohistorical and Aboriginal oral testimonies from the study area. Only slight variations in the techniques used by different rainforest groups were noted.

Previous comparative studies on economic return rates of plant foods have calculated additional variables, such as transport costs and the amount of time spent in one food-collecting patch (Barlow and Metcalfe 1996). In these studies, this information was gathered from contemporary studies or from extended experiments. Unfortunately, these types of data were not available for the research presented here. It is difficult to gather such behavioural information from modern ethnographic studies with only a few Aboriginal rainforest people still collecting and processing rainforest nuts and, to the best of our knowledge, the practice has vanished on the Tablelands. Secondly, although the existence of pre-European food collecting patches on the Tableland has been recorded in oral history testimonies, the clearing of rainforest for agricultural purposes restricts the undertaking of more detailed experimental studies. However, these limitations are not considered a major drawback in trying to understand the energetic value of toxic and noxious rainforest nuts in the Aboriginal rainforest diet.

For the purpose of the experiments, 2.8 kg of yellow walnut and 2 kg of black bean were processed, while for the black walnut and black pine nut, 0.7 kg and 0.2 kg were used, respectively. The black walnut tree is relatively common but, as mentioned above, feral pigs and white-tailed rats eat black walnuts and, as a result, these are difficult to find intact once fallen to the ground. Black pine nut trees are relatively difficult to find in upland rainforest today. The smaller sample of black pine nuts therefore reflects limited access to these trees, as well as their shorter fruiting period. Aboriginal processing would have involved much greater volumes, but prepared in similar stages and leaching times as recorded in our experiments. The final stage was not required for the noxious black walnut and black pine nut. The methodology described below was used to establish the proportion of edible starch and sugars available at each stage of processing.

Collection

A 10 L bucket each of black walnuts and yellow walnuts was collected from the ground with the fruit (pericarp) still intact in approximately 5 minutes. It took approximately 45 minutes to peel 40 nuts. The black pine required approximately 10 minutes to collect a 10 L bucket of nuts from the ground. As the black bean pods were still attached to the trees, shaking and bumping the trees dislodged the pods to the ground, from where a 10 L bucket was collected in about one minute. Three minutes was required to crack open all of the pods by hitting two together along their longitudinal ridge.

Cooking

A ground oven was dug in compacted soil[2] using a shovel and a mattock, and stones, paperbark, ginger leaves and firewood

[2] Traditionally, the oven would have been dug into sand on a creek bank, which would have made digging swift and easy.

were collected[3]. A fire was then lit on top of the stone-lined ground oven. The black walnut and black pine nut were cooked on the coals of the fire until their shells cracked, approximately 10 and 30 minutes, respectively (Figures 2 and 3). These nuts were then removed from their shells by prising them open or cracking them with a stone. The black walnut can be eaten either without further processing, or by adding water and grinding the paste between two stones, wrapping in leaves and returning to the coals for 10–15 minutes. The black pine nut was similarly prepared after cooking by pulverising it between two stones.

The yellow walnut and black bean were prepared by placing them in a ground oven lined with wet ginger leaves and then covered with another layer of wet ginger leaves, followed by a layer of soil (Figures 4 and 5). The black bean also required a layer of wet paperbark as well as the ginger leaves. A small fire was built on top using the coals from the original fire, which had to be maintained for a total of four hours for the yellow walnut and eight hours for the black bean. Once this step was completed, the yellow walnuts were cracked open using two rocks, the seeds removed, grated, wrapped in fresh ginger leaves and cooked for a further 45 minutes in the ground oven ashes. The black beans were sliced into chip-like segments after cooking.

Leaching

Leaching was the final stage in the processing of the yellow walnut and black bean. Traditionally, the cooked nut meal was placed in a finely woven dilly-bag made from the lawyer cane plant (*Calamus australis*), and securely placed between two rocks in a gently flowing section of a small creek. In the experiments, the grated yellow walnut

Figure 2 Black walnut (*Endiandra palmerstonii*) during cooking (photograph by Richard Cosgrove).

Figure 3 Black pine (*Sundacarpus amara*) after cooking (photograph by Richard Cosgrove).

Figure 4 Yellow walnut (*Beilschmiedia bancroftii*) prior to cooking (photograph by Anna Tuechler).

Figure 5 Black bean (*Castanospermum austral*) during cooking (0.2 kg beans were not able to fit into the oven) (photograph by Richard Cosgrove).

[3] The time spent collecting the equipment for cooking, soaking the paperbark overnight for the black beans and in preparing the ground oven was not considered in the overall energy costs. However, these activities would have been part of what can be described as an 'embedded behavioural pattern' in pre-European Aboriginal rainforest occupation, a concept we return to later.

and sliced black beans were placed in individual make-shift dilly-bags made from linen tea towels and a stainless steel strainer, a method used by Maisie Barlow's grandmother. The yellow walnut was leached overnight with a small quantity of water allowed to filter through the bag, while the black bean was partially submerged in a gentle stream for four days.

Following processing, the yellow walnut had a sandy colour with a texture that resembled sawdust, with no obvious taste. The black bean slices were white and lacked any taste. When eaten, however, they made the mouth feel fresh, as described by Maisie Barlow (pers. comm. 2010), who also commented that 'they look and taste just the same as when I used to process them'. The taste of the black pine nut after roasting was sweet and quite delicious, while the black walnut had a nutty flavour that resembled the taste of a roasted hazelnut. Summaries of the experimental processing are presented in Tables 1–4.

Chemical Analyses

Although other studies have identified the proportions of carbohydrate within unprocessed tree nut species (Harris 1987; Hill and Baird 2003), they have not considered the resistant starch component and therefore the importance of cooking for the conversion of digestible/resistant starch. It has been assumed that cooking and leaching are methods used to remove the toxic and noxious properties of the nuts—we suggest that the most important effect of cooking was the conversion of resistant to digestible starch, although we recognise that leaching probably served to eliminate most toxins and bitter tasting compounds as well.

In order to evaluate the effect of cooking, chemical analyses of the total[4] and resistant starch, and the total sugars were undertaken on samples collected from each of the stages of processing: one in its raw state, one after cooking and one after leaching (only required for the yellow walnut and black bean). Total sugars encompass all sugar types found within a source of food. Starch is the stored carbohydrate in most plants (Cummings and Stephen 2007) and resistant starch is starch that remains undigested in the small intestine (Carmody and Wrangham 2009). The objectives of the chemical analyses were to identify (1) the initial quantities of starch and total sugars, and (2) at what time and stage the nutritional composition changed during processing.

Dried nut samples of 200 g each were sent to the Better Research and Innovation (BRI) laboratory in Sydney, where a megazyme method was used to identify the starch quantities, which converted the starch present into dextrins using the alpha amylase enzyme. The enzyme amyloglucosidase was added to the dextrin to reduce it to glucose, which was then measured spectrophotometrically.

BRI followed the official dietary fibre method to ascertain the proportions of resistant starch (McCleary 2010; McCleary et al. 2010). However, as BRI also considers resistant starch to be a constituent of dietary fibre, the proportions of resistant starch in each nut are actually larger when the two are combined. For yellow walnut total dietary fibre was 34.9%, black bean was ca 6.0% and black walnut contained 37.8% of resistant starch. However, for ease of comparison between our experiments and clarity we have used the total starch and total resistant starch percentages (Table 5) as indicators

[4] Total starch values in this study are inclusive of both digestible and resistant starch.

Stage	Time (minutes unless otherwise stated)	Quantity (kg unless otherwise stated)
Collection of yellow walnuts	6	1 x 10 L bucket
Removing fruit flesh	46	6.4 (with fruit on)
Collection of native ginger leaves	5	N/A
Cooking in oven	4 hours	2.0
Shells cracked and kernels removed	8	2.0
Pulverising	24	0.4
Wrap yellow walnut meal in ginger leaves	40	0.4
Re-cook wrapped in ginger leaves	45	0.4
Leaching	ca 8 hours	0.4
Resembling sawdust, tasteless	12–14 hours	0.4

Table 1 Summary of yellow walnut processing experiments showing stages, times and quantities.

Stage	Time (minutes unless otherwise stated)	Quantity (kg)
Collection of black beans	1	4.4 (with pods)
		2.8 (without pods)
Collection of paper bark (including soaking in water)	ca 8 hours	N/A
Collection of native ginger leaves	5	N/A
Removing seeds from pods	3	1.8 (without pods)
Cooking in the oven	8 hours	1.6* (without pods)
Slicing	10	0.2
Leaching	4 days	0.2

Table 2 Summary of black bean processing experiments showing stages, times and quantities. * 0.2 kg beans were not able to fit into the oven.

Stage	Time (minutes)	Quantity (kg)
Collection	10	0.2
Cooking in the oven	30	
Shells cracked and kernels removed	1	

Table 3 Summary of the black pine nut processing experiments showing stages, times and quantities.

Stage	Time (minutes)	Quantity (kg)
Collection	5	0.7
Cooking in the oven	10	0.6
Shells cracked and kernels removed	4	0.2

Table 4 Summary of black walnut processing experiments showing stages, times and quantities.

of the digestible and indigestible carbohydrates. The sugars were analysed using high performance liquid chromatography (HPLC), which separated the organic compounds, allowing for their identification and measurement.

Results

Tables 5 and 6 show the nutritional composition of the yellow walnut, black bean, black walnut and black pine nut, and demonstrate the effect on the ratio of digestible and resistant starch using these processing techniques. Up to four sugars were identified by BRI in the three species of raw nut samples: yellow walnut contained glucose (0.1%), fructose (0.2%) and maltose (1.4%); black bean contained glucose (<0.1%), fructose (0.2%), maltose (3.7%) and galactose (1.0%); and black walnut contained glucose (<0.1%), fructose (1.0%), maltose (0.1%) and galactose (0.1%). These are combined for ease of reporting in Tables 5 and 6.

Total (%)	Yellow Walnut			Black Bean		
	Raw	Cooked	Leached	Raw	Cooked	Leached
Total Sugars	1.7	1.5	4.0	4.9	4.9	0.3
Total Starch	30.0	51.6	70.8	10.0	31.5	68.0
Resistant Starch	30.0	11.7	7.9	< 1.0	3.2	4.0

Table 5 Total sugars, total starch and resistant starch present at the raw, cooked and leached processing stages, for the yellow walnut and the black bean.

Total (%)	Black Walnut		Black Pine Nut	
	Raw	Cooked	Raw	Cooked
Total Sugars	1.9	3.8	3.1	1.6
Total Starch	42.0	44.6	35.0	61.2
Resistant Starch	36.6	20.1	3.4	5.4

Table 6 Total sugars, total starch and resistant starch present during the raw and cooked processing stages, for the black walnut and the black pine nut.

Results indicate that, throughout processing, the black bean and black pine nut contain only small quantities of resistant starch relative to the digestible and total starches. However, even discounting the percentage of resistant starch from the total starch present, cooking produces dramatic increases in the total amount of starch present in both species. The leaching stage more than doubles the percentage of total starch in the black bean. This is similar to the results of the black walnut and yellow walnut, with marked increases in total starches after cooking, as well as after leaching in the yellow walnut. This is perhaps more significant for these two tree nut species as they contain higher percentages of resistant starch in their raw state, nearly 100% of the total starch present. Analytical results demonstrate that cooking increases the percentage of total starch available, while also decreasing the percentage of resistant starch present. Leaching further increases the total starch available in the black bean and yellow walnut. When considering these nuts as a food source, cooking alone produces almost 40% digestible starch in the yellow walnut and >60% after leaching. Similarly, the black bean after processing produces 64% digestible starch and the black pine nut after cooking contains 55.8% digestible starch. By way of comparison, 100 g of cooked potato have 93% carbohydrate containing 364 Kj of energy, while Hill and Baird (2003) estimated that yellow walnut has 1005 Kj/100 g. Overall, this is a high quantity of available starch and energy return on cooked tree nuts.

The total sugars present in the tree nuts during the stages of processing vary. The black walnut demonstrates a high increase of total sugars after cooking, unlike the yellow walnut and black pine, which both show a decrease. The leaching stage produces a 2.5% increase in total sugars in the yellow walnut, providing a higher quantity of total sugars than in its raw state. The total sugars in the black bean are almost 5% in the raw and cooked stages of processing but decrease by 4.6% after leaching. This supports Wrangham's (2009) suggestion that cooking food will release more digestible energy.

Discussion

The results presented above warrant a consideration of the energy benefits these tree nuts may have had in the Aboriginal rainforest diet, taking into account the high energy costs involved in their preparation. Our results demonstrate that there are large quantities of energy available from these nut species once processed. For the experiments presented here, a ground oven had to be built, and the nut trees and ginger plants had to be located in order to recreate traditional techniques of processing. However, we suggest that these activities were likely to have been part of a permanent rainforest existence created around these and other resources sometime in the late Holocene period, and incorporated into other rainforest activities. Oral traditions, and to some extent the ethnohistorical literature, support this suggestion.

Maisie Barlow described the processing of toxic nuts as a continuous activity, i.e. nuts were continuously being processed at various stages of detoxification. This system would not only have ensured that there was always something to eat, but it also suggests that at least some of the processes involved in the preparation of toxic and noxious plant foods could have been spread across a range of other activities. For example, tree climbing to gather nuts would not only have minimised competition from ground-dwelling animals, but other plants and animals available in the tree tops could be collected at the same time, as well as raw materials to be used in artefact manufacture. The combined evidence demonstrates that the detoxification of nuts was not a singular activity but part of an embedded behavioural pattern associated with social activities and other everyday tasks. This pattern has been observed in other regions of Australia in relation to Aboriginal food processing. For example, the simultaneous undertaking of digging for yams and collecting bush mangos was noted in the Keep River catchment by Head et al. (2002).

Patches of rainforest dominated by one or two food-tree species, such as the yellow walnut and black bean, have been encountered in remote rainforest locations during archaeological surveys; this is a rainforest structure which is not generally considered a natural occurrence in the area (Cosgrove 1996; Ferrier 2009). Single species dominant patches were also observed by Harris (1977) on Cape York Peninsula, where areas of open canopy woodland were found dominated by stands of *Cycad* sp. palms; this was attributed to human manipulation of the area to cultivate a single species as a food resource. Also on the Cape, Hynes and Chase (1982) observed that particular plant communities were not the result of chance or modification but instead associated with resource exploitation, as well as territoriality and locality systems. This behaviour produced groves of fruit or seed bearing trees at particular locations, thereby making access more predictable. One important advantage gained from manipulating food patches is the associated increase in predictability, resulting in a reduction of cost-benefit functions operating on the food source (Dwyer 1988).

There is some evidence for human manipulation of rainforest edges to clear campsites, to promote the growth of yams on the rainforest margins and to assist in wallaby hunting (Hill and Baird 2003; Hill et al. 1999). Frequent reference is made in the ethnohistorical literature to grassy openings within the rainforest being maintained by Aboriginal use of fire and the physical removal of vegetation (Lumholtz 1889:91–92; Savage 1989:78–79, 81, 84–86, 89, 106, 116, 139, 142–143, 146–148, 171–172, 190–191, 193). Although fire was used in the cooler months to maintain cycad patches adjacent to rainforest, burning did not progress into the rainforest because it was too damp and the fire was not 'hot' (Hill et al. 1999). These were strategies employed by Aboriginal people in the past to protect economically important nut trees from fire, and to promote a patchy rainforest structure that increased economic biodiversity within food patches.

It was observed that rainforest nuts, such as walnuts, were collected and cached by Aboriginal people, who would bury them in the ground or stockpile them in camps for later use, for example during large wet season ceremonial gatherings (Coyyan 1918; Harris 1987; Mjöberg 1918; Savage 1989). Whether nuts were accidentally left in the ground or deliberately left to encourage certain food trees to grow in specific locations to create food-patches is not known. However, having established food collecting areas would have allowed Aboriginal rainforest people to schedule their seasonal movements according to the availability of food resources. This supports Pedley's (1993) suggestion of a seasonal pattern for the Aboriginal use of some rainforest plants. Tree climbing for foraging would also have reduced the costs associated with the search for food, and increased predictability and reliability, along with the use of traps to hunt turkeys, wallabies and eels, for example. These, and other subsistence strategies, would have effectively reduced the energy costs involved in the gathering of rainforest tree nuts, which could instead be invested in their preparation.

The prey choice model calculates energy costs against energy benefits in hunter-gatherer societies using variables such as times spent collecting in food patches (Metcalfe and Barlow 1992; O'Connell and Hawkes 1984). Based on the findings presented here, we suggest that the gathering and consumption of some plant foods within a hunter-gatherer subsistence strategy should be considered a high energy endeavour that is not always a labour intensive task with minimal energy returns. Our research suggests that the lengthy processing stages involved in preparing toxic and noxious rainforest tree nuts should be considered energy costs that were spread across a range of other activities. Although the results presented here are preliminary, they suggest that the four tree nut species investigated can be considered high cost-high return economic strategies. In these cases, the relatively high energy costs that are associated with the complex processing activities would have been offset by the energy available from the processed nuts, and from other activities undertaken simultaneously to the processing work. Underpinning this is the observation that nuts are produced in prolific abundance at overlapping times of the year. This may explain to some extent why storage and intensive processing of toxic and noxious nuts was undertaken. Madsen and Schmitt (1998) have argued that, when mass collecting of resources is productive, these become more highly ranked at the expense of previously high ranked prey. There is some debate as to whether other foods and their exploitation are reflections of low-key resources, only taken when seasonally available and when highly ranked foods fall below return rates (Johansen 2013). However, in the northeast Qld rainforest, ethnohistorical evidence and oral testimony suggest that tree nut species were available most of the time, as part of the year round diet, supporting the contention by Harris (1987) that they were significant staple foods, abundant and predictable.

Conclusion

Results from processing experiments on yellow walnut, black walnut, black bean and black pine nut demonstrate that significant energy benefits were gained from their incorporation into the pre-European Aboriginal rainforest diet. The research shows that cooking and leaching release significant amounts of starch available for human consumption and an evaluation of the energy present suggests that these four tree nut species have the ability to provide a substantial proportion of carbohydrates when completely processed. The results support the previous suggestion that these plant foods would have been a staple within a varied rainforest diet, and probably significantly contributed to the success of late Holocene permanent Aboriginal rainforest occupation (Ferrier and Cosgrove 2012).

Rainforest tree nuts such as these clearly provided an important source of starchy food in the Aboriginal rainforest diet, at the same time also providing people with a highly predictable and reliable source of high energy food. Further work on quantifying the amount of carbohydrates produced by nuts per season per individual tree species will provide insights into the strategies of mass collecting and contribution to the rainforest diet. Based on the evidence presented here, one hypothesis that presents itself is that the incorporation of substantial numbers of rainforest tree nuts into the Aboriginal rainforest diet may have laid the foundation for social developments in the region that are manifested in the ethnography as large communal ceremonial gatherings. It supports previous observations about the processing of toxic foods, their dietary contribution and the impetus for permanent occupation of northeast Qld's rainforests (Cosgrove 1996; Cosgrove et al. 2007; Ferrier and Cosgrove 2012). We anticipate that further research will expand on the understanding of how and why these food plants were chosen for consumption by the Aboriginal rainforest people of the Wet Tropics Bioregion.

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