Re-Creating an Aboriginal Earth Oven with Clayey Heating Elements: Experimental Archaeology and Paleodietary Implications

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Earth ovens may relate to different ancestral cooking techniques, serving specific needs and functions. In eastern and south-eastern Australia, they were a significant element of a thriving pre-colonial Aboriginal culture. However, today it is extremely rare to find such structures well preserved.

Based on archaeological and historical records, we re-created an earth oven with clayey heating elements in Jadawadjali Country, central western Victoria, and cooked a culturally significant Aboriginal staple food: the yam daisy or *murnong*. The aims of the experiment were to explore the cooking process and investigate the nutritional implications of using this earthen structure for cooking these tuberous roots.

Nutritional analyses of fresh and cooked samples of *Microseris scapigera* (used in place of the traditional *M. walteri*), reveal that the cooking process does not increase the chemical potential energy, but softens and sweetens the solid matter, perhaps providing a desirable and warm baby food. Detailed carbohydrate analysis revealed that the *M. scapigera* is a good source of prebiotic inulin-type fructans (2.71 g/100 g wet wt).

Introduction

Aboriginal earth ovens may relate to different ancestral cooking techniques, serving specific needs and functions. In south-eastern Australia, different types of heating elements for earth oven cooking have been reported: termite (*Drepanotermes perniger*) nest lumps, baked sediment lumps, calcrete nodules, baked clay lumps, and stones (Clark and Barbetti, 1982, p. 145). Pit-hearths with termite nest lumps or stones present a distinctive stratigraphy (Clark and Barbetti, 1982, p. 149; Rhodes *et al.*, 2009, p. 192), since charcoal and charcoal-stained sediment are found beneath and around the heat-retainers, indicating cooking elements placed on top of blazing wood, and left untouched during the oven set-up, or rearranged as in Polynesian earth ovens (Huebert, Allen and Wallace, 2010, p. 63).

Aboriginal earth ovens with clay heating elements are a distinct type, that should not be confounded with rock-filled pit-hearths (Fanning and Holdaway, 2001, p. 86; Rhodes *et al.* 2009, p. 192). The use of amorphous refractory clayey artefacts within earthen cooking structures was typical of wetland habitats of eastern and south-eastern Australia for processing plant resources difficult to digest, especially during the mid- to late Holocene (Martin, 2011). These heat-retainers were an optimum substitute for stones, in environments where those were not available (Mitchell, 1838, p. 81). Earth ovens with clay heat retainers along the Murray River and in western Victoria have been documented archaeologically (Frankel, 1991, pp. 74-86; 2017, pp. 101-110; Lawler *et al.*, 2015) and there are several accounts of cooking by nineteenth century European observers (Frankel and Major 2014).

One description of an earth oven with clay heating elements is given by Curr (1883, pp. 108-109) who reported Aboriginal women at the earthen mounds on the Murray River valley in northern Victoria using a cooking structure made of 'lumps of clay' lining the base of a hole with a fire lit on top. This differs from some modern reconstructions (Coutts *et al.*, 1979, pp. 4-7) which draw on Beveridge's account (1889, pp. 32-34) reporting 'pieces of clay' fired within a hole already packed with firewood. In both Curr's and Beveridge's accounts, the use of movable clay heating elements is also described, but Curr saw this as secondary to a prepared base, as in the account of Dawson (1881, p. 17) from western Victoria. Nonetheless, it is feasible to suppose that Beveridge may have taken for granted the clay horizon reached by the female cook/digger, over which the earth oven was built.

Mirnyongs or 'native ovens' were typical of the resource-rich, temperate environments of eastern and south-eastern Australia (Chauncy, 1878, p. 232). In this landscape, archaeological investigations recovered an *in situ* Aboriginal earth oven with clayey heating elements at Mill Swamp (Victorian Aboriginal Heritage Register 7224-0248 - Mill Swamp). The site is located at Clear Lake, on the south-eastern backshore of Mill Swamp, north-east of Lake Bow (central western Victoria), and surrounded by eucalypt woodland. In July 2015, test pit excavations revealed a 'squashed' anthropogenic hollow in the sand, with charcoal-stained sediment over and around a lining of baked clay-rich elements. This baked clayey material was extremely fragmentary and interspersed with charcoal pieces toward the centre, occasionally overlaid by detached clay-rich lumps. The physical configuration of Mill Swamp's earth oven, reconstructed based on stratigraphic evidence (Campanelli, 2015), was strikingly similar to the earth oven described by Curr (1883, pp. 108-109) and commonly associated with wetland plant processing, especially of native yam daisy.

The Australian yam daisy, or *murnong*, is one of the most culturally significant Aboriginal staple foods in Victoria. It is identifiable as the genus *Microseris* (Asteraceae: Cichorioideae) and occurs as two species: *M. lanceolata* (Walp.) Sch.Bip. and *M. scapigera* Sch.Bip. (Sneddon, 2015), both producing edible roots. *Microseris lanceolata* (M. sp. 3) is the variety traditionally reported as the Aboriginal staple food, but it has been frequently misnamed as *M. scapigera* (Gott, 1983). For this reason, Walsh (2016) has recently decided to clear the confusion over the past nomenclature by re-naming the variety of *M. lanceolata*: *M. walteri* Gand.

The native yam daisy is rich in water, fibre and carbohydrates, with a negligible proportion of fat and a minimum protein content (Gott, 1986). Carbohydrate analysis conducted on *M. scapigera* just breaking dormancy showed that these roots did not contain any digestible starch, but inulin-type fructans (Gott, 1986). Fructans are soluble short-chain carbohydrates that act as specific stimulators of bacteria with putative health benefits and are classified as *prebiotics* (Roberfroid, 1993, 2007).

In his historical account, Dawson (1881, pp. 19-20) reports that the *muurang* (or *murnong*) is left to cook in ground ovens in the evening for breakfast the following day. Gott (1986, p. 113) hypothesised that the process of cooking *murnong* in earth oven may lead to an increase in simple sugars, which were responsible for the sweeter taste of the cooked roots. The increase in fructose may result from degradation of inulin-type fructans and associated with an improved digestibility of the cooked roots. However, the complete depolymerization of inulin-type fructans is not obvious according to Leach (2009, p. 402), though he related to a different, worldwide hot-rock cooking technology, well-defined by Black and Thoms (2014).

Few experiments have been conducted in Australia to investigate the use of earthen cooking structures and their nutritional implications. A re-construction undertaken almost 40 years ago did not succeed in reaching the intended firing temperatures (Coutts, Henderson and Fullagar 1979, pp. 69-70), possibly due to the wrong ratio of diameter: depth of the fire pit. Elsewhere in Australia, field simulation has been used to analyse the energy return of processed plant foods (Tuechler, Ferrier and Cosgrove 2014), but no details were given about the size of the cooking structure, and temperature control, when performed, was not reported. Little attention has generally been paid to cooking temperatures, making some open-air experiences difficult to compare (e.g. Garvey, 2017, p. 7).

In this study, we re-created the earth oven with clay heating elements and cooked yam daisy roots with the aim of understanding the technological function of this underground cooking structure and its nutritional and socio-economic implications. The archaeological experiment was designed based on the information retrieved from historical records, describing the cooking technology from eastern and south-eastern Aboriginal Australia associated with the yam daisy processing, and from the physical configuration of Mill Swamp's earth oven, reconstructed from the stratigraphic evidence.

We set the following conditions:

1. maintain the proportions of the earth oven re-constructed on archaeological basis, regardless of the quantity of food processed;
2. produce clayey heating elements able to survive intact through the cooking process;
3. reach the maximum firing temperatures to allow the longest cooking time;
4. follow the earth-oven assembling steps reported in historical accounts.

Materials and Methods

Traditional implements were used during the earth oven re-creation. For instance, paperbark was used for mixing and moulding during clayey ball preparation, and digging sticks for excavating the pit and moving the embers. Only in one instance, a pair of metal barbecue tongs was used to rearrange the movable heat-retainers in place of wooden stick pieces (Beveridge, 1889, p. 33), as those were considered unsafe.

The food: *Microseris scapigera* roots

The *murnong* has been drastically reduced by the impact of cattle and sheep grazing (Cahir, 2012, pp. 34-35), and it is no longer available in quantities that would have allowed food harvesting for the purpose of this experiment. In contrast, *M. scapigera* (G.Forst.) Sch.Bip. seedlings are common in Indigenous plant nurseries and are available for home cultivation.

The roots of *M. scapigera*, grown in a domestic garden patch in Corio, Victoria, were used for this experiment. *M. scapigera* is a perennial herb, developing 1-3 tapered roots, up to 2 g each, and about 6 cm long during the mid-spring flowering to early seeding period (for more information refer to Sneddon, 2015, p. 127; Walsh, 2016). Cultivated specimens were personally observed flowering in April-June and August-October 2015, but, following historical ethnography (Gott, 1983, p. 10), it was chosen to harvest the tuberous roots (22 October 2015) and conduct the experiment during the spring flowering season. Each plant had an average weight of 4 g of fresh food.

Clayey ball preparation

Preliminary to the earth oven re-creation, the proportion of clay and sand for preparing the heat-retainers was estimated via laboratory tests at the Department of Archaeology, La Trobe University, Melbourne. Seven clayey balls were manufactured using sterile clay sampled from underneath the earth oven at Mill Swamp and sand, sieved through a 2-mm mesh, collected from a disturbed surface uphill at the same location. Following the experiment by Coutts and colleagues (1979, pp. 70, 109-110), who suggested the use of sand as temper in quantities from 10% to 60%, the seven clayey balls were produced containing 0%, 10%, 20%, 30%, 40%, 50%, and 60% of sand, respectively. They were made over a 2-hour period and left to rest for an extra 30 minutes, then placed in alumina crucibles and heated to 550°C in a Thermo Scientific M110 muffle furnace for approximately 2 hours. After cooling, the clayey balls were held with both hands and pulled apart, with a firm pressure. The lumps with 0%, 10%, 20%, and 30% of sand fractured under pressure. The lumps with 40% and 50% of sand did not fracture, while that with 60% of temper presented a crumbling surface. As a result, a proportion of 40% sand and 60% clay was considered appropriate for the preparation of the heat-retainers at the earth oven re-creation.

During the earth-oven experiment, two hundred and nineteen heat-retainers were made from about 26 kg of sand and 39 kg of clay, sourced from the nearby stranded river channel. Each heat-retainer was about 300 g in weight: 120 g sand (40%) and 180 g clay (60%). They were shaped into balls, but, based on archaeological field observations, a regular shape or size seems not to have been important. The heat-retainers were formed by holding a lump of clay and sand in one hand and contributing to the maximum compression with both hands, turning the lump several times. This allows for the reduction of the voids and, therefore, of the water trapped inside.

The location

On the 23rd and 24th of October 2015, the Barengi Gadjin Land Council Aboriginal Corporation, which represents the Traditional Owners of the Jadawadjali language group (Jardwadjali in the literature) (Clark 1990, pp. 236-274), hosted a public event of experimental archaeology and cultural revival on the banks of the Wimmera River, in Haven, south-west of Horsham, Victoria (See Figure 1).

The venue, immediately north of the place *Wopert-Bungundilar* ('House of Feathers') (Smyth, 1878, p. 177), where the giant emu *Tchingal* was finally killed by the *Bram-bam-bult* brothers during the 'Dreamtime' (Isaacs, 1980, pp. 17-18), offered a unique opportunity to perform in a traditional setting what had been preliminarily tested in the laboratory and observed in the field. We had to adapt to a riverine environment, slightly different from the setting at Mill Swamp, located 36 km to the south-west, where the loose sand would have made the excavation easier even with bare hands.

The river banks of the Wimmera River, overgrown with reeds and surrounded by eucalypt woodland, are coated with a firm rooted silty sand, scattered with vegetation litter and fallen hardwood branches. The area contains a remnant indigenous over-storey of dominant yellow box (*Eucalyptus melliodora*), yellow gum (*E. leucoxylon*), grey box (*E. microcarpa*) and red gum (*E. camaldulensis*). The source of the clay and sand for making the heat retainers was a stranded river channel, about 40 m north-east of the experimental earth oven location.

The earth oven re-creation

A pit was dug in a riverine soil using wooden sticks (~40 mm thickness and less than 1 m length) to replicate the digging tools traditionally used by Aboriginal women. The pit was sub-oval in shape, measuring 1.20 x 1.50 m in extent, with a base of 0.80 x 1.00 m and a depth of 0.25 m. The inclination and solidity of the pit's sides led us to line only the base of the pit with clayey balls, while we would have packed the whole concavity, if the pit was dug in loose sand. The rest of the clayey balls were placed to dry on the ledge of the fire pit for 20 minutes (See Figure 2, a). Overall, the set-up of the earth-oven took approximately 30 minutes.

The fire was built gradually, from small sticks and pieces of stringy bark, kindled with an ember in a dry-grass bundle, held with a piece of thin bark (See Figure 3, b). Hardwood branches were added slowly and incrementally, along with small quantities of dry grass. Firewood was collected on the ground and selected for its size (diameter under 10 cm), regardless of its weight.

After 40 minutes, the fire was intense (See Figure 2, b). At the base of the pit, the 148 clayey balls had become the steady bottom of the pit-hearth (See Figure 2, c). In addition, the 71 heat-retainers, originally left to dry on the pit's ledge, were placed on the glowing embers (See Figure 2, d). The hearth was then fuelled for another 20 minutes, using also paper bark and stringy bark (See Figure 2, e).

Subsequently, the cooking structure was cleared, that is to say the movable clayey balls were placed on the pit's ledge and the abundant coals were scooped on one side, exposing the hot basal surface (See Figure 2, f). The base was overlaid with wet reeds of *Carex tereticaulis* (see Gott 2008, p. 221), after Bonwick (1858, p. 184), to accommodate 296 g of edible roots of *Microseris scapigera* (Figure 3, c), and then covered with more wet reeds (See Figure 2, g). The roots were processed wet as reported by Dawson (1881, p. 20). The hot clay balls from the ledge were placed on top of the reeds (See Figure 3, d), and the hot coals were spread over and around the pit-hearth (See Figure 2, h). Finally, large sheets of stringy bark (See Figure 3, e and Figure 2, h), followed by sand, were used to seal the ground oven (See Figure 2, j). The roots of *Microseris scapigera* were left to cook overnight.

The cooking technique

The cooking technique adopted utilises the heat radiating from baked clayey elements and residual embers, placed above and below the edible roots, along with added steam/moisture that helps reduce the drying and shrinking of the vegetables. The heat is also expected to be transferred by conduction inside the watery roots (Brown, 2014, pp. 103-106).

Data recording

The experiment was recorded using photos and video. Firing and cooking temperatures were monitored using two CENTER 309 data-logger thermometers (k type) with four input channels. Four thermocouples (#1, #2, #3, #4) were placed on top of the heat-retainers lining the bottom of the pit-hearth, recording every two minutes for 22 hours (See Figure 3, b). Two thermocouples (#5, #6) were positioned between the two layers of wet reeds, on the two sides of the food pile, recording every two minutes for 18.5 hours (See Figure 3, c).

pH tests

The pH of the raw materials was measured using a commercial soil pH test kit or Litmus paper test strips.

Sampling of *Microseris* roots

The roots were harvested on the 22nd of October 2015 (See Figure 3, a) and cooked the next day. A subsample (155 g) of raw roots was rinsed, drained, and posted in a thermally insulated bag to the laboratory at the Central Clinical School, Monash University, Melbourne. A subsample (112 g) of cooked roots was washed, drained, and kept refrigerated after cooling, then handed to the same facility in a thermally insulated bag with ice packs on the 26th of October 2015.

Measurement of short-chain carbohydrates and nutritional profile of *Microseris* roots

The raw sample of *Microseris scapigera* was washed, drained, and frozen. On the next day, the frozen sample was freeze-dried for approximately 3-6 days. The freeze-dried sample was then ground and analysed as per standard operating procedures. Weights of the sample before and after freeze-drying were recorded for conversion of results from g/100 g on dry sample basis to g/100 g on original sample basis. The cooked sample of *Microseris scapigera* was treated as supplied and analysed following the same method.

Total fructan content was measured enzymatically using a commercially available assay kit (Megazyme Fructan HK Assay Kit, Megazyme International Ireland Ltd, Wicklow, Ireland; a modification of AOAC Method 999.03 and AACC Method 32.32) as described in Muir *et al.* (2007). Total starch was also assessed enzymatically using kits (Megazyme Total Starch Assay Kit, Megazyme International Ireland Ltd, Wicklow, Ireland). Sugars, including glucose, sucrose, fructose, lactose, sugar polyols (mannitol, sorbitol) and oligosaccharides (galacto-oligosaccharides - GOS, raffinose, stachyose) were separated using a combination of High Pressure Liquid Chromatography (HPLC) using an ELSD (ELSD Waters 2424, HPLC Pump Waters 515, Waters Autosampler 717 Plus and a Waters Column Heater) and Ultrahigh Pressure Liquid Chromatography (UPLC) with Ethylene Bridge Hybrid (BEH) Amide column as described in detail elsewhere (Halmos *et al.*, 2016; Muir *et al.*, 2009).
The nutritional profile (protein fat, dietary fibre, energy, ash and moisture content) was carried out by AEGIC Sydney Analytical Services (Riverside Corporate Park, North Ryde, NSW, 2113) using standard AOAC approved techniques.

Results and Discussion

pH tests

The sand, with a pH of 5.0, was the most acidic of the raw materials, slightly more than the clay (pH 5.5). Tap water, added to mould the heat-retainers with a spray bottle, had a pH of 6.0, similar to that of the river water used to soak the local reeds (pH 5.0-6.0). The raw roots of *Microseris scapigera* had a pH of 6.0 after soaking in tap water for 3 minutes.

Clayey heating elements

More than 97% of the clayey heating elements survived the cooking process intact (See Figure 3, f). Our experience leads us to suggest that the optimal percentage of sand for heat-retainer preparation is 40-50%, provided that the clay exhibits good plasticity and enough moisture as it is, when extracted from the ground, without being separated from its organic or inorganic inclusions. We can hypothesise that tempered lumps, to be moulded, may have been naturally obtained from where a diffuse interface between a clay substratum and a sand deposit was found, in stagnant water.

The earth oven cooking

The firing and cooking temperatures are provided in Figure 4.

The fire was started at 11:54 am (23 October 2015) and built up over 40 minutes. The firing temperature, recorded by thermocouples #1, #2, #3, and #4, placed on top of the heat-retainers lining the bottom of the pit-hearth, went from a minimum of 42°C (#4) to a maximum of 729°C (#4). The average temperature after approximately 40 mins of firing was 602±68°C (#1, #2, #3, #4).

After the movable heat-retainers were placed on the glowing embers, the fire was fuelled for approximately 20 minutes. Over this time period, the firing temperature ranged from a minimum of 497°C (#1) to a maximum of 702°C (#2). The firing temperature slightly decreased, ranging between 244°C (#2) and 667°C (#4), while the base of the oven was exposed, the food placed in the oven, protected by wet reeds and covered by hot heat-retainers and coals, and the oven was eventually sealed with sheets of stringy bark and sand.

The cooking process lasted for more than 18 hours, from 1:42 pm (23 October 2015) to 7:56 am (24 October 2015), and the environmental temperature ranged between 3 and 20°C. At the beginning of the cooking process, the thermocouples at the base of the oven recorded a mean temperature of 323±76°C (#1, #2, #3, #4), whereas those positioned at the side of the food, between the two layers of wet reeds, recorded a cooking temperature averaging around 96±2°C (#5, #6). During the overnight cooking, the cooking temperature, recorded by thermocouples #5 and #6, reached a peak of 98°C and 154°C, and then slowly decreased to 39°C and 37°C (after approximately 18 hours).

At the end of the 18-hour cooking process (See Figure 3, g-h), the crunchy and bitter roots of *Microseris scapigera* had become soft, almost creamy, and palatable, with a particular sweet-smoky smell and a nutty taste, and fairly moist and warm. Some sand and charcoal residues were found in the food that required to be rinsed with water prior to consumption. For this reason, we agree with what is suggested by Beveridge (1889, pp. 33-34) that the ashes, along with the embers, should not be associated with the movable heating elements. This would probably make the oven-building easier to handle, lowering also the cooking temperatures, and reducing the risk of drying the vegetables too quickly. In fact, at the end of the cooking process the reed cover was dry, and burnt toward the outside, but it had successfully protected the food in the centre, which retained its own moisture.

Nutritional analyses of *Microseris* roots and socio-economic implications

Tables 1 and 2 show the results of the nutritional analyses of raw and cooked tubers of *Microseris scapigera*.

Sample	Moisture (%)	Wet wt/ dry wt ratio	Protein	Fat	Carbohydrate	Dietary Fibre	Energy (kJ/100 g)	Ash
R15/00077 (raw)	88.08	8.39						
- g/100 g wet wt			3.05	0.39	3.35	3.28	150.14	0.75
- g/100 g dry wt			27.50	3.30	28.10	27.50	1260.00	6.30
R15/00078 (cooked)	84.41	6.41						

- g/100 g wet wt			3.45	0.53	4.93	4.41	196.48	0.94
- g/100 g dry wt			22.10	3.40	31.60	28.30	1260.00	6.00

Table 1. Moisture content and macronutrient results (% basis) for *Microseris scapigera*

Sample	Starch	Glucose	Fructose	Sucrose	Lactose	Polyols	GOS	Fructan
R15/00077 (raw)								
- g/100 g wet wt	0.39	0.00	0.23	0.14	0.00	0.00	0.02	2.71
- g/100 g dry wt	3.25	0.00	1.90	1.19	0.00	0.00	0.11	22.76
R15/00078 (cooked)								
- g/100 g wet wt	0.51	0.00	0.27	0.18	0.00	0.00	0.04	3.62
- g/100 g dry wt	3.25	0.00	1.74	1.12	0.00	0.00	0.24	23.21

Table 2. Starch, sugars and oligosaccharides (g/100 g) for *Microseris scapigera*

In the fresh sample (See Table 1), the percentage of moisture (88.1%) is higher than what previously observed (Gott, 1986, p. 112). Carbohydrate (3.4 g/100g), fibre (3.3 g/100g), and protein (3.1 g/100g) are respectively the major nutrients. The quantity of starch is limited (0.4 g/100g) (See Table 2), though not nil as reported in Gott (1986, p. 112). This may be due to the different and more sensitive analytical methods used in this study or to the different harvesting period.

After cooking, the edible roots exhibit a significant variation in the protein and carbohydrate content, presumably due to Maillard reaction (Van Boekel, 2006) and caramelisation (Kroh, 1994) (See Tables 1-2). It is worth stressing that the results relating to the cooked sample on wet weight basis represent food that has been rinsed after cooking. On dry basis, there is no trackable increase in simple sugars, nor in the chemical potential energy of the cooked food (See Tables 1-2).

Interestingly, the fructan and galacto-oligosaccharide (GOS) content is slightly increased by the cooking process, both on dry and wet basis (See Table 2). These prebiotic carbohydrates are of the extreme importance for humans because they stimulate growth and metabolic activity of intestinal bacteria contributing to a healthy body. This is because prebiotic carbohydrates cannot be digested by enzymes or absorbed across the small intestine, but are transported to the bowel where they undergo hydrolysis and fermentation by colonic microflora. This process produces short-chain fatty acids and lactic acid, among other products, which are an important source of energy for the human body and stimulate the immune system (Leach, 2007; Roberfroid, 2005).

Hunter-gatherers have likely included in their diet prebiotic foods such as tuberous roots (Leach, 2007). When subjected to a heating process, the long chains of inulin-type fructans may partially degrade into more digestible short chains (Leach, 2009). With respect to our earth-oven experiment, the cooking process induced little depolymerisation of the fructans, an improvement in the texture of the roots of *Microseris scapigera*, and an increase in the content of oligosaccharides, that was probably responsible for the sweetness of the cooked tubers. Altogether, the processing of *murnong* through earth-oven cooking produced a food plausibly more digestible and palatable.

We know that yam daisies were also eaten raw (Gott, 1983, p. 9), but perhaps a need for feeding the weanlings left behind (Marlowe, 2010, pp. 104-105) may explain the labour-intensive practice that, as shown by the results of our experiment, does not seem to serve any culinary purpose other than softening and sweetening a low-ranked, easily obtainable food (Gott, 2008, p. 216; Marlowe and Berbesque, 2009). Nonetheless, cooking may have increased the demand for the otherwise low-energy-density food. If our speculation is correct, the preparation of desirable and warm baby food, rich in prebiotics (Wang, 2009), may have contributed in shaping the tradition of *murnong* as a staple food and become central part of traditional Aboriginal life (Cahir, 2012). Historical records (Mitchell, 1838) report that on 10 August 1836, in the open grasslands of the Glenelg River valley, in the south-western Jadawadjali language area, Major Sir Thomas Livingstone Mitchell met an Aboriginal woman carrying an infant on her back, firewood and fresh yam daisy roots in a rush basket, burning pieces of bark in the left hand, and a digging stick in the right (Mitchell, 1838, pp. 209-210, Plate 44). Apparently, the woman had just harvested the roots, not far from the base camp, and she was going to start a fire to process the food, which was considered by Mitchell “the food of the native women and children” (Mitchell, 1838, p. 270).

Conclusion

In this study, we have successfully replicated an ancient cooking technology in order to analyse its effects on a traditional staple food from the eastern and south-eastern Aboriginal Australia. The archaeological evidence has been used as a point of reference for re-creating the physical configuration of the fire pit, having a diameter to depth ratio of 5-6, and for producing durable heating elements, consisting of 40% sand and 60% clay. Historical records have provided information about the traditional steps of earth-oven set-up and cooking.

During the experiment, we observed that:

1. the clay-rich raw material used for moulding heat-retainers may be naturally available in stagnant water;
2. fallen hardwood branches with small cross-sections and lightweight may be a perfect wood fuel;
3. the smouldering pit-hearth can be closely approached up to a temperature of circa 600°C;
4. coals should be completely removed from the base of the fire pit before the earth oven set-up, and not combined with the movable heat-retainers on the top.

At the end of the experiment, when the earth oven was emptied, we assessed that the basal heat-retainers at the centre of the fire pit were highly degraded, infilled and surrounded by most charcoal pieces. This stratigraphic record is consistent with the archaeological evidence at Mill Swamp.

Through experimental archaeology, we have proven that setting-up an earth oven with clayey heating elements is an activity that can be performed in a quick and safe way, even with the collaboration of unskilled individuals. The time required to make refractory and durable clayey balls may depend on experience, but it takes only two firing steps of circa 30 minutes each to prepare a cooking device able to slow-bake unattended tuberous roots overnight (for at least 12 hours). The use of clay-rich heating elements permits control over the cooking temperatures. Once the food has been inserted into the earth oven and the oven sealed, the temperatures reached a peak at 154°C (cooking temperature) and 416°C (firing temperature) and then slowly decreased to, respectively, 37°C and 33°C (after approximately 18 hours).

The process of cooking the roots of *Microseris scapigera* in the earth oven gives a desirable taste and texture to the food, enhancing its flavour, although it may not increase the chemical potential energy of the roots. We may infer that *murnong* was a significant part of the traditional Aboriginal life, especially of women and children, being a desirable and warm food, rich in prebiotics, and suitable for the weanlings.

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