PROGRESS ON THE CHEMICAL TYPING OF SELECTED PACIFIC CULTIGENS

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This paper presents a summary of progress to date of my work on the use of chemical techniques to identify organic residues on sherds of prehistoric Pacific pottery. In particular, I have been trying to identify the chemical signatures of certain Pacific cultigens, in order to assist in an understanding of prehistoric economies and plant transfers. The potential of studying chemical traces on pottery in order to establish the presences of plant or animal materials has been accepted for some time (Morgan et al. 1973; Evans and Biek 1976; Rottlander and Hartke 1982). The possible results of decomposition and contamination have been outlined and the ability of the vesicular fabric of pottery to retain chemical traces has also been well established (Rottlander and Schichtherle 1979; Allan 1984).

As there existed no previously established chemical standards for the cultigens in question - banana, rice, sago, sweet potato, taro and yam, - 45 plant samples of these six cultigens were extracted and analyzed using infrared and ultraviolet (Hill and Evans 1988b). These results appear in Figure 1 for infrared (IR), and Figure 2 for ultraviolet (UV). To produce the standards, at least half a dozen modern samples of each plant were used. Each sample was then crushed and placed in a "thimble", this being a cellulose tube neutral to the chemical process (Hill 1988).

The laboratory techniques followed for each sample are as follows. The thimble containing the sample is placed in a "soxhlet" apparatus (a circulating system made of glass) in which a solvent is heated. The heated solvent rises through the apparatus, condenses, and then passes back down through the thimble to the flask of solvent at the bottom. This continues for about four hours after which the flask containing the solvent and the extract of the residue is cooled.

Four different solvents can be used, and hence four separate extractions take place for each plant sample (Evans and Hill 1982). These solvents are heptane, chloroform, 2-propanol and distilled water. This group of solvents is used for several reasons. Most materials will be selectively extracted by them, and they are all particularly useful for subsequent tests such as High Performance Liquid Chromatography (HPLC). Heptane tends to extract any polar lipids, triglycerides and waxes present; chloroform separates out any resins, drying oils and wood tars; 2-propanol separates phospho lipids, sugars, amino acids and proteins; and distilled water separates polar lipids, salts, sugars and carbohydrates.

The sample extract is then evaporated on to a small potassium bromide disk (which is neutral to infrared), where it can be examined by a twin beam infrared spectrometer. A twin beam system allows the comparison of a reference potassium bromide disk on to which some of the solvent used on the current sample has been evaporated, and the sample disk which contains the solvent plus whatever has been extracted. The result is that the spectrometer will only identify the difference between the two disks, which can only be that which has been extracted from the organic residue sample.

As there were no consistent variations in wavelength occurrences between heptane, chloroform and propanol extracts, the investigation concentrated on obtaining a full range of heptane extracts processed over the 45 plant samples obtained. For the reader unfamiliar with chemistry, the IR chart (Figure 1) should show fairly clearly that there do appear to be significant groupings of wavelength occurrences related to each of the six plants analyzed. For some wavelengths, such as 1720 cm-1 for sago, 1370 cm-1 for rice, and 1100 and 900 cm-1 for taro, there are almost no other occurrences for the other plants analyzed. For other wavelengths, such as 1740 and 1710 cm-1 for rice, there are other occurrences for other plants under study, but none of these have both wavelengths as strongly as the very large rice peaks.

Rice has proved the most clear-cut of the six plants on IR, and it is most fortunate that this plant provided the sample group I first began with in 1982 (Hill 1984). If it had not been so decisive, I may not have persisted with this approach. None of the other five plants have proved quite so specific, but wavelength combinations of size, or overall peak patterns and areas of peaks, have nevertheless helped to produce fairly distinctive differences in appearance between the plants.

The UV chart, however, indicates that these results have been less consistent, with some wavelengths not appearing to be detected, thereby reducing confidence in the possible use of UV for the screening process. It is not, for instance, able to differentiate between sweet potato and taro at this level. However, the 266 wavelength appears to be common to all three root crops analyzed.

Chemical analysis has also been used successfully on occasion to make specific identifications of food and food sources from archaeological ceramics (Needham and Evans 1987). Work has now begun using HPLC (High Performance Liquid Chromatography), a far more sensitive technique, to analyze plant samples for the presence of lipids. Lipids can be broken into three main groups; simple lipids (fats and waxes), compound lipids (such as triglycerides), and derived lipoids (mainly fatty acids, alcohols and sterols) (Christie 1988). By using HPLC, the components of chemical residues can be identified and a possible third way found of establishing a standard for each of the six plants studied. HPLC standards will also confirm whether IR or UV is more accurate in distinguishing between them.

This is the only area where work has already been carried out on chemical analysis of the nutritional value of some common foods (Paul and Southgate 1978).

In the near future, work will proceed with analyzing samples of other useful Pacific cultigens such as coconut, breadfruit, Polynesian arrowroot and Pueraria lobata, in order to produce a wider range of useful plant standards. In the meantime, to test the application of the screening methods described here, potsherd residues from several sites in the Pacific have been processed by IR and UV in the same way as the plant samples. An example of the potential usefulness of this approach is work carried out recently on samples from Rungruw on Yap Island in the Carolines (Table 1). The results of the infrared analysis appear in Figure 3, and ultraviolet in Figure 4.

Table 1. Sherd samples from Rungruw, Yap Island, Micronesia.

Test Nos.	Date	Pottery Type
Y1HA	2150 B.P.	Calcareous sand tempered
Y2HA	2150 B.P.	Calcareous sand tempered
Y3HA	2150 B.P.	Calcareous sand tempered
Y4HA	2150 B.P.	Calcareous sand tempered
Y5HA		Calcareous sand tempered
Y6HA	550 B.P.	Plain ware
Y7HA	550 B.P.	Plain ware
Y8HA	550 B.P.	Plain ware
Y9HA	550 B.P.	Plain ware
Y10HA	1900 B.P.	Plain ware
Y11HA	1900 B.P.	Plain ware
Y12HA	2150 B.P.	Calcareous sand tempered
Y13HA	450 B.P.	Laminated ware
Y14HA	250 B.P.	Laminated ware
Y15HA	250 B.P.	Laminated ware
Y16HA	250 B.P.	Laminated ware
Y17HA	250 B.P.	Laminated ware
Y18HA	Modern	Modern

Infrared wavelength patterns and standards suggest that traces of the following plants have occurred in the sherd samples listed:

Banana - None detected
Rice - Y11, Y12, Y13
Sago - Y9
Sweet Potato - Y2, Y4, Y5, Y6, Y7, Y8, Y10, Y11, Y13, Y16
Taro - Weak traces for Y3, Y4, Y10, Y11, Y13, Y14

Ultraviolet wavelength patterns and standards suggest the following:

Plant	Extr.	1780	1740	1730	1720	1710	1660	1645	1630	1610	1600	1550	1530	1510	1460	1435	1410	1380	1370	1265	1250	1235	1160	1120	1110	1100	1095	1050	1020	985	970	935	910	900	890	835	800	720
Banana	B1HB		*			*									*			*	*		B		*		*				B								*	*
	B2HB		*			*						*			*			*			B		*			*			B								*	*
	B3HB		*			*						*			*			*			B		*						B								*	*
	B4HC		*			*						*			*			*			B		*		*				B								*	*
	B5HB		*			*					*	*	*		*			*			B		*						B								*	*
	B6HC		*			*						*			*			*			B		*						B								*	*
	B7HC		*			*						*			*			*			B		*						B						*			*
	B8HC		*			*						*			*			*			B		*		*				B								*	*
Rice	R1HA		R			R			*					*	*		*		R	*		*	*		*		*		*	*	*		*					*
	R2HA		R			R			*			*			*	*	*		R	*		*	*		*		*			*		*						*
	R3HA		R			R		*		*	*			*	*	*			R	*		*	*		*		*	*	*		*		*		*	*		*
	R4HA		R			R		*	*		*			*	*				R	*		*	*		*		*	*	*	*	*		*		*	*		*
	R5HA		R			R		*		*	*			*	*	*	*		R	*		*	*		*		*	*	*		*		*			*		*
	R6HC		R			R	*				*	*		*	*		*		R			*	*				*		*		*	*	*					*
	R5HA		R			R	*		*		*	*		*	*		*		R	*		*		*				*	*	*	*			*				*
	RPHA		R	*		R	*	*		*		*		*	*		*		R	*		*		*				*	*		*			*	*			*
	CPHB		R			R	*				*	*		*	*		*	*	R	*		*	*		*			*	*	*		*			*	*		*
	CRHA	*	R			R	*	*		*	*	*	*	*	*	*	*		R	*		*	*		*		*	*	*	*	*	*				*		*
Sago	SAH2		*		S	*	*		*	*		*	*		*			*				*			S				*		*		*					*
	S2HA		*	*	S				*	*			*		*			*	*		*		*		S			*	*		*				*			*
	S3HB		*		S										*				*		*		*		S													*
	S4HA		*		S				*	*		*	*	*	*			*			*	*	*		S										*		*	*
	S5HA		*		S		*		*	*			*		*			*					*		S			*							*			
	S6HA		*		S										*			*					*		S			*	*						*		*	*
Sweet Potato	K1HD		*	*		*	*	*	*	*		*		K	*	*	*	*				*	*	*				*	*			*						*
	K2HA		*						*		*			K	*				*		*			*									*					
	K3HB		*									*		K	*		*					*	*		*				*									*
	K4HA		*			*			*		*			K	*		*		*				*					*			*		*				*	*
	K6HA		*			*					*			K	*				*			*	*						*									*
	K5HA		*				*	*			*		*	K	*		*		*				*				*		*	*							*	*
Taro	T1HB		*			*	*			*	T	*	*	*	*			*				*		*		T		*	*					T	*			*
	T2HA			*		*					T	*			*			*			*	*	*			T			*					T				
	T3HA		*			*	*		*	*	T	*	*		*			*				*	*			T			*		*			T				*
	T4HA		*			*					T	*			*			*				*	*			T		*						T				*
	T5HA		*			*			*		T				*			*				*	*			T		*			*			T				*
	T6HA		*			*					T	*			*			*			*	*	*			T		*	*		*		*	T	*			*
	T7HA		*			*					T			*	*			*				*	*			T			*		*			T			*	*
	T8HA		*			*	*		*		T	*	*	*	*			*			*	*	*			T			*					T			*	*
Yam	V1HB		*			*	V		*		*	*	*		*			*			*	*		*	*			V	*		V		*		*		*	
	V2HB					*	V		*			*	*		*			*					*		*			V	*		V							
	V3HA		*			*	V					*	*		*			*			*		*		*			V			V		*				*	*
	V4HA		*			*	V		*	*		*	*		*			*	*		*	*	*	*		*		V	*		V		*		*		*	*
	V5HA		*			*	V				*	*			*			*			*	*	*		*			V			V		*	*			*	*
	V6HA		*			*	V				*	*		*	*			*			*	*	*		*	*		V	*		V			*	*			*
	V7HA		*			*	V			*			*		*			*			*		*			*		V			V							

*	Present
N	Not Detected

Figure 1. IR wavelength occurrences (cm-1) for 45 plant samples using Heptane. Extr. = sample extraction numbers. Columns with letters indicate peaks which serve to indicate the particular plant (T = taro, R = rice etc.).

Figure 2. UV wavelength occurrences for 45 plant samples using Heptane. For explantions of codes see Figure 1.

Eastern Carolines, Yap Island

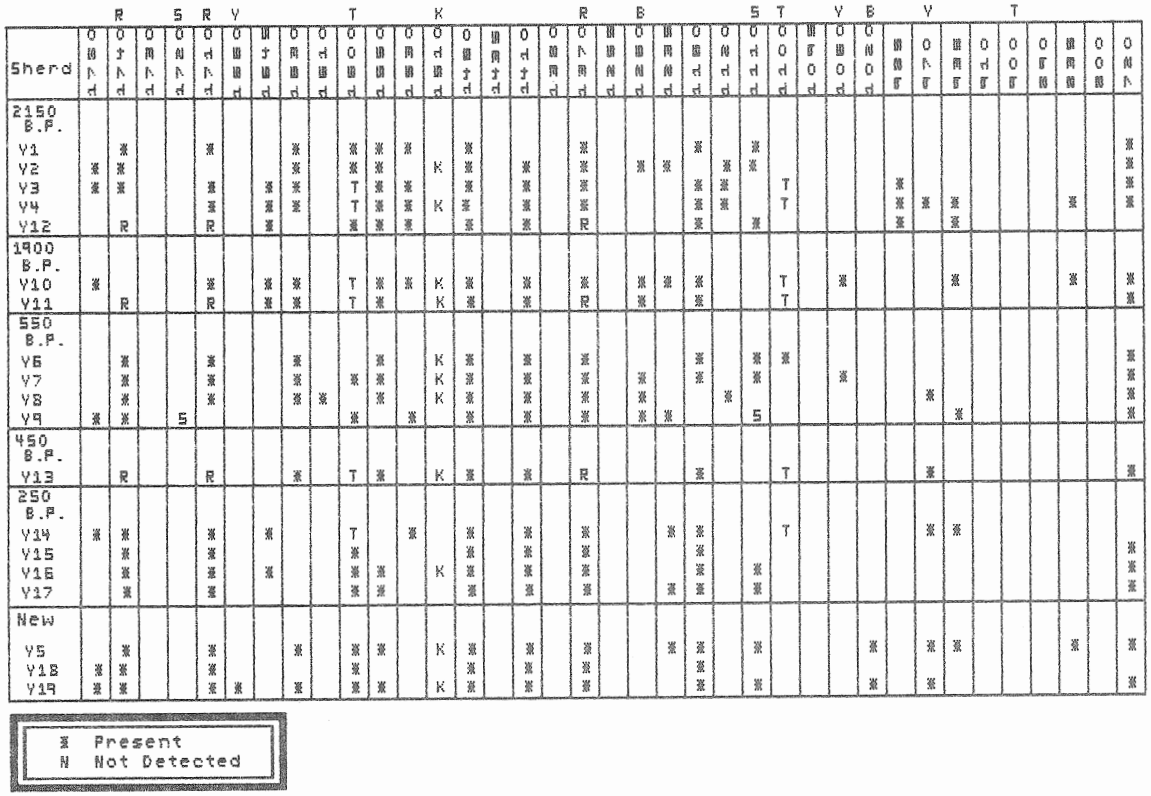


Figure 3. IR wavelengths of Heptane extracts from 19 Yap archaeological samples.

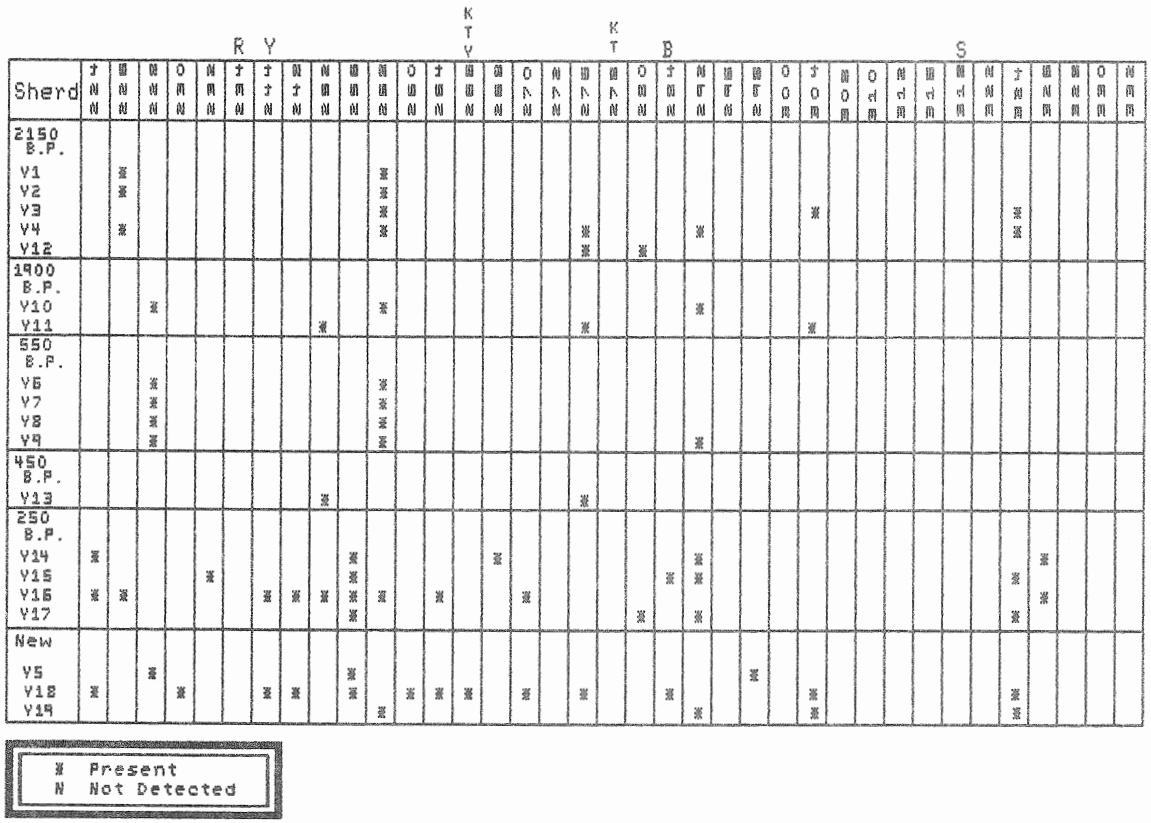


Figure 4. UV wavelengths of Heptane extracts from 19 Yap archaeological samples.

Banana	-	Y15, Y18
Rice	-	None detected
Sago	-	None detected
Sweet Potato	-	None detected
Taro	-	None detected
Yam	-	None detected

As there are no overlaps in apparent indications, the failure of either IR or UV detection to register chemical differences may be significant. On the other hand, each method may be recognising different components of each plant. The second possibility seems the most likely, but it remains to be confirmed by further analysis of the extracts using HPLC.

There have been varying successes with other samples tested from the sites of Madai Cave in Sabah (East Malaysia), Ulu Leang I in southwestern Sulawesi, Ngaua and Nendo in the Santa Cruz Islands (Hill and Evans 1988a), and Natunuku on Viti Levu, Fiji (Hill, Evans and Card 1985). The accuracy of these results is also being tested by applying HPLC to the same sherd extracts. Gas Liquid Chromatography (GLC), which is also far more sensitive than IR or UV, may also be used for further analysis (Morgan et al. 1984; Patrick et al. 1985).

REFERENCES

Allan, J.P. 1984. Medieval and Post-Medieval finds from Exeter.1971-1980. Exeter Archaeological Reports 3:37-9.

Christie, W.W. 1988. HPLC and lipids; a practical guide. Pergammon Press.

Evans, J., Biek, L. 1976. Overcooked food residues on potsherds. Proceedings of the 16th. Symposium on Archaeometry, Edinburgh, U.K.

Evans, J. and Hill, H. E. 1982. Dietetic information by chemical analysis of Danish Neolithic potsherds: a progress report. Proceedings of the 22nd Symposium on Archaeometry, Bradford, U.K., pp. 224-8.

Hill, H.E. 1984. Chemical analysis of pottery residues. Bulletin of Leicester Pottery Firing Group, Vol.2, July, pp. 86-89.

Hill, H.E. 1988. Producing standards for identifying food remains on ancient pottery. 1st Conference, Association of Southeast Asian Archaeologists in Western Europe, London, UK. In Press.

Hill, H.E., Evans. J. and Card, M. 1985. Organic residues on 3000 year old potsherds from Natunuku, Fiji. N.Z. Journal of Archaeology 7: 125-8.

Hill, H.E., and Evans, J. 1988a. Vegeculture in Solomon Islands prehistory from pottery residues. Proceedings of Science In Archaeology Conference, University of Glasgow, Sept. 24-26, 1987. BAR In Press.

Hill, H.E., and Evans, J. 1988b. Movement of peoples and plants from Asia. In Foraging and Farming (eds D.R.Harris and G.J.Hillman). George Allen & Unwin. In Press.

Morgan, E.D., Cornford, C., Pollock, D.R.J. and Isaacson, P. 1973. The transformation of fatty material buried in soil. Science and Archaeology 10: 9-10.

Morgan, E.D., Titus, L, Small, R.J. and Edwards, C. 1984. Gas chromatographic analysis of fatty material from a Thule midden. Archaeometry 26(1): 43-8.

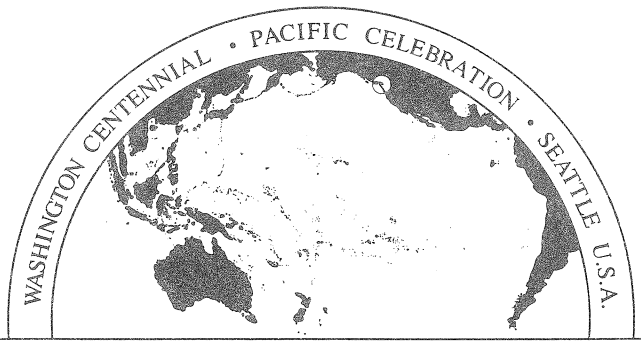
Needham, S. and Evans, J. 1987. Honey and dripping: Neolithic food residues from Runnymede Bridge. Oxford Journal of Archaeology 6(1): 21-8.

Patrick, M., de Koning, A.J. and Smith, A.B. 1985. Gas chromatographic analysis of fatty acids in food residues from ceramics found in the Southwestern Cape, South Africa. Archaeometry 27(2): 231-6.

Paul, A.A. and Southgate, D.A.T. 1978. The composition of foods. HMSO/Medical Research Council.

Rottlander, R.C.A. and Hartke, I. 1982. New results of food identification by fat analysis. Proceedings of the 22nd. Symposium on Archaeometry, Bradford, U.K: 218-23.

Rottlander, R.C.A. and Schlichtherle. H. 1979. Food identification of samples from archaeological sites. Archaeophysika 10: 260-7.



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