

Traditional storage of pandanus nuts in the Papua New Guinea highlands

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Abstract

Nuts of *Pandanus julianettii* and *P. brosimos* provide the sole traditional storable foodstuff in the highlands of New Guinea. This paper gives an overview of traditional methods for preparing pandanus nuts for storage in the Central, Eastern Highlands, Southern Highlands and Western Highlands provinces of Papua New Guinea.

Samples of nuts stored in these provinces were examined for fungal and insect infestation, and their water relationships studied. The mycoflora reflected the tropical origins of the material, with *Eurotium* and *Aspergillus* species being most common, but the presence of *Paecilomyces lilacinus* in some samples was unexpected. Insect infestation was negligible and restricted to native cockroaches (Blattodea). Sorption isotherms for husks and kernels were determined.

Introduction

The thin-shelled cultivated pandanus, *Pandanus julianettii*, and the thick-shelled wild pandanus, *P. brosimos*, (Pandanaeae) grow extensively throughout the highlands of New Guinea (Rose 1982, 1986; Stone, 1982a), where they are endemic (Henty 1982). They are considered to be the most important of the fruit and nut trees grown by the people of the New Guinea highlands (Hyndman 1984), and make a significant seasonal contribution to the diet and nutrition of the highland population (Harvey and Heywood 1983; Rose, 1982; Sinnott 1975; Waddell 1972; Wohlt 1978).

The edible fruit, called a cephalium or syncarp, is composed of hundreds of finger sized drupes (nuts with a shell). The syncarp is carried on a stout stalk or peduncle. The nuts are hexagonal, cone shaped, approximately 1.5 cm wide and 7–10 cm long (Figs 1–6). During the harvest the ripe fruit may be consumed raw or roasted. Sometimes the syncarp is split into quarters and immersed in mud or water as a form of temporary storage during which fermentation occurs (Rose 1982; West and Laiam, pers. comm.).

For longer storage, the nuts are preserved by drying and smoking, and in this form provide the sole traditional storable foodstuff in the highlands (Wohlt 1978). The dried nuts have a high thiamine content (Peters 1958) and provide a superior source of protein compared with lima beans, fern and green vegetables (Bradbury et al. 1985).

The syncarps are ellipsoidal 30–35 cm long, 25–30 cm in diameter (Henty 1982), and weigh between 5–16 kg. When fully ripe and mature they fall, and at this stage the drupes separate from one another very easily. Nuts are harvested both by collecting the fallen syncarps and by cutting ripe fruit from the trees.

In preparation for drying, whole syncarps are split into halves or quarters, then the outer fleshy tissue is trimmed off and the core (peduncle) removed. This process exposes the inner and outer surfaces of the nuts, which are held firmly together by 'connective' tissue. Nuts obtained from fallen syncarps, that split apart, are cleaned to remove all extraneous tissue to completely expose the shell before they are dried. They are usually collected into a net bag.

Commonly the split syncarps and bags of separated nuts are stored in the family house on a platform 1.6–2.0 m above the hearth, in which a fire smoulders day and night. Thus the nuts are smoked continuously during the storage period. In some areas, depending on the weather, the nuts are dried in the sun by day and replaced over the hearth by night. However, this only occurs during an initial period of two to three weeks after harvesting, after which the nuts are stored continuously over the hearth. In the Goilala area of the Central Province there appears to be an established minimum of two to four month drying/smoking time before nuts are considered ready for consumption. Sometimes, the nuts may be shelled and placed in a net bag, or pandanus leaf basket, that is suspended over the hearth (Eastburn 1984; Rose 1982).

In general there does not seem to be a limit on the time that nuts are exposed to smoke; the process continues until the nuts are consumed. However, nuts may be moved away from the direct heat and smoke of the hearth after they are deemed to have dried sufficiently, which might reflect a consumer preference for lightly smoked nuts. Sometimes the smoke flavour may be deliberately intensified by burning 'special' leaves on the drying fire (West and Laiam, pers. comm.).

Special smoke houses are constructed after a bumper harvest, when there is insufficient space to dry the entire crop in the family house. In the smoke houses, the nuts are placed on a platform (which may be closer to the fire than in the family house), under which a fire is kept burning 24 hours a day for up to two months. During this time the nuts and split syncarps are turned to ensure they dry evenly. Thereafter the nuts may be consumed immediately, sold or placed in the family house for further drying and storage.

Nuts that have been fermented underwater may also be dried and smoked for storage (West and Laiam, pers. comm.).

There are reports that nuts have been stored for several years. However, in practice the storage period seems to vary from four months to one year, with rare instances of storage up to two or even three years. Their food value is well understood and they are widely consumed during times of food shortage (Bourke 1988). In addition nowadays, their cash value is frequently exploited. They are sold in local markets during the harvest period and after some three to four months storage, when fresh nuts are no longer available.

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Fig. 1. Pandanus syncarps.



Fig. 2. Outer fleshy tissue being trimmed from a ripe pandanus syncarp.



Fig. 3. Smoke dried shelled nut meats in a pandanus leaf container.

The full nutritional and economic value of traditional nut trees has, until recently, been largely overlooked. Pandanus nuts are no exception. They can be defined as underexploited tropical plants (National Research Council 1975) and meet the selection criteria of being neglected and useful, having economic potential, and promise for wider exploitation. This potential was recognised by Stone (1982b) who made the first of a number of unsuccessful proposals for agronomic research aimed at developing *P. julianettii* and *P. brosimos*.

Recently, work has been undertaken in the Solomon Islands to develop techniques for commercial production, processing and marketing of the indigenous 'Ngali' nut (*Canarium* spp. [Burseraceae]). Simply packaged dried and roasted kernels have been retailed with reasonable success on the domestic market and strategies have been developed to exploit export markets (Evans 1991). Similar proposals have been made for pandanus nuts (Camarotto and Bourke, in press) who include them in a list of alternative crops that could be exported from Papua New Guinea.

The work reported here was undertaken to gain an overview of the traditional methods used to prepare pandanus nuts for storage. The objective was to discover whether the nuts were subject to insect or fungal infestation during storage and establish their water relationships.

Storage Practices and Nut Samples

This study was undertaken in the Central, Eastern Highlands, Southern Highlands, and Western Highlands Provinces of



Fig. 4. Smoke dried in-shell pandanus nuts.

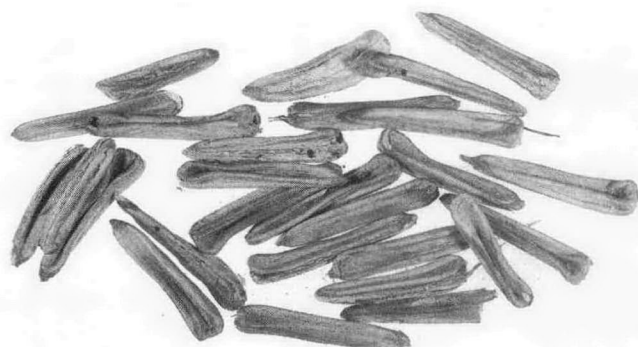


Fig. 5. Smoke dried shelled pandanus nut meats.

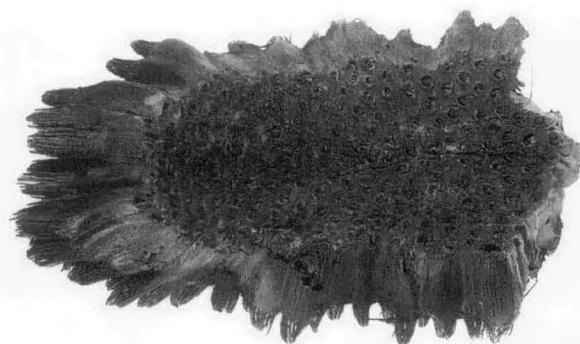


Fig. 6. Smoke dried portion of a pandanus syncarp showing holes cut at basal (peduncle) end of nut shells.

Papua New Guinea from April 1981 to May 1983 (Fig. 7). During this time practices involved in preparing nuts for storage were observed directly during two harvests, discussed during extension patrols and with villagers involved in storage observation trials.

Methods

Storage observation trials were established in two provinces. The objective was to obtain samples of stored nuts at monthly intervals during the storage period, and record any practices involving the nuts during that time.

Samples of smoked nuts were also obtained from markets and villages over the duration of the study.

In April 1981, shortly after the harvest had ended in the Southern Highlands, a number of people living in Iombi (Yombi), Kalano and Oyaka villages (located along the Mt Hagen—Mendi road in the vicinity of the Ialibu turn off), consented to participate in a storage observation trial. One household was involved at Kalano and another at Oyaka, whilst four participated at Iombi. Due to the value of pandanus nuts in the local economy it was necessary to 'rent' the produce from each household for the duration of the trial and purchase the monthly samples.

A second observation trial commenced after the harvest in the Eastern Highlands in April 1982, at Henkae, Tapo No1 and Tirae villages near Kainantu. This involved one household each at Henkae and Tirae, and two at Tapo No1.

The material stored at all sites involved in the trials consisted of both split syncarps and separated nuts. The syncarps

were sampled by breaking off a number of nuts, approximately equal in number to those taken from the separated nuts.

Sampling continued for six months in both provinces. The samples were placed into airtight tins as they were collected then transported to Port Moresby, where they were stored at 15–25°C. The material was airfreighted to Sydney in April 1984 for the laboratory analyses reported below.

Additional samples of smoked nuts were obtained in the Western Highlands Province from the Mount Hagen market, and from the following villages in the Goilala district of the Central Province: Pokili, Kilemaiti, Itoueue, Kopoiui, Kotele, Piliua, Karom, Lamauru, Oropoueo and Kataipi.

Insect Infestation of Stored Pandanus Nuts

Insects were only found infesting nuts in split syncarps. In all cases the infested nuts were found to have damaged shells. This occurs during the splitting process, and when the outer fleshy tissue and the end of the peduncle are removed. The process is traditionally carried out using sharpened sticks, which cause little or no damage. Nowadays steel axes or machetes are often used, which due to their sharpness, frequently cut and open the ends of the shells thus providing the insects access to the kernel.

The only insects found were native cockroaches (Blattodea).

Under village conditions insects reportedly pose no problem, and no storage losses are attributed to insect infestation. Despite records (Eastburn 1984; Rose 1982) of unshelled nuts being stored, none were encountered during the study period. This might reflect a greater susceptibility of shelled nut kernels to infestation by insects.

Mycoflora of Pandanus Nuts

Methods

Twenty-nine samples of pandanus nuts were examined. Nineteen were from the Western Highlands, two from the Central Province, four from the Eastern Highlands, and four from the Southern Highlands. The latter represented two samples taken from different sites at the beginning, and two at the end, of a six-month storage period.

From each sample, 20 nuts were taken. These were hand-shelled, surface sterilised with sodium hypochlorite for one minute, drained, then plated out onto DRBC agar (Pitt and Hocking 1985), five nuts per plate. The plates were incubated at 25°C for five days. The amount of fungal invasion was

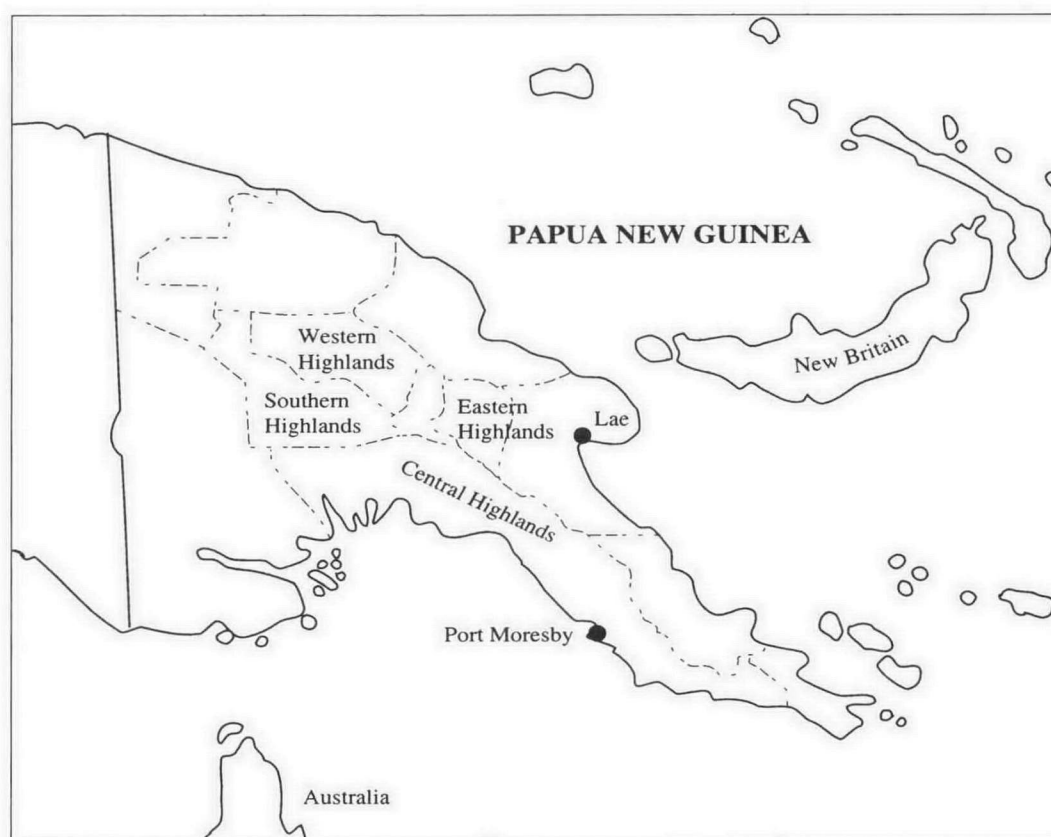


Fig. 7. Map of Papua New Guinea showing study areas.

assessed as low (<35%), intermediate (35–65%) or high (>65%), according to the number of pandanus kernels supporting fungal growth. Fungal colonies were subcultured onto appropriate media and identified, at least to genus level, using the methods outlined in Pitt and Hocking (1985).

Results

No fungi were detected in two (7%) of the samples examined. Both these samples were from the Southern Highlands, one from the beginning of the storage period, and the other from the end. However, they were not taken from the same household. Of the 27 remaining samples, most (72%) had a low rate of fungal infection, 7% were intermediate, and 14% were heavily infected with fungi.

The range of fungi isolated from the pandanus samples is shown in Table 1. Xerophilic fungi were dominant in the mycoflora: *Eurotium* species were the most frequently encountered fungi, occurring in 55% of samples. *Aspergillus* species were also common, with the xerophilic species, *A. restrictus*, isolated from 21% of samples, and *A. niger* occurring in 14% of samples. *A. flavus* and *A. parasiticus* were not encountered in any of the samples. The *Penicillium* species that were isolated were also xerophiles, although not strongly so.

Discussion

The composition of the mycoflora reflects the tropical origins of the samples. Twenty-one of the 29 samples contained *Eurotium* species and/or *Aspergillus* species, all of which grow well at 30°C, a temperature typical of the tropics, with many species capable of growth at much higher temperatures. *Paecilomyces lilacinus* and *Paec. variotii* also grow well at 30°C, but *Penicillium* species grow better at lower tempera-

tures, and were comparatively poorly represented in the mycoflora. Most of the species isolated would be regarded as 'storage' fungi. Species traditionally regarded as 'field' fungi (e.g. *Fusarium*, *Alternaria*, *Drechslera*) were isolated infrequently.

The occurrence of *Paec. lilacinus* in six of the 29 samples (all from the Central Province) was surprising, as it is a soil-

Table 1. Fungi isolated from 29 samples of pandanus nuts from Papua New Guinea, showing frequency of occurrence.

Species	% of samples
<i>Eurotium</i> species	55
<i>Aspergillus</i> species (total)	45
<i>A. restrictus</i>	21
<i>A. niger</i>	14
<i>Penicillium</i> species (total)	
<i>P. citrinum</i>	17
<i>P. chrysogenum</i>	3
<i>P. viridicatum</i>	3
<i>Paecilomyces</i> species (total)	28
<i>P. lilacinus</i>	21
<i>P. variotii</i>	3
<i>Cladosporium</i> species	10
<i>Rhizopus stolonifer</i>	10
<i>Fusarium</i> species	6
<i>Drechslera</i> species	6
<i>Alternaria</i> species	3
<i>Sclerotinia rolfsii</i>	3
Unidentified fungi	6

borne fungus not commonly encountered in foods (Pitt and Hocking, 1985) and it is not regarded as xerophilic. It has been reported to grow in 15% (w/v) NaCl (equivalent to 0.95 a_w) but not in 20% NaCl (0.87 a_w) (Tresner and Hayes 1971). It is possible that *Paec. lilacinus* is more resistant to the smoking process than some other fungi.

Water Relationships of Pandanus Nuts

Methods

Samples, collected from two different households at Iombi village in the Southern Highlands, were selected for detailed determination of water sorption isotherms. Adsorption and desorption isotherms were determined for both husks and kernels.

Sorption isotherms

The nuts were shelled manually, and the proportions of kernel and shell noted. Using a sharp knife to avoid bruising, the kernels were cut by hand into 3 mm slices across the main axis, and divided into two proportions, each of approximately 500 g.

For the adsorption isotherm, one portion was gently dried in an air oven below 45°C (the minimum temperature necessary to reduce the moisture content below 3%), then equilibrated in 2 L glass storage jars at 15°C for a week. Subportions, of approximately 50 g, were transferred to 400 mL glass screw-top jars and moistened with various quantities of distilled water to produce samples of various moisture contents. The water was uniformly distributed by shaking and rolling the jar, and the samples were equilibrated for two weeks before determination of equilibrium relative humidity (ERH) and moisture content.

To determine the desorption isotherm, the other portion was prepared by moistening it with distilled water to raise its moisture content above 20%. After equilibration for two weeks, subfractions, of approximately 50 g, were gently dried in an air oven below 45°C, to produce samples with a range of moisture contents. These were then transferred to 400 mL screw-top glass jars, and equilibrated for a week before determination of e.r.h. and moisture content.

Samples of husk were prepared in a similar manner, except that, being of much lower bulk density, the weights used were smaller.

No mould growth was evident in any of the samples whilst these tests were carried out.

Moisture content

Moisture content was determined in duplicate by drying subsamples (approx 10 g) in light aluminium dishes in an air oven for 16 hours at 103°C, using the standard method for

cocoa beans (ISO 1980). The dishes were removed from the oven, covered, and cooled over silica gel before weighing.

Equilibrium relative humidity was determined with a humidity meter (Vaisala [Finland] Model HMP 11) using continuous comparison with saturated salt humidity standards (Greenspan 1977). The saturated salt solutions were prepared in similar screw-top jars to those used for the pandanus samples, using AR grade salts and distilled water. Working in a controlled temperature room at the desired temperature, the samples and humidity standards were arranged in increasing order of humidity. Starting at one end of the row of jars, the humidity probe was inserted into the headspace (through a hole in the lid of the jar, otherwise sealed with a rubber stopper), and a reading taken after 10 minutes. The jars were read in ascending order of humidity, and again in descending order. At the conclusion of the run, sample readings were corrected using the readings of the standards.

Results and discussion

Proportion of kernel to husk

The pandanus nuts from different provinces differed in appearance, especially in the thickness of the shell. As shown in Table 2, there is a corresponding difference in the proportion of the nut represented by the kernel.

Sorption isotherms

The sorption isotherms for husks and kernels of two samples of Southern Highlands pandanus nut, determined at 15°C, are plotted in Figure 8. The isotherm for whole nuts can be obtained by combining kernels and husks in their weight proportions.

There is little difference between the adsorption and desorption isotherms of the kernel (i.e. there is no hysteresis) and at a given humidity, the kernel would come to the same moisture content whether it had been initially dryer, or more moist. However, the husk shows a large degree of hysteresis. For example, husk with a moisture content of 9% could have reached this state by drying in air of 46% r.h., or by taking up moisture in air 65% r.h. This hysteresis will tend to protect the kernel from changes in moisture content when ambient conditions vary, but will make it more difficult to dry the kernel in the whole nut, than as kernel alone.

There is little difference between the isotherms of the pandanus samples from different households. The possibility that pandanus nuts from other regions may differ cannot be discounted. However, such differences would be expected to be slight, even between *P. julianettii* and *P. brosimus* and between different cultivars of these two species.

Before storage, the e.r.h. of food products should be reduced below 65% to prevent growth of moulds. It can be seen from the isotherms that pandanus kernels must be dried to below 8.5% to reach this e.r.h. The moisture content in the non-fat

Table 2. Details of pandanus nuts from various provinces, as received.

Province ^a	Moisture content (%)		e.r.h. ^b (%)	Composition by weight (%)	
	Kernel	Husk		Kernel	Husk
SH	6.1	8.7	54	39	61
C	4.4	8.9	43	73	27
EH	6.2	9.9	56	64	36

^aSH (Southern Highlands): smooth, thin shell; C (Central): rough, thick shell; EH (Eastern Highlands): intermediate thickness shell.

^bERH inferred from initial moisture content. With an e.r.h. below 65% (i.e. a_w below 0.65), pandanus will be protected from mould growth by the low availability of water.

component of most horticultural produce equivalent to an ERH of 70% is similar, but corresponds to differing over-all moisture contents because of differing fat contents. This is illustrated in Table 3, which compares values for various produce.

Early workers failed to allow for hysteresis when determining the sorption isotherms of produce, and found a large scatter in their results. It is now well established that some products exhibit more hysteresis than others. Cocoa beans for example exhibit greater hysteresis than green coffee. The significance of this is that drying requires a lower relative

Table 3. Comparison of moisture characteristics of pandanus with other tropical products. Moisture contents given are those required to reduce the e.r.h. below 65%.

Product ^a	Oil content (% dry basis)	Hysteresis ^b (% mc)	Moisture content (% wet basis)
Pandanus	nd	u	8.4
Pandanus (husk)	nd	± 1.0	9.5
Green coffee	~12	u	12 ^c [C]
Linseed [A]	41	± 0.2	8.2
Raw cashew nut	50	u	8.4 [D]
Peanuts [A]	51	u	6.3
Cocoa beans	55	± 0.2	6.5 [C]
Copra (smoked)	[A] 69	± 0.5	5.5
Macadamia nut	76	—	4 [B]

^aKernel of nuts except where indicated. Reference book values except those from [A].

^bu = no measured hysteresis; - = absorption not distinguished from desorption; nd = not determined.

^cArabica and Robusta are similar.

Sources: [A] Pixton and Warburton (1971); [B] Wooton, A.E. in Gough and Lippiatt (1977); [C] Sharp, A.K. PNG produce, unpublished results; [D] Okwelugu and Mackay (1969).

humidity than would otherwise be expected. Conversely, a product exhibiting hysteresis is better buffered against changes in storage r.h. than one that does not. Pandanus husk was found to display a relatively large degree of hysteresis, and the kernel little hysteresis. Pandanus nuts stored in husk will, therefore, be better buffered against fluctuations in humidity.

It can be seen from the isotherms that pandanus kernel must be dried to below 8.5% for safe storage. By this measure, all samples reported in this study were over dried.

It has been observed previously (Pixton and Warburton 1971) that cereal grains and oilseeds differ in their moisture isotherms, but that the difference is largely attributable to differences in oil content, i.e. the moisture contents are similar when moisture content is expressed on an oil-free basis. The dependence of acceptable moisture content on oil content is illustrated in Table 3, showing a decrease in acceptable moisture content with increasing oil content. This illustrates the fact that a product's e.r.h. is a better measure of its stability than its moisture content. With the ready availability of humidity probes, it is now practicable to measure e.r.h. with reasonable accuracy, provided that the instrument is calibrated regularly.

Conclusion

The fungi isolated from the pandanus nuts examined in this study were typical of those encountered in many stored products in tropical regions. Compared with many other products stored in the tropics, fungal contamination levels were fairly low and no aflatoxigenic fungi were isolated. Heat and antimicrobial compounds generated during the smoking process no doubt reduce the fungal spore load on stored nuts, while the intact shell acts as a physical barrier to fungal and insect infestation invasion.

The study showed that traditional methods reduce nut moisture content to a level sufficiently low to prevent the growth of most spoilage microorganisms. The moisture isotherm of pan-

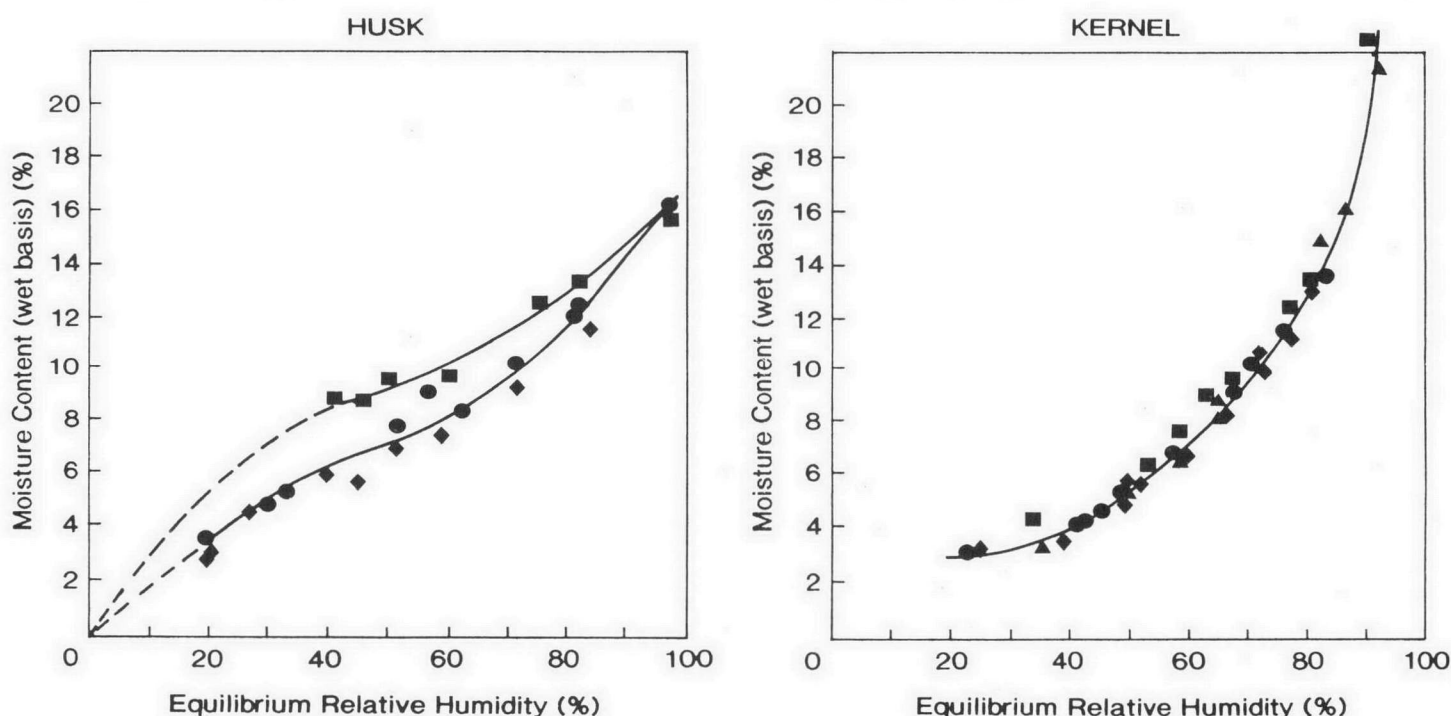


Fig. 8. Sorption isotherms of pandanus (Southern Highland samples 52 and 53) determined at 15°C. Left: sorption isotherm of husk; right: sorption isotherm of kernel. ●, absorption, house 2; ■, desorption, house 2; ◆, absorption, house 3; ▲, desorption, house 3.

danus kernels is similar to that of cashew nuts. The study showed that the greater hysteresis of husks relative to kernels serves to buffer the kernels against changes in humidity, and supports the traditional practice of in-shell storage.

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References

- Bourke, R.M. 1988. *Taim Hangre*: variation in subsistence food supply in the Papua New Guinea highlands. Thesis submitted for the degree of Doctor of Philosophy at the Australian National University. 370p.
- Bradbury, J.H., Hammer, B., Nguyen, T., Tamate, J., Anders, M. and Millar, J.S. 1985. Analyses of vegetables from the highlands of Papua New Guinea. *Papua New Guinea Medical Journal* 28, 127–130.
- Camarotto, C. and Bourke, R.M. (In press) Potential for exporting fruit from Papua New Guinea to overseas markets during their off seasons. *Papua New Guinea Journal of Agriculture, Forestry and Fisheries*.
- Eastburn, D. 1984. Pandanus nut harvest. In: *Paradise Tales*, a selection of stories from Air Niugini's in-flight magazine. Robert Brown and Associates (Aust) Pty, Bathurst, NSW, Australia. ISBN 0 949267 23 6, 26–28.
- Evans, B.R. 1991. The production, processing and marketing of Ngali nuts (*Canarium* spp.) in Solomon Islands. Unpublished report, Dodo Creek Research Station, Ministry of Agriculture and Lands, Honiara, 37p.
- Gough, M.C., and Lippiatt, G.A. 1977. Moisture humidity equilibria of tropical stored produce. Part II—Oilseeds. *Tropical Stored Products Information* 34, 49–61.
- Greenspan, L. 1977. Humidity fixed points of binary saturated aqueous solutions. *Journal of Research of the National Bureau of Standards A Physics and Chemistry* 81A, 1,
- Harvey, W.J. and Heywood, P.F. 1983. The Research Report of the Simbu Land Use Project. Volume IV Nutrition and Growth in Simbu.
- Henty, E.E. 1982. Some nut bearing plants in Papua New Guinea. In: Bourke, R.M. and Kesavan, V. eds, *Proceedings of the Second Papua New Guinea Food Crops Conference Goroka, 14–18 July 1980*. Department of Primary Industry, Port Moresby, Papua New Guinea, Part 1, 78–85.
- Hyndman, D.C. 1984. Ethnobotany of Wopkaimin *Pandanus*: significant Papua New Guinea plant resource. *Economic Botany* 38, 3, 287–303.
- ISO 1980. International Standard ISO-2291: 1980. Cocoa beans—Determination of moisture content (Routine Method). International Organization for Standardization, Geneva, Switzerland.
- National Research Council (U.S.). Panel on underexploited tropical plants with promising economic value. 1975. *Underexploited Tropical Plants With Promising Economic Value*. Report of an ad hoc panel of the Advisory Committee on Technology Innovation, Board on Science and Technology for International Development. Commission on International Relations. National Academy of Sciences, Washington, DC, USA, ix, 188 p.
- Okwelugu, T.N. and Mackay, P.J. 1969. Cashewnut moisture relations. *Journal of the Science of Food and Agriculture* 20, 697–702.
- Peters, F.E. 1958. The chemical composition of South Pacific foods. South Pacific Commission Technical Paper No 115. Noumea, New Caledonia. 58p.
- Pitt, J.I. and Hocking, A.D. 1985. *Fungi and Food Spoilage*, Academic Press, Sydney. 413p.
- Pixton, S.W. and Warburton, S. 1971. Moisture content relative humidity equilibrium, at different temperatures, of some oilseeds of economic importance. *Journal of Stored Products Research* 7, 261–9.
- Rose, C.J. 1982. Preliminary observations on the pandanus nut (*Pandanus julianettii* Martelli). In: Bourke, R.M. and Kesavan, V. eds, *Proceedings of the Second Papua New Guinea Food Crops Conference, Goroka, 14–18 July 1980*. Department of Primary Industry, Port Moresby, Papua New Guinea, Part 1, 160–167.
- Rose, C.J. 1986. Tabular descriptions of crops grown in the tropics. 16 Karuka (*Pandanus julianettii* Martelli). CSIRO Institute of Biological Resources, Division of Water and Land Resources, Canberra, Australia, Technical Memorandum 86/21, 52p. ISBN 0 643 04060 9.
- Sinnett, P.F. 1975. *The People of Murapin*. Institute of Medical Research Monograph Series No 4. E.W. Classey Ltd, Oxford, England. xii, 208p.
- Stone, B.C. 1982a. New Guinea Pandanaceae: first approach to ecology and biogeography. In: Gressitt, J.L. *Biogeography and Ecology of New Guinea*. I, 401–436.
- Stone, B.C. 1982b. Agronomic study of Karuka. Proposal and scheme for an agronomic study of *Pandanus julianettii* and *Pandanus brosimus*, the karuka nut trees of Papua New Guinea. Unpublished manuscript, Department of Primary Industry, Horticulture Section, Port Moresby, Papua New Guinea.
- Tresner, H.D. and Hayes, J.A. 1971. Sodium chloride tolerance of terrestrial fungi. *Applied Microbiology* 22, 210–213.
- Waddell, E. 1972. *The Mound Builders*. Agricultural Practices, Environment, and Society in the Central Highlands of New Guinea. University of Washington Press, Seattle and London. 253p.
- Wohlt, P.B. 1978. Ecology, agriculture and social organisation: the dynamics of group composition in the highlands of Papua New Guinea. Ph.D. dissertation, University of Minnesota, USA.