

The effects of sodium hypochlorite dipping, temperature and duration of storage on the quality of fresh taro corms destined for overseas markets

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ABSTRACT

A study to determine conditions that promote the longevity of stored taro corms (*Colocasia esculenta* (L). Schott var. *esculenta*) following harvest was carried out in Samoa in 2001 in response to rotting and weight loss problems. The study investigated the possibility that storage of corms at 5°C causes chilling damage, thus enhancing corm rot, and to confirm the beneficial effects of sodium hypochlorite as a rot control dip. 320 freshly harvested 8 months old mature corms were randomly divided into two groups. One group was dipped in a 0.1% solution of sodium hypochlorite (NaOCl) and the other in water, for 2 minutes and packed into perforated plastic bags so that each contained 40 corms. The bags were then randomly selected into 4 groups so that each dip treatment was represented in every group. The four groups were cool stored for 2 weeks at temperatures of 5°C, 10°C, 15°C and ambient.(25°C) respectively. After 2 weeks, the bags were removed from the coolers, stored at ambient and sampled every 7 days for weight and corm loss. Results showed that over the two weeks of on shelf display following removal from cool storage, corms that were stored at 5°C sustained the least corm rot at 15.8%, followed by 10°C at 16.5% with the highest at 50.5% for 15°C. These results show that chilling damage did not occur at the storage temperature of 5°C and that the best temperature range to store taro corms in order to minimise corm rot when removed to ambient for on-shelf display is 5 to 10°C. Dipping in a 0.1% solution of sodium hypochlorite significantly reduced corm rot from 34.2% to 26.0% and weight loss from 4.0% to 3.7%. However the chemical dip had no significant effect on the number or weight of rootlets that sprouted from the stored corms.

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INTRODUCTION

Migration of Pacific islanders in the past several decades to New Zealand, Australia and the United States has resulted in an increasing population of Pacific islanders in these countries (Low, 1986; Beever, 1988). Since taro (*Colocasia esculenta* (L.) Schott var. *esculenta*) is an important staple food for Pacific islanders, this migration has given rise to the taro trade to supply the demand created by these expatriate/ immigrant populations, particularly in New Zealand where the biggest market is located.

Taro is a perishable tropical root crop and the success of trade in 'fresh' taro necessitates the minimisation of post harvest losses in quantity and quality (Coursey, 1975; Rickard, 1983). Unfortunately, the post-harvest characteristics of taro are poorly understood and published data in this field are meagre (Booth, 1974; Coursey and Booth, 1975; Paull and Coltman, 1989). However, several studies and observations of the taro export industry, particularly of the trade between Samoa and New Zealand reveal that the major problems with taro corms retailed in New Zealand are weight loss and short shelf life (Wilson, 1983a; Wilson, 1983b; Beever, 1988; Brown, 1994). This has resulted in continuous losses to the taro export industry (Wilson, 1983b; Leadbitter, 1984; Low, 1986; Beever, 1988). Losses caused by rotting are believed to be high and preliminary trials carried out in New Zealand showed that losses ranged from 18-35% during a period of 9 days following removal from cool storage (Leadbitter, 1984). There is evidence that using a vapour barrier to reduce water loss from taro corms could solve the weight-loss problem; however, little is known about why taro corms have a short shelf life following removal from cool storage.

It has been suggested that the short shelf life of taro corms exhibited for sale in the New Zealand market may be due to chilling damage caused by shipping and storage at the current temperature of 5°C (Fullerton and Porea, 1982). The corms are normally in good condition while in cool storage but deterioration rapidly occurs when removed to ambient (Booth, 1974; Watson, 1979; Rickard, 1983). Chilling damage would be expected from tropical produce stored at low temperatures (Wilson, 1983b; Beever, 1988); for example, yam and sweet potato, two other tropical root crops, have been known to suffer chilling damage at 12°C or lower (Booth, 1974; Linneman, 1981). The most common symptoms of chilling damage are internal tissue breakdown, increased water loss, susceptibility to decay, failure to sprout, and changes in culinary qualities (Booth, 1974; Wilson, 1983b). Beever (1988) was of the opinion that surface infections of corms could well be the result of either chilling damage or bruising.

In the Pacific as well as some Asian countries, taro as a subsistence crop is traditionally left in the ground when mature and harvested when required for consumption (Plucknett *et al.* 1970; Jackson and Gollifer, 1975; Coursey and Booth, 1975). Also, non-refrigerated storage after harvest in underground pits for up to 5 months has been reported from China (Cooke *et al.* 1988). Underground storage systems obviously work but where a large volume of taro corms is destined for overseas markets then other means of storage are needed. The current trade in taro corms has made it necessary to investigate ways of prolonging the storage- and shelf life of exported taro. Reliable information on how to achieve this is not available which highlights the need for research to provide the required information.

The current export handling system in the Pacific involves the storage of taro corms at 5°C (3 to 7°C) during shipment, at auction and at the retail outlet for a period of up to 28 days, followed by removal to ambient where they are exhibited for sale (Wilson, 1983b; Leadbitter, 1984; Low, 1986; Beever, 1988; Cooke *et al.* 1988).

Although losses due to physical and physiological factors are understood to be associated with the storage of the physiologically active corms, it is widely accepted that the major cause of rapid rotting following harvesting is due to attacks by pathogenic fungi (Booth,

1974). Losses of up to 20% within 10 days have been reported (Jackson and Gollifer, 1975). The major causal organisms have been identified and although it has been shown that they are capable of invading undamaged corm tissue under conditions of high humidity (Jackson and Gollifer, 1975), it is generally accepted that they gain entry into harvested corms through wounds caused by the removal of cormels and petiole base as well as injuries sustained during handling (Jackson and Gollifer, 1975; Rickard, 1983; Wilson, 1983b; Leadbitter, 1984; Jackson, 1985; Paull and Coltman, 1989; Agbor-Egbe and Rickard, 1991).

Benomyl ($C_{14}H_{18}N_4O_3$) is effective where *Botryodiplodia theobromae* is the predominant decay organism but it is not suitable for use in countries, such as Samoa, where *Phytophthora colocasiae* (Taro Leaf Blight) and *Pythium splendens* cause major storage losses. Dipping corms in a 1% solution of sodium hypochlorite (NaOCl, household bleach or chlorox) for 10 minutes before storage is reported to control all common storage decay fungi except *Sclerotium rolfsii*. Dipping should be carried out within 24 hours of harvest (Jackson, 1980; Wilson, 1983b; Cooke *et al.* 1988). Ooka and Trujillo (1982) on the other hand reported satisfactory results from dipping cleaned corms in a 0.5% solution of sodium hypochlorite for one minute (Ooka and Trujillo, 1982). Rots associated with *Sclerotium rolfsii* progress slowly and this is unlikely to contribute greatly to storage problems provided that corms are kept dry and well ventilated (Jackson and Gollifer, 1975). Sodium hypochlorite seems to have a high potential due to its ability to control a wide spectrum of rot causing micro-organisms that include *Phytophthora colocasiae* and *Pythium splendens* (Jackson, 1980; Wilson, 1983b) and the fact that it is readily available. It should seriously be considered as an option in Samoa where Taro Leaf Blight is well established. However, recommendations on concentration and duration of dipping seem to have been based more on assumptions than actual researches on taro corms.

Research in Tunisia, in an effort to control potato soft rot and black leg caused by *Erwinia spp.*, found that dipping tuber seeds in a 1.2% solution of sodium hypochlorite for 10 minutes reduced weight loss by 30 to 66% depending on variety and storage conditions. However it did not eliminate inoculum in suberised lenticels or vascular tissue (Romdhani and El-Mahjoub, 1991). A 0.02% solution of sodium hypochlorite was found to be a good

post-harvest disinfectant for *Xanthomonas campestris* pv. *citri* (bacterial canker) on the surface of citrus fruit in Reunion but poor penetration through the peel prevents it from destroying micro-organisms in lesions (Monnier and Ferracci, 1986). A trial to test the sanitising efficiency of sodium hypochlorite, iodine and ethyl alcohol on whole husked coconut surface in Philippines indicated that sodium hypochlorite at 0.01% solution was economical and the most efficient in reducing the bacterial population by 90% (Mabesa *et al.* 1981). In Argentina, a 0.024% solution of sodium hypochlorite was effective in reducing decay on the local tomato cultivar Platense (Barreiro *et al.* 1977). Microbial deterioration of harvested cassava tubers can be prevented by dipping them into a 2.5% solution of sodium hypochlorite (Lozano *et al.* 1978).

As can be seen, the sodium hypochlorite concentration and dipping duration vary with different crops and it is therefore important to carry out actual dipping research on taro corms to determine this information. Dipping for 2 minutes in a 0.1% solution of sodium hypochlorite was selected as a starting point in the evaluation of this chemical as a postharvest dip of taro corms.

Objective and Aims

The main objective of this study was to gain a better understanding of the factors that influence the shelf life of taro corms after cool storage. In line with this objective, the specific aims of the study were as follows:

1. To determine the effect of dipping taro corms in a 0.1% solution of sodium hypochlorite (chlorox) on taro quality;
2. To determine the effect of storage temperature on taro quality;
3. To determine whether taro corms stored at 5°C (as currently practised) suffer chilling damage,
4. To determine whether cool storage is better than storage at ambient temperature,
5. To determine the optimal storage temperature for taro corms,
6. To determine the effect of post-storage duration on taro quality,

7. To investigate the relationship between storage temperature and rootlet growth from the stored corms.

MATERIALS AND METHODS

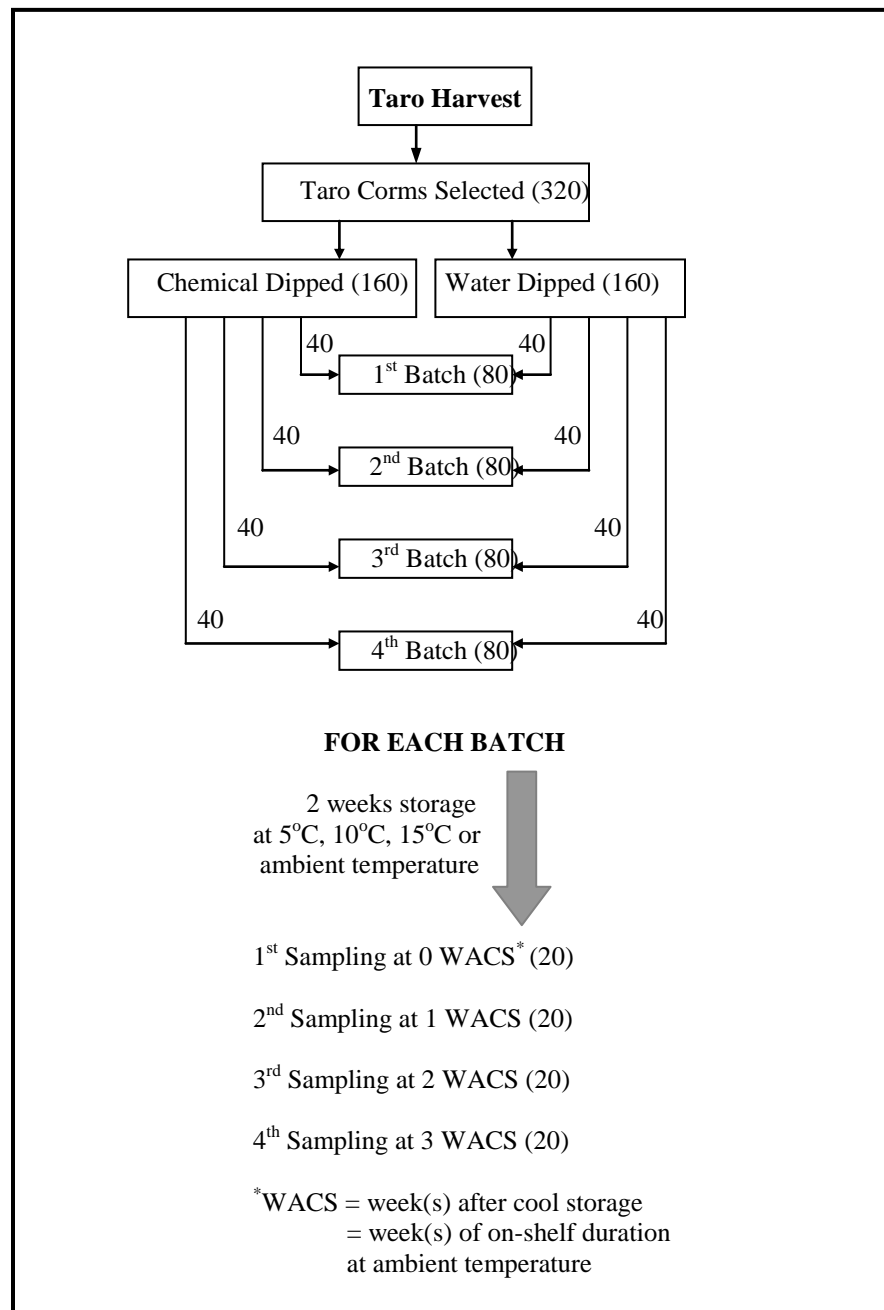
Experimental Procedure

A key objective of the procedure was to harvest taro corms and subject them to the processes and conditions that would befall taro destined for the markets, particularly those located overseas, where a period of cool storage and a post storage duration of on-shelf display at the ambient temperature are part of the process. Various processes and conditions were included to investigate their effect on taro quality - in search of processes and conditions that would minimize the deterioration of taro corm quality. (One of the alternative conditions investigated was storage at the ambient temperature to determine whether there is any advantage of 'cool storage' in the first place.)

As shown in the diagram below, 320 harvested taro corms of similar size and free of bruises and harvest injury were selected and randomly divided into two groups of 160 corms each. Corms in the first group were dipped in a 0.1% solution of sodium hypochlorite for 2 minutes, and corms in the second group were dipped in water for 2 minutes. After dipping in sodium hypochlorite, the 160 corms in the first group were subdivided into 4 groups of 40 corms each; each corm was individually weighed, recorded and labelled, and each group of 40 corms was then packed into a perforated polyethylene (clear plastic) bag and labelled "chemical dipped". Similarly, after dipping in water, the 160 corms in the second group were subdivided into 4 groups of 40 corms each; each corm was individually weighed, recorded and labelled, and each group of 40 corms was then packed into a perforated polyethylene (clear plastic) bag and labelled 'water dipped'.

The 8 bags of taro corms (4 bags of 'chemical dipped' and 4 bags of 'water dipped' corms) were rearranged into 4 batches with each batch consisting of 1 bag (40 corms) of 'chemical dipped' taro and 1 bag (40 corms) of 'water dipped' taro.

The four batches (each with 80 corms) prepared above were then placed in cool storage for 2 weeks under different temperatures - one batch for each of the 4 temperature conditions, i.e., 5°C, 10°C, 15°C and the last batch stored at ambient or normal room temperature. After cool storage, all 4 batches were moved to ambient temperature to simulate the period of display on shop shelves at the ambient temperature. During this period of on-shelf display, the quality of the taro corms was monitored over time by sampling 20 corms (10 from “chemical dipped” and 10 from “water dipped”) from each batch at 0, 1, 2 and 3 weeks after cool storage.



Schematic diagram of the procedures showing initial harvest, dip-treatment and preparation of 4 batches (of 80 corms per batch) of taro corms for cool storage (at 4 different temperatures) for 2 weeks, followed by random sampling (to monitor corm quality) from each batch at 0, 1, 2, and 3 weeks after removal from cool storage and exposure to ambient temperature.

Sampling and % Corm Weight Loss

The 20 corms randomly sampled from each batch at each sampling were analyzed for their quality on the basis of the following parameters: (a) % corm rot, (b) % loss in corm weight i.e. weight loss due to transpiration and respiration, (c) number of rootlets, and (d) weight of rootlets. At each sampling the sampled corms were weighed and % Corm Weight Loss calculated.

Number and Weight of Rootlets, and % Corm Rot

Each corm sampled was observed for rootlet sprouting since failure to sprout is an indicator of chilling damage. The rootlets were removed then counted and weighed. To determine % corm rot, the corm skin was first peeled away with a knife and the weight of the peeled corm (i.e., corm without skin) is taken as total weight; the rotten or rotting parts are then removed with a knife, weighed and % corm rot calculated.

Statistical Analysis

Due to the non-normality of the distributions of all the data (number and weight of rootlets, and corm weight loss and rot) measured during the duration of the experiment, the Kruskal-Wallis non-parametric test was used to compare the individual effects of the different levels of storage period and temperature, and dipping treatment on the above measurements.

RESULTS AND DISCUSSION

Effect of the Sodium Hypochlorite-Dip Treatment

Table 1: Effect of the Sodium Hypochlorite-Dip Treatment on Taro Corms and Rootlets

Dipping	Number of Rootlets	Weight of Rootlets (g)	Corm Weight Loss (%)	Corm Rot (%)
Water	6.7	0.15	4.0	34.2
0.1% Chlorox	8.6	0.28	3.7	26.0
χ^2	1.03	0.52	4.20	4.58
P	> 0.05	> 0.05	< 0.05	< 0.05

The effect of the sodium hypochlorite-dip treatment is shown in Table 1. The 2 minute dip in sodium hypochlorite resulted in a significantly lower rot of taro corms i.e., 26.0% compared to the 34.2% rot in the untreated taro, i.e. taro dipped in water. Furthermore, the sodium hypochlorite-dip also resulted in a significantly lower loss in corm weight (3.7% vs 4.0% weight loss) after cool storage and on-shelf display. The sodium hypochlorite might have formed a layer over the surface or in the skin of the taro corms limiting the loss of moisture and, therefore, corm weight and the chemical layer might have also suppressed the growth and multiplication of the rot organisms. The sodium hypochlorite may have also had a direct and negative, chemical effect on the rot organisms, thereby limiting their growth and multiplication. The difference in the effect of sodium hypochlorite and water, though statistically significant, is not really great; hence the economic benefit of the treatment needs to be investigated. Furthermore, a question that remains to be answered is "Can the 26.0% rotting with sodium hypochlorite be further reduced with a higher concentration of sodium hypochlorite or a longer dip and what will be the corresponding effect on the eating quality of taro? This will also be investigated in future research.

Sodium hypochlorite is a chlorinated inorganic disinfectant used in laundries, swimming pools, ponds and drinking water to name a few. Chlorine is the active ingredient and according to the Environmental Protection Agency of the United States it is counted among those few substances "generally recognised as safe" and that "post-harvest uses on all agricultural commodities are exempted from the requirement of a tolerance, or legal residue limit, because (it poses) no known hazard to the public health". It is allowed as a

terminal sanitising rinse on food processing equipment and in washing or assisting in lye peeling of fruits and vegetables. In solution, it is inherently unstable and degrades with age liberating chlorine gas until all the active strength disappears. This degradation accelerates in temperatures above 40°C and exposure to sunlight. Since all corms to be consumed have to be peeled then boiled or roasted in temperatures of at least 100°C any residues remaining, though unlikely, would be completely driven off. More studies will be carried out in follow up research to determine a dipping procedure that safely exploits advantages offered by sodium hypochlorite and to consider other types of 'safe' chemicals, chemical concentrations, dip durations and effect on eating quality.

Table 1 also shows that the sodium hypochlorite-dip treatment had no significant effect on the number or weight of rootlets that sprouted from the stored taro corms.

Effect of Cool Storage Temperature

Table 2: Effect of Cool Storage Temperature on Taro Corms and Rootlets

Storage Temperature (°C)	Number of Rootlets	Weight of Rootlets (g)	Corm Weight Loss (%)	Corm Rot (%)
5	14.4	0.49	3.0	15.8
10	3.58	0.06	3.1	16.5
15	10.77	0.29	4.9	50.5
Ambient	1.91	0.03	4.4	37.7
χ^2	37.81	29.53	4.40	35.37
P	< 0.001	< 0.001	> 0.05	< 0.001

Four cool storage temperatures were investigated: 5°C, 10°C, 15°C and storage at the ambient temperature - to act as a control. Storage of taro corms at the ambient temperature (approximately 25°C) resulted in a lot of rotting (37.7%), which is significantly reduced with cooler storage - if the cool storage temperature is kept at 10°C or lower. Cool storage at temperatures of 15°C may provide an environment conducive to the growth and multiplication of the rot organisms since storage at 15°C results in more rotting than if the corms were stored at the lower temperatures. However this does not hold true for corms stored at ambient temperature (25°C) where % corm rot is lower than

that of the 15°C treatment. This does not follow the trend that the higher the storage temperature the higher the corm rot. Corms of the ambient storage treatment were the only ones not confined in a cooler and this may have had an effect on the results. This needs further investigation.

Table 2 also shows that cool storage at the lower temperatures (10°C or lower) seemed to reduce the weight loss of the corms; however, this reduction in weight loss is not statistically significant. The results imply that the best means of maintaining corm quality is to keep the storage and on shelf display temperature (e.g. at supermarkets) between 5 and 10°C and that removal to ambient must be avoided unless the ambient temperature at the retail point is within this range.

Cool storage temperatures have a significant effect on the number and weight of rootlets that sprouted from the stored taro corms, however, there is no simple relationship between cool storage temperatures and either the number or weight of the rootlets. It is interesting to note, though, that corms stored at 5°C sprouted the highest number and weight of rootlets, an indication of freshness, and caused the least % corm rot. This implies that chilling damage did not occur at this temperature and that cool storage below 10°C and above 5°C suppresses corm rot. It is important to point out that corms stored at 15°C and lower did not sprout rootlets while in cool storage. Vigorous sprouting was only observed when corms were removed to ambient on-shelf storage. Corms that were stored at ambient had rootlets sprouting during the second week of storage i.e. while corms of the other 3 treatments were still in the coolers. Most of these rootlets had died before sampling was to begin one week later and were therefore not counted. This would have had a big influence on the low number and weight of rootlets recorded for ambient storage as indicated in Table 2. It could be misleading to conclude that cool storage at 5°C prior to removal to ambient storage will cause more rootlet sprouting than just storage at ambient temperature. A general conclusion can be made that cool storage at 5°C suppresses rootlet sprouting and that the corm would resume normal sprouting about 1 week following removal to ambient. In other words, storage at ambient encourages rootlet sprouting while cool storage suppresses it. It must be stressed here that rootlet

sprouting on taro corms, especially those destined for overseas retail markets, is not desirable since their absence is part of the quality requirements. Their presence on corms necessitate their removal thus contributing to labour costs and corm weight loss. Methods of suppressing rootlet sprouting while maintaining corm quality (such as freshness) are important to the taro export industry. These issues and other relationships would be explored further in future studies.

Effect of On-Shelf Duration

Table 3 shows that the on-shelf duration of the taro corms has a significant effect on % corm rot, % corm weight loss, and the number and weight of rootlets that sprouted. The % corm rot, as well as the % corm weight loss, increased with extended on-shelf duration. These are to be expected since the corm is a severed plant organ that is progressing towards total natural decay. The highest number of rootlets was observed after 1 week of on-shelf ambient storage (following 2-weeks of uninterrupted cool storage) and the lowest at 3 weeks. This indicates that rootlet sprouting peaks at the end of the first week of on-shelf ambient storage and that cool storage merely suppresses it. The relationship between weight of rootlets and on-shelf duration is not clear.

Table 3: Effect of On-Shelf Duration on Taro Corms and Rootlets

On-shelf duration after storage for 2 weeks at 5°, 10°, 15°C and ambient (weeks)	Number of Rootlets	Weight of Rootlets (g)	Corm Weight Loss (%)	Corm Rot (%)
0	7.8	0.24	0.8	9.0
1	11.0	0.14	2.9	24.4
2	9.0	0.41	4.7	29.2
3	2.9	0.08	7.0	58.0
χ^2	20.50	14.80	109.98	88.74
P	< 0.001	< 0.01	< 0.001	< 0.001

CONCLUSIONS

Results of this study show that:

1. Dipping the harvested taro corms in a 0.1% solution of sodium hypochlorite significantly reduced % corm rot (from 34.2% to 26.0%) and % loss in corm weight (from 4.0% to 3.7%). However this chemical dip has no significant effect on the number or weight of rootlets that sprouted from the stored corms.
2. In general, storage at cooler temperatures (5 to 10°C) reduced % corm rot and % loss in corm weight.
3. There is no evidence to support the claim that taro corms stored at 5°C suffer from chilling damage.
4. Cool storage at 10°C or cooler is beneficial compared to cool storage at higher temperatures including storage at the ambient temperature.
5. The optimal cool storage temperature is 5°C resulting in the lowest % corm rot and % loss in corm weight. Storage at this temperature also produced the highest number and weight of rootlets following removal to ambient temperature (25°C).
6. During 3 weeks of 'on-shelf display' at ambient temperature (after 2 weeks of storage at 5°, 10°, 15°C and ambient) the study found that as the on-shelf duration increased, % corm rot as well as % loss in corm weight increased linearly while the number and weight of rootlets that sprouted during storage generally increased to a maximum after 1 week of on-shelf duration (for number of rootlets) and after 2 weeks of on-shelf duration (for weight of rootlets) before decreasing to the lowest level (for both parameters) after 3 weeks of on-shelf duration.
7. The cool storage temperature has a significant effect on the number and weight of rootlets that sprouted but there was no clear relationship between temperature and number or weight of rootlets that sprouted. Follow-up studies will clarify the nature of this relationship, if any exists.
8. Follow-up studies will be undertaken to:
 - (i) Determine the effect of storage temperature on taro quality at 0, 1, 2 and 3 weeks of on-shelf display at the ambient temperature. There is also the need to compare these findings with continuous cool storage of corms (including the on-shelf display duration) to ensure optimum corm quality.
 - (ii) Investigate how the type, concentration and duration of the chemical dip may be manipulated to further reduce the deterioration of taro quality over time,

and also investigate the corresponding effects on the eating quality of taro. In this study, ambient temperature refers to the local Samoan ambient temperature of approximately 25°C while for New Zealand and other countries, ambient temperature is totally different. This and other considerations should result in some changes in procedure for future studies that follow on from this one.

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