Pacific Horticultural & Agricultural Market Access Plus Program

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Market Evaluation of the Taro High Pressure Washer and Hot Water Treatment System

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Market evaluation of taro High Pressure Washer and Hot Water Treatment System

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Acronym List

Acronym	Description
MAF Samoa	Ministry of Agriculture and Fisheries – Samoa
SROS	Scientific Research Organisation of Samoa
Ah Liki	Ah Liki Investment Corporation Ltd
PFR	Plant & Food Research (legal entity – The New Zealand Institute for Plant and Food Research Ltd)
MPI	Ministry for Primary Industries (formerly MAF NZ)
HPW	High pressure washer/washing
HWT	Hot water treatment
HPW+HWT	Combined treatment by HPW followed by HWT, hydro-cooling and drying
MeBr	Methyl bromide (fumigation)
SOP	Safe/Standard Operating Procedure

Summary

This modest-sized project has been able to make some important steps towards commercialising a non-methyl bromide (MeBr) fumigation treatment of fresh taro for export to New Zealand, and possibly even Australia. A systems-based treatment involving high pressure washing (HPW – 50 psi for 15 seconds), hot water treatment (HWT – 48°C for 25 min), hydro-cooling (≈ 25 min at ambient temperatures) and overnight drying. This had been developed in previously New Zealand-funded work and was combined with grading and trimming of the taro base (the entire system and process is hereafter referred to as “HPW+HWT”).

The process was documented, appropriate signage developed and staff at Ah Liki (the largest exporter of Samoan taro) were trained to carry out the treatments alongside standard commercial export. In a small-scale commercial setting, 600 taro were treated and exported, and the ability to pass New Zealand import phytosanitary inspection by MPI (Ministry for Primary Industries) was examined on 10 shipments. Efficacy in terms of pest control and quality was compared with results from standard commercial practice, which always results in MeBr fumigation. Quality during shelf life (with and without 7 days of further storage) of the taro was determined on three occasions, the last one combining HPW+HWT with MeBr to determine the impact of fumigation of HPW+HWT-treated taro (worst case scenario).

A commercial engineer was contracted to design and provide an estimated cost for a complete commercial system. This was carried out in collaboration with the exporter and Plant & Food Research (PFR) staff.

Commercial phytosanitary verification trials – export to New Zealand and MPI import inspection

We have shown that a HPW+HWT system can meet New Zealand’s MPI quarantine requirements. We demonstrated this on 600-taro lots exported to New Zealand. In nine out of 10 shipments, consignments were passed by New Zealand’s MPI inspectors. The only failed consignment resulted from an internal nest of termites in one taro (many alive at the time of inspection) that might have been detected with more careful grading. This emphasis on careful grading during packing, and the design of a post-HPW grading station is an example of the higher standards and a stronger systems approach to market access that we are recommending.

Commercial taro quality verification trials – export to New Zealand and out-turn quality of HPW+HWT- and MeBr-treated taro

The key quality problems during shelf life are rots of the body and the cut base of the taro corms. There were some differences in response between the trials, but the following overall conclusions can be made. For taro held at 20°C (shelf life) after ship arrival (no further storage), rots on the body of taro corms were found to be lower in HPW+HWT-treated taro than MeBr-only treated taro in most cases.

Similar results were observed for taro stored for another 7 days then moved to shelf-life conditions. While there were rots on the cut base of the taro, no clear trends were evident (i.e. comparing HPW+HWT with MeBr), nor were there in the appearance of the petiole base. Because of the retail practice of trimming taro during shelf life (every day or two), rots to the cut corm base and leaf petiole bases are not of as much commercial significance as body rots.

Thus, shelf life quality of HPW+HWT-treated taro was generally as good as, or better quality than that of MeBr-treated taro, even if HPW+HWT taro were subsequently MeBr treated. This has given the importer confidence in the quality from a supply chain perspective. In consultation with the key Samoan commercial exporter, a system was designed and approximately costed using New Zealand suppliers.

The increase in rots during product storage for an additional week is an important result since this demonstrates the challenge of reaching more distant markets such as Australia, where an additional 5 weeks of storage may be required.

Design and cost of commercial HPW+HWT unit

Consideration was given to throughput requirements, now and in the future, as well as slight changes to the system based on the need for a more robust system and the challenges of plant material binding to the existing brush system. The final system developed includes an incoming trimming and light grading step, followed by HPW, a grading table, then HWT, a cooling bath, drying tunnel, and finally a bagging station. The

design of the full commercial treatment system allows continuous treatment, grading, drying and bagging of taro at a throughput that should meet future growth potential. Approximate costs were sourced from New Zealand providers, and costs were $NZ989,333 (WST1,760,000) and $NZ227,000 (WST404,000) for other considerations (shipping and commissioning), with a total cost of $NZ1,216,393 (WST2,180,000 / AUD$1,154,772).

While this treatment system has been shown to be an effective alternative to MeBr fumigation in a commercial setting, it does have other negative aspects such as energy use (with related carbon footprint impacts), and water use. However, mitigation of these could be achieved by use of alternative technologies such as solar heating and more extensive water recycling.

A significant potential benefit of the HPW+HWT system is the potential use of this system for taro leaf blight control, and thus access to the Australian market. This may open up a new market for fresh taro and would clearly provide significant potential fiscal benefit to Samoa by increasing exports.

Conclusion

Using semi-commercial trials, this work demonstrated the potential of HPW+HWT as an effective replacement for MeBr fumigation for taro to access New Zealand, and even potentially Australia should control of leaf blight be proved effective. The project also developed designs and costings for a fully commercial system designed to process 33.5 tonnes of taro per 9-hour day.

General introduction

Taro corms are exported to New Zealand, and are a popular product with the Pacific consumer sector. Taro exports are a significant portion of Samoa's export revenue, accounting for 14% of all exports, and being the largest horticultural export. However, taro are a challenging product from a biosecurity perspective owing to the presence of mites and nematodes, soil residues, the nature of the corm – which is pitted and rough with many crevices and holes – and the presence of dead leaf stems, which are very fibrous. Thus, nearly all imported taro from the Pacific Islands are fumigated with methyl bromide (MeBr). The Ministry for Primary Industries (MPI) wishes to reduce the application of MeBr – an ozone-depleting gas – because its use is being limited (recapture requirements), and its general use is being more closely examined worldwide. MeBr alternatives are generally more complicated to use and have very considerable lead-times to develop through to robust commercial systems. Unfortunately, these alternatives nearly always have considerable downsides such as treatment cost, treatment time, significant capital investment, or the need for a systems approach/hurdle technologies – i.e. multiple treatments.

Use of high pressure washing (HPW) followed by a hot water treatment (HWT) can reduce, and/or eliminate pests arriving in New Zealand and thus reduce use of MeBr. In collaboration with government and commercial stakeholders in Samoa, and following several years of initial research, scientists from PFR in New Zealand have been trialling a specially engineered (pilot-scale) high-pressure washing machine and hot water treatment for taro to help to remove or kill the frequently intercepted pests during pre-export processing. This was funded through the New Zealand Government-funded Better Border Biosecurity (B3) program (C17.11 – Risk reduction and quarantine treatments offshore).

The development of this system started in 2014 and the journey is summarised in Section 2.1.2 (below), but in short it involved refining treatment conditions for both HPW and HWT stages for insect kill or removal while balancing taro quality following storage. This work was conducted at Nu'u Research Station and Atele Packhouse with MAF Samoa and more latterly with Ah Liki.

By 2020, a system was developed with a single standard HPW and HWT combination, and export of 600-taro consignments along with commercial exports to New Zealand, through the importer Mellow Foods, were developed and trialled to examine out-turn.

The current intervention is now required to continue to build exporter and importer confidence in the system; to address the lessons learned from the trials to date, including what will be involved in converting to full-scale commercial operations; and to update the various operating procedures and guidance materials.

PHAMA Plus will work with commercial facility/exporter, Ah Liki (the leading partner), with PFR and MAF providing supporting functions to finalise the feasibility work on the HPW-HWT, and to assess if this treatment could be viable at a commercial scale while still ensuring that the fresh taro comply with New Zealand's biosecurity import requirements and commercial quality requirements.

At a meeting with Ah Liki on 14 February 2020, it was reported that the batch that was sent to New Zealand (for PFR quality testing and MPI inspection at the border in New Zealand) in January 2020 was a success. The February–April 2020 batches were also successful, and both cases provide confidence in proceeding with further feasibility work, including the likely costs (additional and savings) of the HPW-HWT option. After the intended work is finished and the viability of the HPW-HWT assessed, PHAMA Plus with Ah Liki, PFR and MAF will be in a better position to decide (based on the viability assessment) on the feasibility of scaling up to a commercial level, with a focus on involving other exporters.

PHAMA Plus agreed to further develop this technology package by:

1) Developing training materials and training staff in use of the HPW+HWT system to carry out taro treatment and export (SOPs (Standard Operating Procedure, manuals, signage)
2) Carrying out commercial export of 10 shipments of taro that have been treated with the HPW+HWT system and inspected by MPI staff

3) In consultation with the lead exporter, scope then design a commercial unit capable of treating taro for export to New Zealand. A reasonable estimate of cost for such a unit will be developed (this is not a full detailed design/drawing/costing)
4) Conducting a workshop on the findings of the verification trials.

This report covers points 1–3 of the above, and a virtual seminar was held on 15 July 2021 (point 4), as well as presenting the design suggestions.

Introduction and background

Current taro export protocol

The current export system is briefly summarised as follows.

Taro is harvested in the villages, and involves pulling from the ground, trimming of the top and bottom, and subsequent cleaning by hand to remove as much leaf material and roots as possible. This involves the use of water and cleaning tools such as coconut shell, a scrubbing brush or similar.

Taro is then transported by ute or small truck to the packhouse where further cleaning is carried out if needed, although significant effort has gone into ensuring cleaning occurs in the villages, to streamline the packing process. Taro are not graded by size, and generally little quality grading is done in the packhouses. Air-drying on mesh frame-tables is carried out if the taro are wet, sometimes overnight or with the use of fans.

Taro are lightly graded for quality (particularly rots) and placed into plastic woven sacks with holes pre-cut to a total weight of 20 kg, which, depending on taro size, is generally ≈ 30 taro (although some varieties tend to be smaller or larger).

A phytosanitary certificate is issued by MAF Samoa and taro are loaded into 20-foot reefer containers set at 8–10°C, for export to New Zealand on a fortnightly basis. On arrival at the importer (from The Ports of Auckland), a sample of 600 taro are inspected by MPI staff in accordance with MPI regulations. If mites or nematodes are found, fumigation with MeBr for 4 hours is carried out, but if snails are found (a rare occurrence), fumigation for 24 hours is necessary, generally resulting in very extensive damage to the taro. Taro are then moved to the importer's coolstore for distribution, and are generally kept cold until they are displayed for sale.

For retail display at ambient temperatures, the brown or dry outside leaf bases are removed by hand (Figure 1), the top re-trimmed, and any rotten or poor quality tissue cut off from the base. Generally this process is repeated every day or two during the shelf life/display period (a number of days) to maintain as fresh an appearance as possible. This means that after a week or so of display there is little or no leaf base present (Figure 2Figure 2. Retail display of taro in New Zealand, showing reduced removal of poor-quality leaf petioles and taro flesh over shelf/display time.A). As tissue rots or dries out, further taro tissue is trimmed away and the price is reduced to clear (Figure 2B).

Figure 1. Trimming of taro out of coolstore for display at retail outlet. The corm base is cut and leaf petiole bases that are brown or shrivelled are removed.

Display of taro with reduced petiole base

Older taro with no leaf base and lowest quality (in the bags on the right)

Figure 2. Retail display of taro in New Zealand, showing reduced removal of poor-quality leaf petioles and taro flesh over shelf/display time.

In terms of timing of this entire process, the estimated timeframes are outlined in Table 1. Overall the aim is to minimise the time between harvest and packing, since taro quality decreases with longer storage time, particularly after three weeks. In total, therefore, it can take 10-14 days to reach the wholesaler from harvest, who will very quickly pass it to the retailers. It should be noted that COVID-19 has caused significant changes to shipping reliability and processing at the wharves. Thus, overall, the storage time from harvest to sale in New Zealand is generally between 2 and 3 weeks, allowing another week for shelf life / retail display and sale. The disruption to shipping/supply chains from COVID-19 can add up to another week.

Table 1. Estimated timing for the taro supply chain from Samoa to retail sale in New Zealand.

Supply chain stage	Estimated time
Harvest to the Samoa packhouse	2-3 days
Taro to be processed and packed at the packhouse	1-2 days
Ship loading in Samoa (Apia)	1
Voyage time to New Zealand	7-9 days
Once in New Zealand, taro wil be held by the ports and MPI allowing time for inspection and fumigation	4 days
Retailers will keep taro for an additional 7–10 days in storage to supply the second week of sales (since ships arrive fortnightly)	7-10 days

Development of the washing and hot water treatment protocol – B3-funded research

Over the last seven years, the New Zealand-funded B3 (Better Border Biosecurity) programme has examined a wide range of factors in developing the current recommended treatment. The treatments were carried out in Samoa, taro were exported to New Zealand in commercial consignments with appropriate MAF Samoa phytosanitary certification, the product was inspected by MPI, and some taro quality work was carried out simulating New Zealand shelf life conditions.

The research commenced in 2014 with a visit to Samoa to scope the potential for HWT to control mites and nematodes for access to the New Zealand market, while retaining product quality. This visit sought to introduce the programme, seek inputs and advice from MAF Samoa researchers and taro corm exporters in Samoa, identify prospective work teams, evaluate facilities, collect mite- and nematode- infested materials to initiate laboratory colonies for hot water treatments, and identify the equipment and the resources necessary to carry out the project to a successful completion.

Following this initial visit, trials were carried out over ≈ 1 year (e.g. Chhagan et al. 2015) carrying out diverse trials examining the duration and temperature of HWTs for control of mites and nematodes using small-scale water baths (up to 90 L). Treatments of insects off taro between 47.5 and 52.5°C were carried out and taro quality was examined for treatments ranging from 47.5 to 60°C for a range of durations. Nematodes (Meloidogyne spp. and Rotylenchulus spp.) off taro were found to be more easily controlled than mites, and mite eggs were more difficult to kill (Jamieson et al. 2016). Some idea of tolerance of two different varieties of taro to HWT was gained, where product was stored to simulate export to New Zealand, although shelf life conditions in Samoa are clearly warmer than in New Zealand. Limitations to taro quality were leaf-base browning and rots, although the leaf-bases can be peeled off – a current practice for imported taro.

In 2016, trials explored the potential to examine infestations of mites on taro, but it was found that this was only possible on very poor quality taro, and while data were obtained, the rotten nature (disintegrating) of the taro product probably introduced significant anomalies to the results. Further taro quality trials were carried out and in 2016 the concept of a high pressure washing (HPW) step (rolling brushes and overhead nozzles) was introduced, which aimed to improve the cleaning by removing dirt and the many stem base residues and roots. A HPW was designed, built, tested, shipped to Samoa and installed at Atele packhouse (Woolf et al. 2017a,b). Trials examined duration and pressure, and a low pressure (<50 psi) for ≈ 15 seconds was identified as effective. Various combinations of HPW and HWT were carried out, including on newly developed cultivars, and storage trials were done in Samoa.

In 2017, a pilot-commercial HWT system (≈ 2 m^3) waterbath was modified, shipped and installed with the HPW at Atele so that larger amounts of taro could be treated at one time. The HWT system could treat 12 crates of taro (≈ 250 corms) and could be applied immediately after HPW. Refinement of combination treatments was carried out which led to lower temperatures (48 to 50°C), which were needed to maintain taro quality following storage and shelf life simulation.

In 2018, the two systems were moved to Ah Liki packhouse, since space and power was required at Atele packhouse for processing of frozen taro for export. Ah Liki was also well placed to carry out commercial trials and to export the product to New Zealand where their importer (Sam Yip of Mellow Foods, Ōtāhuhu, Auckland) was willing to work with PFR to coordinate MPI inspections and fumigations as necessary.

Because artificial insect inoculation could not be carried out, it was decided that exporting taro to New Zealand as part of a commercial shipment could allow a "real world" test, because MPI inspectors could inspect the taro for presence of insects in the standard commercial manner. To achieve this, the taro needed to be effectively isolated from other taro, and a separate phytosanitary certificate issued.

Treatment combinations were refined comparing 48°C for 25 min and 50°C for 12.5 min with and without HPW treatment, and taro quality was assessed at PFR (Jamieson et al. 2018). Treatment quality was compared with that of control (untreated) taro that had been fumigated, and found to be roughly equivalent. Live insects were found at higher temperatures and short durations (50°C for 15 min).

In 2019, continuing trials developed a standard treatment (HPW of 50 psi followed by 48°C for 25 min), air-drying and a packing system (fine mesh bags inside standard plastic sacks). We also introduced the recommendation that the base of the taro be trimmed before export, which removed the old taro tissue – an area that was high risk for harbouring insects and also being more prone to rots. This also meant that taro were handled individually and so this increased the chance the poor quality product would be removed. Export and storage trials were carried out.

In 2020, a new MP policy of fumigation was made that required treatment duration to be 4 hours (no longer accepting the 2-hour treatment for eggs), unless snails were observed in which case treatment must be for 24 hours. Product quality was compared between fumigated controls and HPW+HWT product, where it was found that HPW+HWT-treated product was superior in quality for assessments in the week after arrival, and in the second week where product was coolstored (as happens commercially for the wholesaler to bridge the supply until the next ship arrives).

The PHAMA proposal was developed in late 2019 and funding commenced in July 2020, during which time shipments were carried out with MPI inspections. COVID-19 affected operations in both countries, disrupting shipments, and staff time via work from home restrictions etc.

The above work was carried out in collaboration with MAF Samoa, Ah Liki, and Mellow Foods – we very much appreciate the time, effort and significant in-kind contributions made by all parties.

Pilot pressure washing/hot water treatment system

The system developed during the previous B3-funded research stream as outlined above led to a standardised protocol using two key units – the HPW and the HWT systems.

Documentation and training in use of pilot washing/hot water treatment system

The following key steps were developed from previous B3-funded work and this PHAMA PLUS project.

Trimming/grading

Very poor-quality taro is graded out in nearly all cases in the field and are not sent to the packhouse. However, some parts of the taro corm may be a biosecurity risk. At arrival at the packhouse, corm tissue with holes/cavities, wounds, or rotten areas (particularly the base of the taro) should be trimmed off since they may harbour pests. The old taro tissue, particularly where there is a "waist" shape, is also a risk (Figure 3) should be trimmed, and thus generally most of the base of the corms are trimmed.

Rotten base of taro – Unacceptable

Narrow “waist” unacceptable – Trim/cut off

Narrow “waist” unacceptable – Trim/cut off

Figure 3. Trimming/grading step. It is critical to remove taro or tissue that is at risk of harbouring pests.

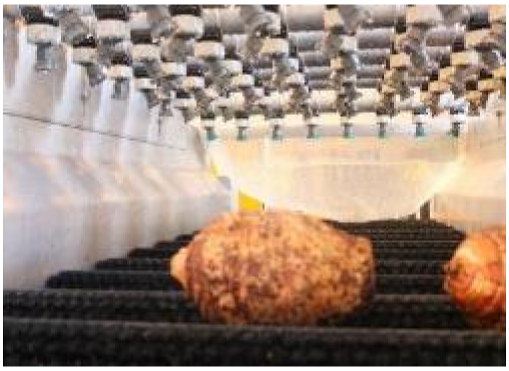
High pressure washing (HPW)

Pressure washing over rolling brushes was found to be effective for cleaning the taro (Figure 4). The standard treatment was a pressure of 50 psi (3.4 bar) for 15 seconds, and treatment time was determined by the feed rate of taro, since taro move through the washer by pushing against one another (the brush rollers are static).

Tank and filtration on left

Infeed

Angled nozzles



Brush bed (rotating)

Figure 4. High pressure washer system for taro.

Hot water treatment (HWT) and cooling

The hot water treatment that was found to be effective for disinfestation and did not reduce taro quality, was 48°C with 25 minutes of immersion time (Figure 5). To achieve the target temperature, this large waterbath was heated to a slightly higher temperature (≈ 0.5°C higher than the target) and the set temperature dropped back once the taro were immersed. Temperature is defined as the return temperature from the bath.

Following HWT, it was important to remove the heat from the taro, as it was observed in previous work that placing warm taro in sacks resulted in significant "sweating", with condensation in the sacks that tended to result in increased rots. To remove heat, an ambient temperature bath was used (

Figure 6). Taro were immersed in that bath for approx. 25 minutes.

Drying

To ensure complete drying and cooling, taro were placed on metal racks (Figure 7) overnight at ambient temperatures. The following day the product was bagged and placed in the refrigerated container for export.

Figure 5. Pilot-scale hot water treatment (48°C) of approx. 200 kg of taro in 12 plastic crates. Water is pumped under the crates, flows up the stack and over the top where it flows over a weir and is heated using electric elements.

Figure 6. Taro in the cooling bath. Note the natural orientation of most taro with leaf petiole upwards.

Figure 7. Overview of Ah Liki staff carrying out the treatment process. Incoming taro on the right (bagged and in the flume (top right), high pressure washer (middle- right), hot water bath (left), and taro drying on racks (bottom left).

Training

In the course of the B3 work and in all the experiments conducted by PFR staff at Ah Liki, the packhouse staff worked with PFR staff to carry out the various trials, and therefore gained a good deal of experience. For the PHAMA PLUS project, formal training, systems and signage were developed. Training was given to Ah Liki packhouse staff including hands-on demonstrations of how the machines were to be operated and cleaned. An experimental protocol was developed and translated to Samoan (Annex 1.1), and specific training was given to the packhouse staff, including the packhouse manager, as to how the experimental protocol was to be carried out. This training included a complete run-through of an experimental consignment with PFR staff present. Print-outs of instructions that had been translated into Samoan from English. Instructions on use of the HPW and HWT units are provided in Annex 1.2 and 1.3, respectively, and were attached to the machines for future reference. At the conclusion of the November 2019 visit it was agreed that the Ah Liki staff were sufficiently skilled and trained to be able to carry out the experimental consignments without supervision. This was extremely timely given the November visit was the last PFR staff visit to date, owing to the COVID-19 outbreak.

It is important to note that the treatment instructions printed out and placed on the hot water bath were slightly different from those written in this report. That is because there is an offset with the probe placement that means that its readings are not consistent with what is actually being delivered to the taro. To rectify this, the instructions have a slightly different temperature setting so that the taro actually receive the water that is 48°C (as verified by a temperature probe placed in the water in the "return" position. In subsequent work, the key aim is to achieve the 48°C target.

Aside from the staff at the Ah Liki packhouse carrying out the experimental consignments of taro, there were training and collaborations with other Samoan entities, namely MAF (Ministry of Agriculture and Fisheries), SROS (Scientific Research Organisation of Samoa), and Ah Liki head office staff. MAF staff were particularly instrumental in the initial stages during the experimental phase of work, and the SROS staff provided support when requested and especially with the translations. The staff who were trained are recorded in

Table 2.

Table 2 Staff trained in the PHAMA-PLUS project.

Institution	Female (5)	Male (10)
Ah Liki	Ana Lilo	Alex Brunt
		Asione Ah Chong
		Setu Tomi
SROS	Seeseei Molimau-Samasoni	Tieko Lemaota
	Veronica Vaaiva	Sione Iosefa
MAF	Fa'alelei Tunupopo	Vesi Tapuni
		Sam Pulou

Commercial phytosanitary verification trials – export to New Zealand and MPI import inspection

Introduction

Our previous work has shown that inoculating mites and nematodes onto export quality taro is not a reliable means of determining disinfestation efficacy, and research carried out with taro that already contained mites (by necessity quite rotten) led to compromised results (Jamieson et al., 2018).

One way to determine the efficacy of the HPW+HWT system is to carry out commercial export of treated product that is inspected by MPI in the standard manner – i.e. 600 units of product.

To this end, it was agreed that carrying out 10 exports would serve as the best means of examining efficacy and provide the fastest path to demonstrating efficacy in a near-to-commercial system.

Materials and methods

A brief summary of the protocol is provided here, and the detailed protocol used is presented in Annex 1.1. As noted above, Instruction Manuals for the HPW and HWT are provided in Annexes 1.2 and 1.3, respectively.

Export quality taro were used, i.e. without holes, wounds or rotten tissue. The old basal tissue was trimmed off.

The control (untreated) taro was handled in the standard manner and placed in standard sacks (with holes pre-cut in the sacks), then labelled.

High pressure washed and hot water treated taro: 600 taro (≈ 30 sacks) were passed through the HPW unit (≈ 15 seconds – about two taro every second) and checked for quality. Hot water treatment for 25 min at a temperature of >48°C was carried out followed by cooling for approximately 25 min in an ambient water bath. Taro were then air-dried overnight, placed in an insect-proof cotton bag sealed with cable ties, and carefully placed into standard sacks, then labelled.

A separate phytosanitary certificate for the treated taro was made along with the control (untreated) taro, and the taro were shipped to New Zealand in a standard refrigerated container. Shipments and inspections are listed in Table 3.

Table 3. Information on shipments and inspection for taro exports from Samoa to New Zealand.

Run #	Date	Product quality assessed	Notes
1	16/12/2019	No	PFR present, only one phytosanitary cert.
2	30/01/2020	Taro quality assessed	PFR present,
3	5/03/2020	No	PFR Not present,
4	7/04/2020	No	PFR Not present owing to lockdown
5	10/08/2020	No	PFR present
6	27/08/2020	No	PFR not present owing to lockdown
7	15/09/2020	No	PFR present
8	2/10/2020	No	PFR not present
9	29/10/2020	No	PFR not present
10	13/11/2020	No	PFR not present
11	7/12/2020	Taro quality assessed	PFR not present
12	11/5/2021	Taro quality assessed	PFR not present, only one phytosanitary cert.

Results and discussion

Since December 2019 to May 2021 taro have been treated offshore using our hot water and high pressure washing system, dried, bagged, and shipped to Auckland Mellow Foods (Sam Yip). Nine of the twelve consignments of taro were given clearance to be released without fumigation by MPI inspectors who inspected all the 600 treated taro for pests. Two of the treated consignments were unable to be inspected because of a clerical issue. One of the consignments was inspected and required fumigation owing to the presence of live termites – note that termites had not been investigated in this research. Each consignment had been high pressure washed and then hot water treated at a temperature of 48°C for 25 minutes. All consignments that were inspected were found to have no target pests alive (mites and nematodes), while at the same time all the non-treated standard commercial consignments (controls) were fumigated for 4 hours using MeBr because of the presence of mites and or nematodes (Table 4).

Table 4. Results from shipments and inspection for taro exports from Samoa to New Zealand.

Consignment number	Date	Insects found	MPI clearance given	Notes
1	16/12/2019	Nematodes ~ commercial consignment	N/A - owing to lack of separate phytosanitary certificate *	PFR present at inspection, only one phytosanitary certificate
2	30/01/2020	No live pests	Yes	PFR present at inspection
3	5/03/2020	No live pests	Yes	PFR Not present at inspection
4	7/04/2020	No live pests	Yes	PFR Not present at inspection owing to lockdown
5	10/08/2020	Termites	No – due to termites *	PFR present at inspection
6	27/08/2020	No live pests	Yes	PFR not present at inspection owing to lockdown
7	15/09/2020	No live pests	Yes	PFR present at inspection
8	2/10/2020	No live pests	Yes	PFR not present at inspection
9	29/10/2020	No live pests	Yes	PFR not present at inspection
10	13/11/2020	No live pests	Yes	PFR not present at inspection
11	7/12/2020	No live pests	Yes	PFR not present at inspection
12	11/5/2021	Nematodes ~ commercial consignment	N/A - owing to lack of separate phytosanitary certificate *	PFR not present at inspection, only one phytosanitary certificate

* Container fumigated for 4 hours

Commercial taro quality verification trials – export to New Zealand and out-turn quality of HPW+HWT and MeBr-treated taro

Introduction

Previous work has shown that the quality of taro that had been HPW+HWT treated and non-fumigated was as good as that of unwashed product that had been fumigated (in response to MPI inspection, which found the presence of insects – mostly mites). However, the importer had some reservations that if taro that had been HPW+HWT-treated was fumigated (i.e. if insects were found in some shipments), that quality might be reduced. The first two trials presented below show the comparison of shelf-life quality of HPW+HWT-treated taro with that of MeBr-fumigated corms. The final trial examined the impact of fumigation on taro by sourcing product that had been both HPW+HWT treated AND fumigated. This final trial was somewhat challenging because of shipping times, COVID-19 and staff availability.

Because taro are stored for an additional week in order to fill supply between fortnightly ship arrivals, we divided the taro into two groups – “No additional storage” and “Additional storage”, thus reflecting retail practice.

The work included here was funded by the B3 (Better Border Biosecurity) programme, but is included here since it is important to provide confidence to exporters and importers alike.

General materials and methods

Taro were harvested, cleaned after harvest and transported to the Ah Liki packhouse. The HPW+HWT treatment of 600 taro was carried out by pressure washing (50 psi for 15 seconds) followed by HWT (48°C for 25 min), hydro cooling, overnight drying and bagging in special insect-proof sacks (see Annex 1 for details). A separate phytosanitary certificate was provided for these sacks. The remainder of the container was filled with taro treated in the standard manner (i.e. standard industry control). The container was shipped to New Zealand in the standard manner to the importer Mellow Foods (Mangere, Auckland). All HPW+HWT-treated taro were inspected by MPI staff, as were the untreated taro, and if insects were found (which they were in all untreated taro), a 4-hour MeBr fumigation was carried out. If treated taro (i.e. HPW+HWT) were not found to have pest insects (i.e. separate inspection of the two lots – two phytosanitary certificates), PFR staff then uplifted and transported them to Mt Albert Research Centre (MARC), Auckland. For Trial 3, HPW+HWT-treated taro were exposed to fumigation, to provide a “double treatment”.

The two treatments lots were divided into two groups – the first were placed directly to 20°C for assessment (i.e. “no additional storage”). The second group were placed at 10°C for a further week (“additional storage”, simulating the holding of taro for one week as happens in retail; see Section 2.1.1). The taro were assessed during the shelf-life period for body rots (Figures 8 to 11), petiole quality, petiole colour and firmness. The taro held at 20°C were laid out on tables and visually assessed, and petioles were trimmed if necessary. In all three trials taro were assessed by using the rating scales below.

1) Body rots – area of body of the taro with rot:
    - 0%
    - 1–5 %
    - 6–10%
    - 11–20%
    - 21–30%
    - 30–100%
2) % of cut base with rots – the proportion of the cut stem with rots present:
    - 0%
    - 1–25%
    - 26–50%

- 51–75%
- 76–100%

Figure 8. Body rots in taro. Rots can be seen concentrated in one spot around the centre. The browning and shrivelling the leaf base petiole is also apparent.

Figure 9. Body rots in taro. Rots can be seen scattered all around the body of the taro. The browning and shrivelling the leaf base petiole is also apparent.

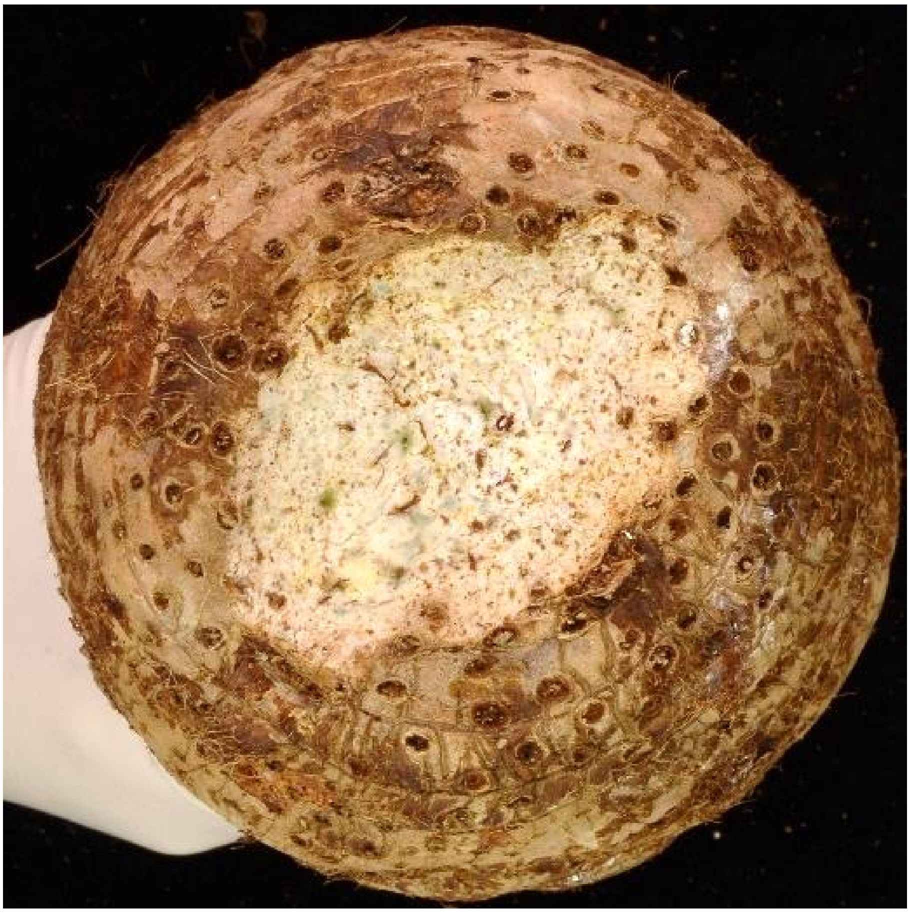


Figure 10. Rots in the cut base of the taro.

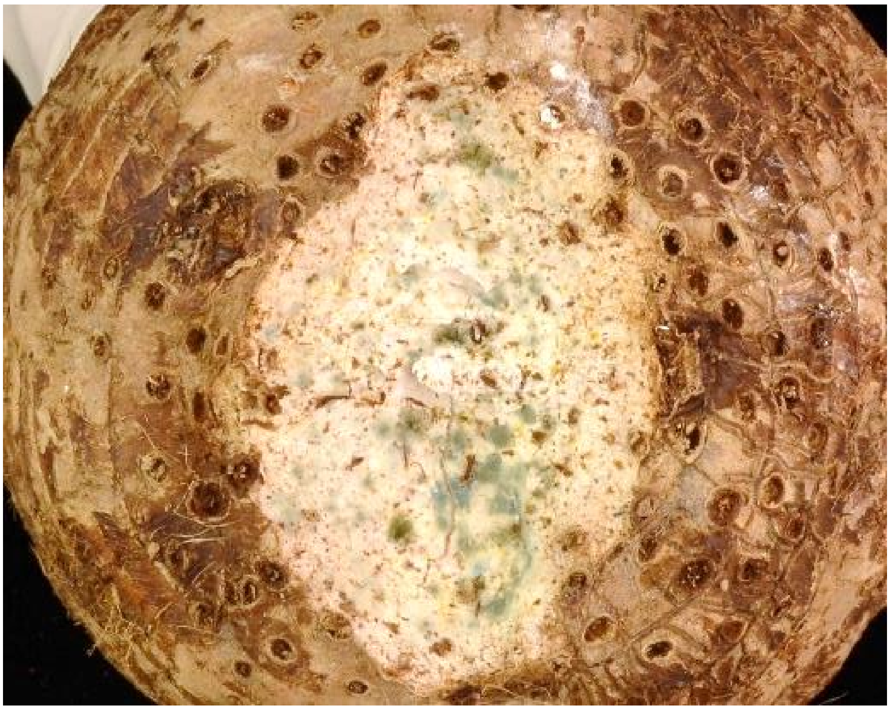


Figure 11. Cut base rots close up.

Data are presented as bar graphs (Figures 12 – 23) with the proportion of fruit (i.e. percentage of taro) that fall into each of the categories (i.e. areas of the body or cut surface that had rots). The best results are the higher proportions of taro in the lower categories (i.e. 0%) and the worse quality are where there are more taro in the higher categories (right side of graphs).

Three "HPW+HWT plus MeBr" shipments were made, from January 2020 to May 2021 (Table 5).

Table 5. Chart showing the sample numbers of taro and treatments made.

Trial number and timing	MeBr [Y]	HPW+HWT [Z] only	Total # of taro
Trial 1 – January/February 2020			
No additional storage	10	11	21
Additional storage (1 week)	10	10	20
Trial 2 – December 2020			
No additional storage	21	15	36
Additional storage (1 week)	15	16	31
Trial 3 – May 2021			
No additional storage	7	7	14
Additional storage (1 week)	8	7	15

[Y] Commercial methyl bromide fumigation for 4 hours.

[Z] High pressure washing and hot water treatment followed by hydro-cooling and drying

Trial 1 – January/February 2020 – Comparing HPW+HWT with MeBr treatment

Materials and methods

The consignment arrived in Auckland at Mellow Foods on 30 January 2020. A total of 600 taro (30 bags) were closely examined by MPI in the presence of PFR staff. Only dead mites were found in these inspections, so no fumigation was required for the treated taro. Two bags of the non-fumigated taro and two bags of the commercially treated taro (fumigated with MeBr) were brought to MARC. Half of them were placed directly to 20°C ("no additional storage") to simulate the condition they would be subjected to when being sold; the other half were stored at 10°C to be assessed one week later ("additional storage"), representing the longer storage time before being sold.

For the "no additional storage" group, taro in the first half of the consignment were assessed on the day they arrived (day 0), then on the second, fifth and seventh days at 20°C. For the "additional storage" group, after storage taro were evaluated on the 0, second and fifth days.

Results and discussion

The impact of MeBr on body rots was clear even with no storage, with MeBr-treated taro having more rots (i.e. higher proportion of taro with more than 0% rots; Figure 12) than HPW+HWT-treated taro. After 7 days at 20°C, most MeBr-treated corms had body rots in excess of 6% of the surface of the corm. In contrast, HPW+HWT-treated corms had a maximum rot extent of 5% after seven days at 20°C. The difference between HPW+HWT and MeBr treatment was even more marked after an additional week of storage at 10°C (Figure 13). At day 0, HPW+HWT-treated taro had <5% of the body affected by rots, while all fumigated taro had more than 6% rots ,and over 75% of the taro were between 11 and 30% affected. After 5 days of shelf life, 75% of the HPW+HWT-treated taro had no body rots, whereas for fumigated taro, 100% of the taro body rots were in excess of at least 11%.

For rots on the cut base of the taro, there were no clear differences between HPW+HWT and fumigation for "no additional storage" taro (Figure 14). However, after an additional one week of storage, MeBr fumigation resulted in increased rots on the cut base (Figure 15). At the first day of assessment there were > 50% of the HPW+HWT-treated taro with no rots at the cut base, while taro in the MeBr treatment on the same assessment day had at least 50% of the taro with a minimum of 25% rots on the cut base.

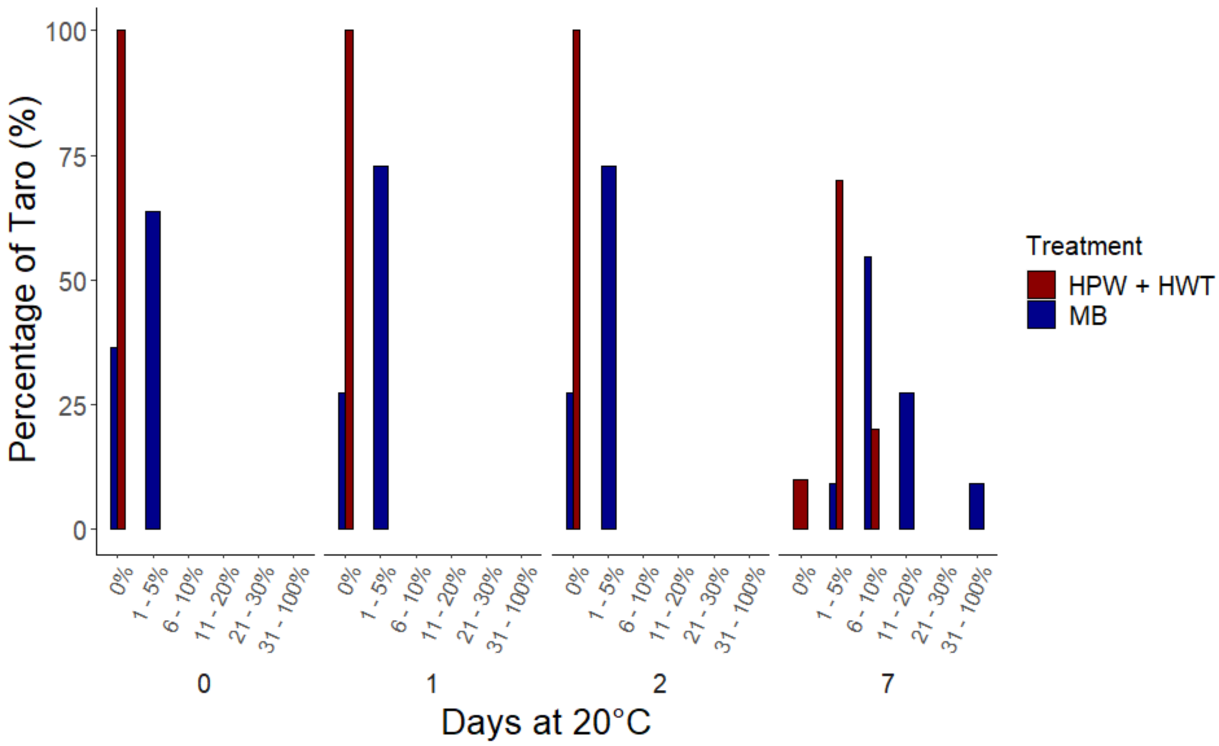


Figure 12. January/February 2020, body rots, no additional storage. Proportion of body rots for each category (i.e. the proportion (%) of taro surface with rot expression) during shelf life (20°C) following shipping to New Zealand. HPW+HWT: Taro were pressure washed (50 psi for 15 seconds) and hot water treated (48°C for 25 min). MB: Non-treated (control) taro fumigated with MeBr on arrival in New Zealand.

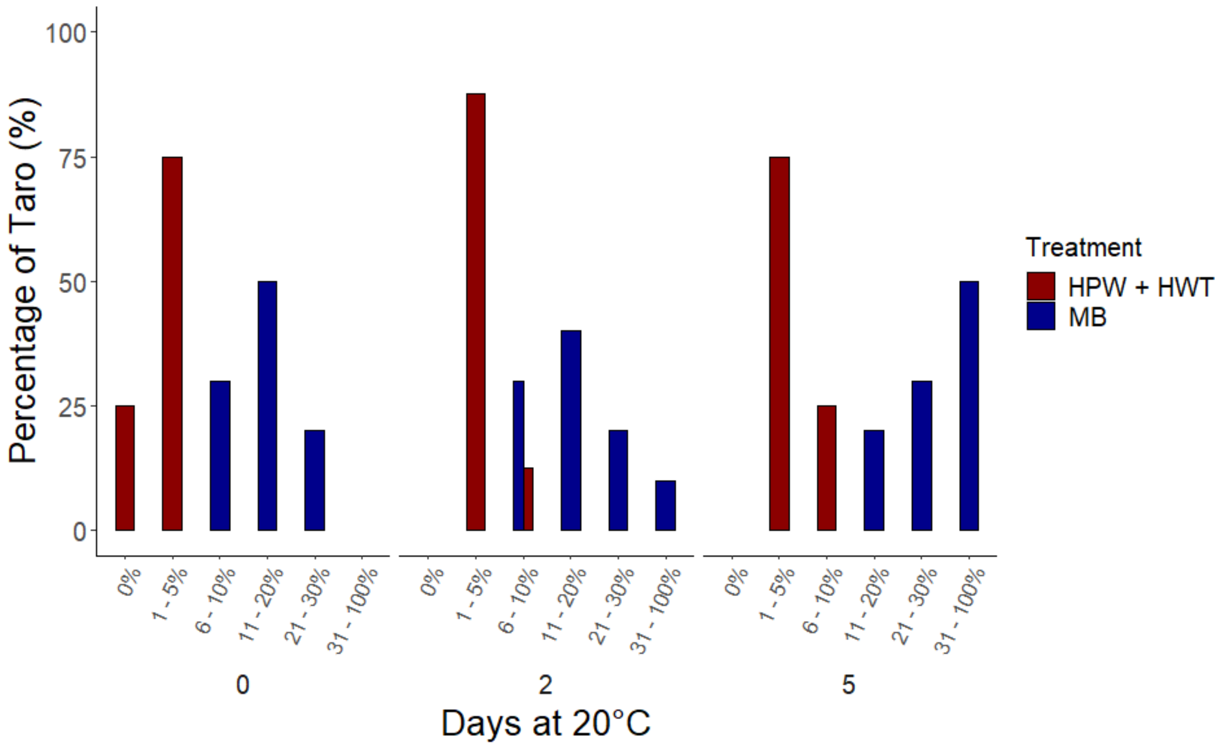


Figure 13. January/February 2020, body rots, additional storage. Proportion of body rots for each category (i.e. the proportion (%) of taro surface with rot expression) during shelf life (20°C) following shipping to New Zealand and one week of additional storage. HPW+HWT: Taro were pressure washed (50 psi for 15 seconds) and hot water treated (48°C for 25 min). MB: Non-treated (control) taro fumigated with MeBr on arrival in New Zealand.

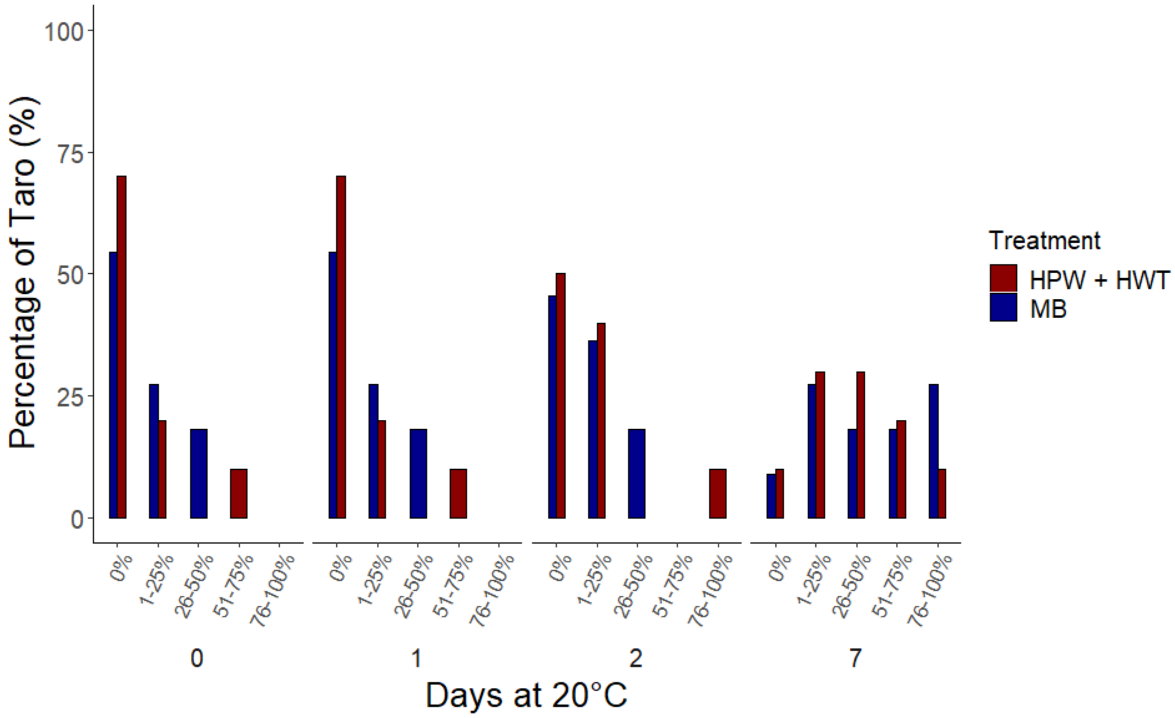


Figure 14. January/February 2020, cut base rots, no additional storage. Proportion of the cut base with rots for each category (i.e. the proportion (%) of cut surface with rot expression) during shelf life (20°C) following shipping to New Zealand. HPW+HWT: Taro were pressure washed (50 psi for 15 seconds) and hot water treated (48°C for 25 min). MB: Non-treated (control) taro fumigated with MeBr on arrival in New Zealand.

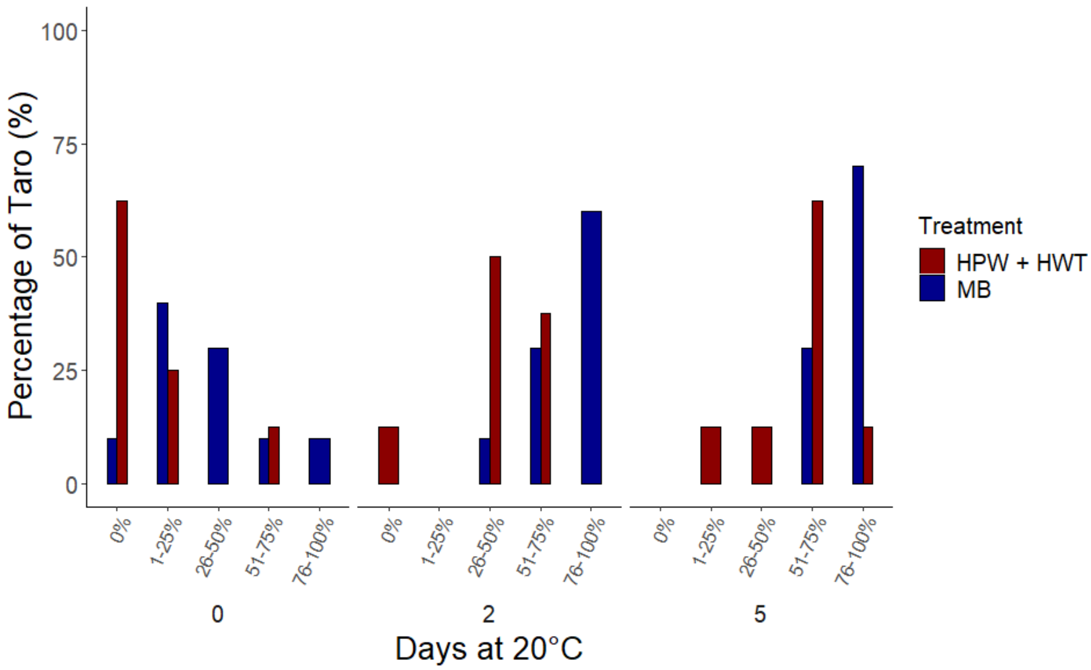


Figure 15. January/February 2020, cut base rots, additional storage. Proportion of the cut base with rots for each category (i.e. the proportion (%) of cut surface with rot expression) during shelf life (20°C) following shipping to New Zealand and one week of additional storage. HPW+HWT: Taro were pressure washed (50 psi for 15 seconds) and hot water treated (48°C for 25 min). MB: Non-treated (control) taro fumigated with MeBr on arrival in New Zealand.

Trial 2 – December 2020 – Comparing HPW+HWT with MeBr treatment

Materials and methods

This taro shipment arrived in Auckland on 7 December and a total of 600 taro (30 bags) were examined by MPI. This time PFR staff could not assist the inspection. No pests were found, so no fumigation was required for the treated taro. Two bags of the non-fumigated taro and two bags of the commercially treated taro (fumigated with MeBr) were brought to MARC. Half of them were stored at 20°C to simulate the condition that they would be subject to when being sold; the other half were stored at 10°C to be assessed one week later, representing the additional storage treatment.

For the "no additional storage" group, taro in the first half of the consignment were assessed on the day they arrived (day 0), then on the second, fifth and seventh days at 20°C. For the "additional storage" group, after storage taro were evaluated on the 0, second, fifth and seventh days.

Assessments examined the extent of body rots per taro, petiole quality, petiole colour, firmness of taro and the percentage of the cut base that was covered with fungi.

Results and discussion

For taro placed at 20°C without further storage, body rots were slightly higher for HPW+HWT-treated corms than for MeBr-treated corms on day 0 (Figure 16), but for days 2, 5 and 7, MeBr-treated taro were of slightly poorer quality.

Where taro were stored for a further week, HPW+HWT-treated corms were of better quality than MeBr-treated corms for days 0 and 2, but the quality was similar by days 5 and 7, although there were some HPW+HWT-treated corms with no rots, and MeBr-treated corms had more rots, of 30–100% (Figure 17).

Rots on the cut base of the taro followed a different pattern from that observed in Trial 1. For corms not stored after fumigation, MeBr-treated corms had 0% rots on the cut base, while 50% of the HPW+HWT-treated taro had at least 26% rots on the cut base from day 0, and these proportions did not change significantly over the shelf-life period (Figure 18).

After an additional week of storage, rots increased significantly, and again the pattern did not change significantly during shelf life (Figure 18). Around 45% of the MeBr-treated taro had 0% of the base covered with fungus, and around 15% had up to 25% or less of the base with rots. For HPW+HWT-treated taro, around 15% had the base free of rots and around 45% had 25% or less of the cut base with rots (Figure 19).

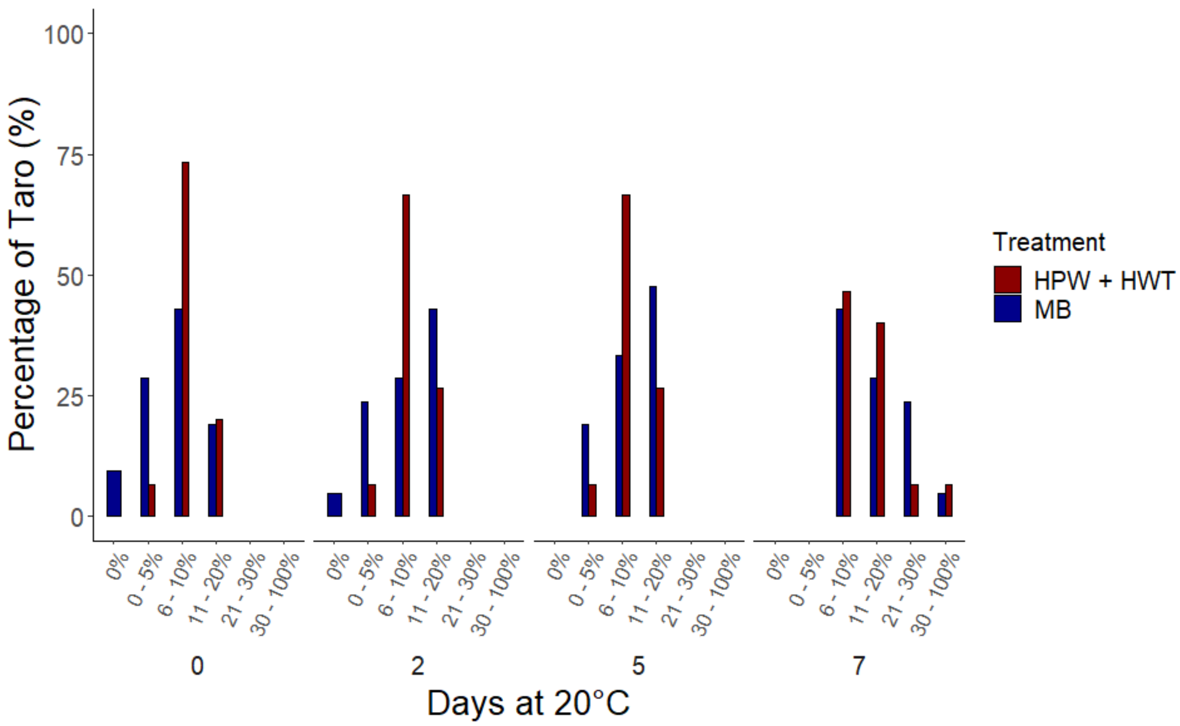


Figure 16. December 2020, body rots, no additional storage. Proportion of body rots for each category (i.e. the proportion (%) of taro surface with rot expression) during shelf life (20°C) following shipping to New Zealand. HPW+HWT: Taro were pressure washed (50 psi for 15 seconds) and hot water treated (48°C for 25 min). MB: Non-treated (control) taro fumigated with MeBr on arrival in New Zealand.

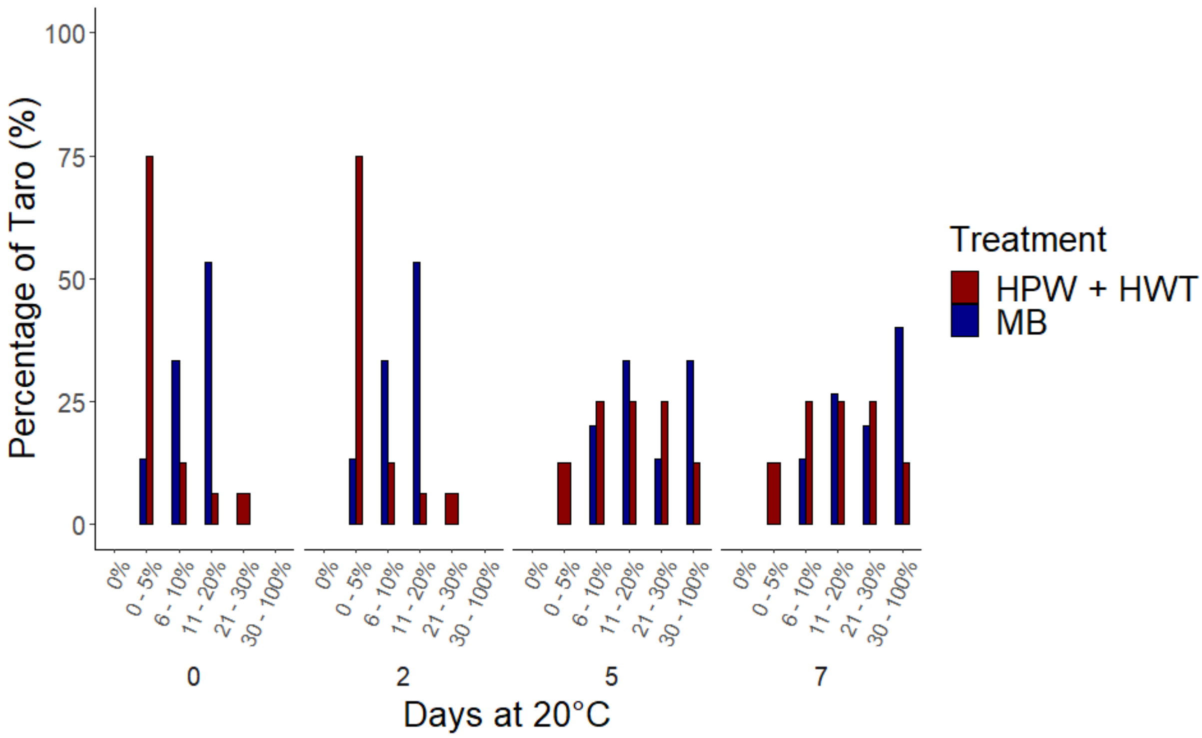


Figure 17. December 2020, body rots, additional storage. – Proportion of body rots for each category (i.e. the proportion (%) of taro surface with rot expression) during shelf life (20°C) following shipping to New Zealand and one additional week of storage. HPW+HWT: Taro were pressure washed (50 psi for 15 seconds) and hot water treated (48°C for 25 min). MB: Non-treated (control) taro fumigated with MeBr on arrival in New Zealand.

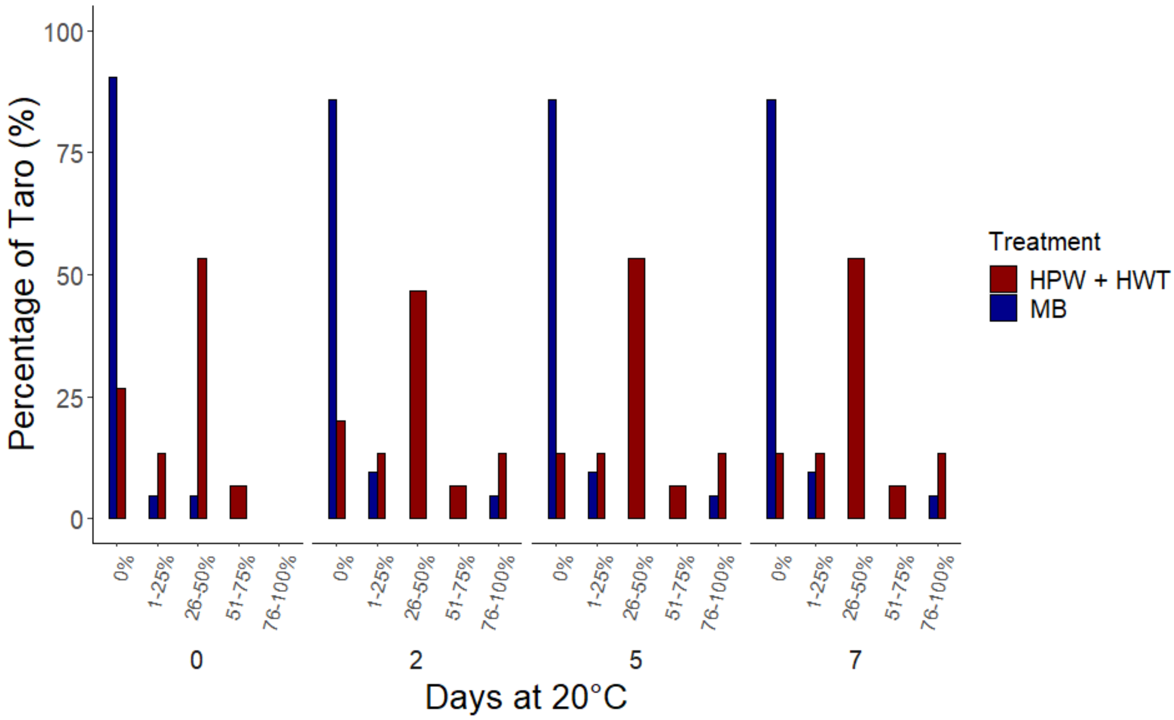


Figure 18. December 2020, cut base rots, no additional storage. Proportion of the cut base with rots for each category (i.e. the proportion (%) of cut surface with rot expression) during shelf life (20°C) following shipping to New Zealand. HPW+HWT: Taro were pressure washed (50 psi for 15 seconds) and hot water treated (48°C for 25 min). MB: Non-treated (control) taro fumigated with MeBr on arrival in New Zealand.

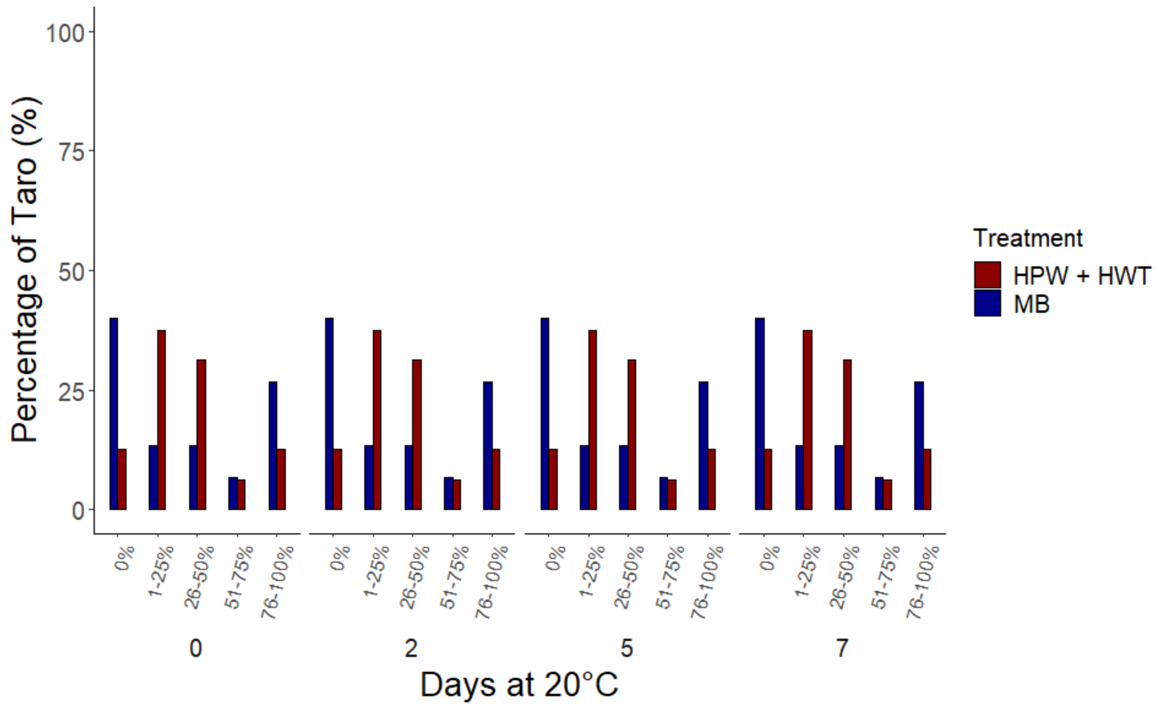


Figure 19. December 2020, cut base rots, no additional storage. Proportion of the cut base with rots for each category (i.e. the proportion (%) of cut surface with rot expression) during shelf life (20°C) following shipping to New Zealand and one week of additional storage. HPW+HWT: Taro were pressure washed (50 psi for 15 seconds) and hot water treated (48°C for 25 min). MB: Non-treated (control) taro fumigated with MeBr on arrival in New Zealand.

Trial 3 – May 2021 – Comparing HPW+HWT plus MeBr treatment with MeBr-only treatments

Materials and methods

This trial was designed to examine the effect of MeBr treatment of taro that had previously been treated with HPW+HPW, that is, a combined treatment of HPW+HPW in Samoa, and MeBr on arrival in New Zealand.

This taro shipment arrived in New Zealand on 11 May 2021. A total of 600 taro (30 bags) were examined by MPI. This time PFR staff did not assist the inspection. Live nematodes were found on untreated taro, so a 4-hour fumigation with MeBr was required. Taro that had been treated with HPW+HWT were included in the fumigation (although no insects were found on these taro). Two bags of each treatment were brought to MARC. Half of them were placed directly into 20°C ("no additional storage") to simulate the condition they would be subjected to when being sold; the other half were stored at 10°C to be assessed one week later ("additional storage"), representing the longer storage time before being sold.

During the first week, the taro in the first half of the consignment was assessed on the day they arrived (day 0), then on the third, fifth and eighth days of being held at 20°C and were discarded after the last assessment. For the second week, the second half of the taro shipment, which had been stored at 10°C, was removed into the assessment room at 20°C and was evaluated on the 0, third and fifth days, before being discarded.

Assessments examined the extent of body rots per taro, petiole quality, petiole colour, firmness of taro and the percentage of the cut base that was covered with fungi.

Results and discussion

For taro not further stored, body rots increased over the 7-day shelf life period (Figure 20). HPW+HWT + MeBr-treated taro in day 0 were 100% free of body rots, while taro treated only with MeBr had 45% of the taro with between 1 and 5% body rots. On the fifth day of assessment, 100% of the HPW+HWT + MeBr-treated taro had 1 to 5% body rots, while only 75% of the MeBr-treated taro were rated 1 to 5%.

After an additional one week of storage, rots increased compared with those in non-stored taro, and also increased over the shelf-life period (Figure 21). For HPW+HWT + MeBr- treated taro, almost 75% of the taro had no more than 5% body rots, and by the fifth day this decreased to about 60%. For the MeBr-only treatment, generally there were more rots in higher categories than for the combined treatment.

For the cut base of the taro not stored, HPW+HWT + MeBr- treated corms had a high proportion of taro with no rots at day 0 (80%), and this declined over the shelf-life period to about 45% (Figure 22). MeBr-treated taro on the other hand had 60% of the taro with severe rot (51–75%) and only 15% with no rots. By day 8, MeBr-treated taro had 75% with very severe rots on cut tissue (i.e. the 76–100% category).

After one week of additional storage, more rots were present on the cut base after removal from storage (day 0), with 44% with no rots for HPW+HWT + MeBr- treated taro but only 25% for MeBr-only treated taro (Figure 23). With increasing shelf-life time the proportion of rots increased, with higher proportions of taro with rots in both treatments. However, the MeBr-only treated corms had significantly more rots than those in the HPW+HWT + MeBr treatment (e.g. 76% taro for MeBr with severe rots).

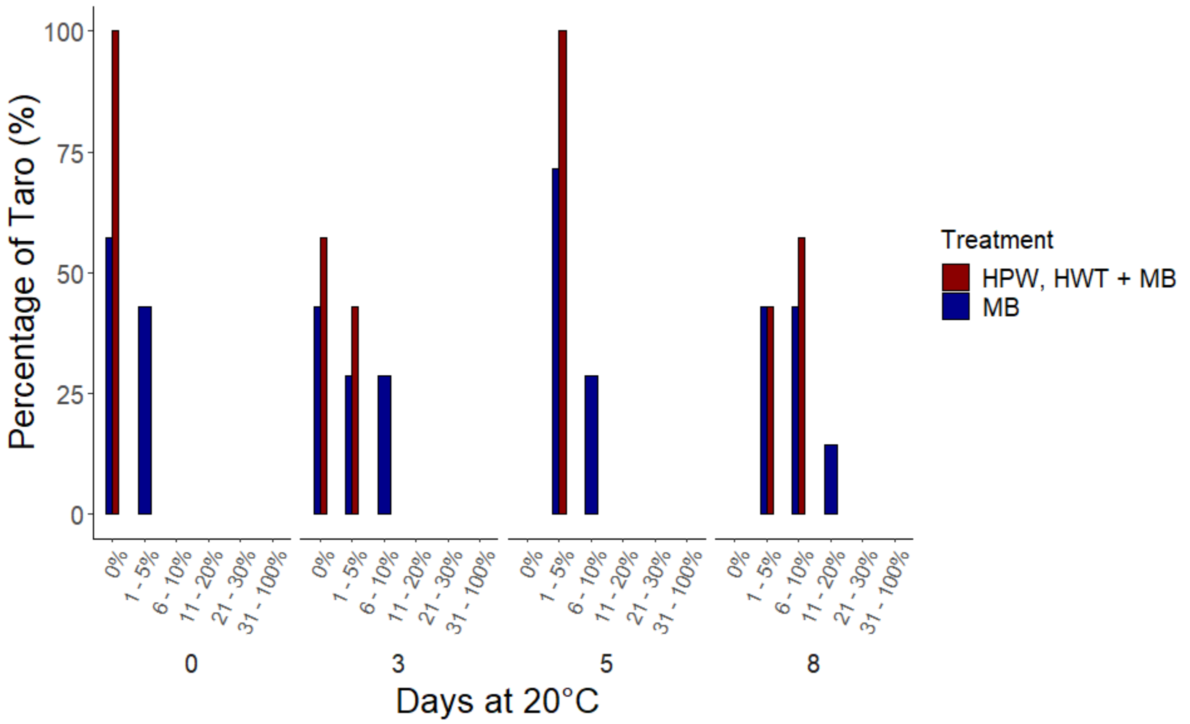


Figure 20. May 2021, body rots, no additional storage. Proportion of body rots for each category (i.e. the proportion (%) of taro surface with rot expression) during shelf life (20°C) following shipping to New Zealand. HPW, HWT + MB: Taro were pressure washed (50 psi for 15 seconds) and hot water treated (48°C for 25 min) and fumigated with MeBr. MB: Non-treated (control) taro fumigated with MeBr on arrival in New Zealand.

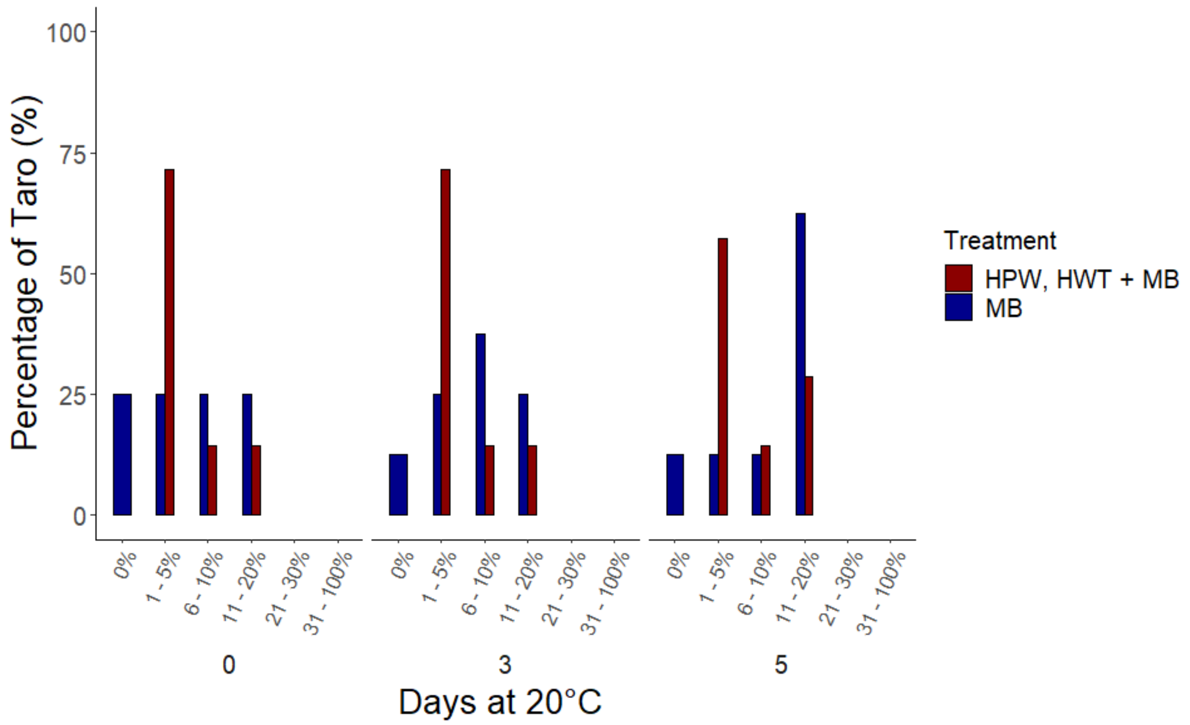


Figure 21. May 2021, body rots, no additional storage. Proportion of body rots for each category (i.e. the proportion (%) of taro surface with rot expression) during shelf life (20°C) following shipping to New Zealand and one additional week of storage. HPW, HWT + MB: Taro were pressure washed (50 psi for 15 seconds) and hot water treated (48°C for 25 min) and fumigated with MeBr. MB: Non-treated (control) taro fumigated with MeBr on arrival in New Zealand.

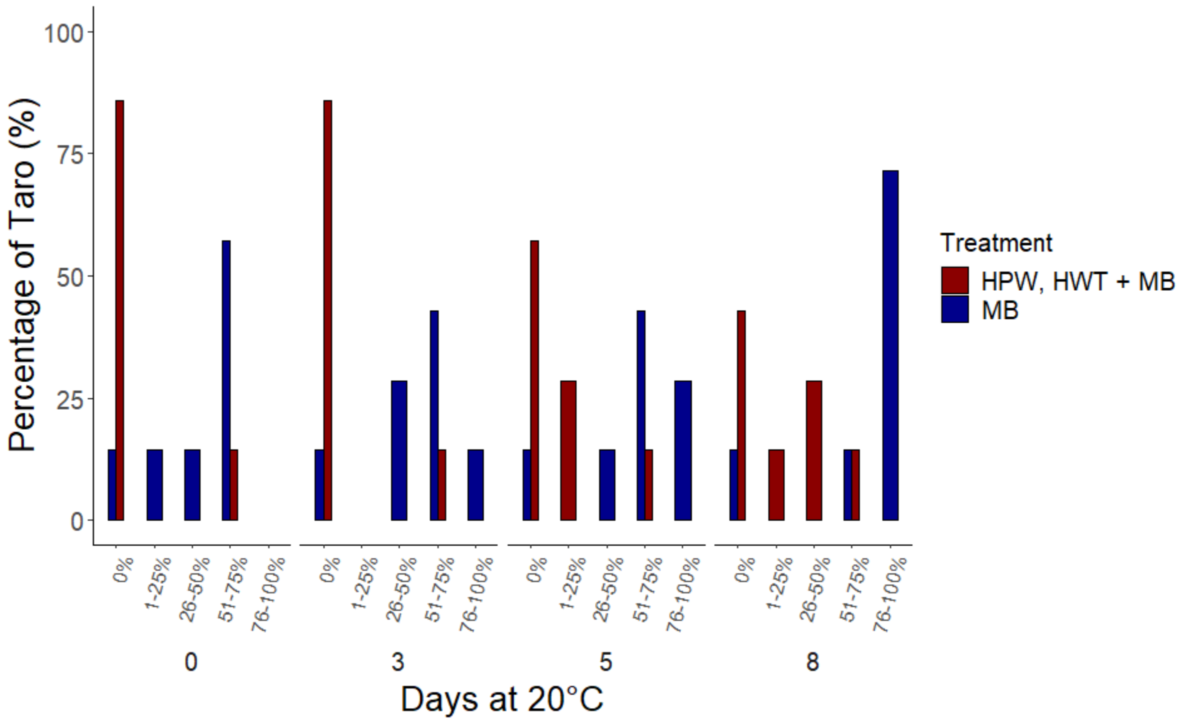


Figure 22. May 2021, cut base rots, no additional storage. Proportion of the cut base with rots for each category (i.e. the proportion (%) of cut surface with rot expression) during shelf life (20°C) following shipping to New Zealand. HPW, HWT + MB: Taro were pressure washed (50 psi for 15 seconds) and hot water treated (48°C for 25 min) and fumigated with MeBr. MB: Non-treated (control) taro fumigated with MeBr on arrival in New Zealand.

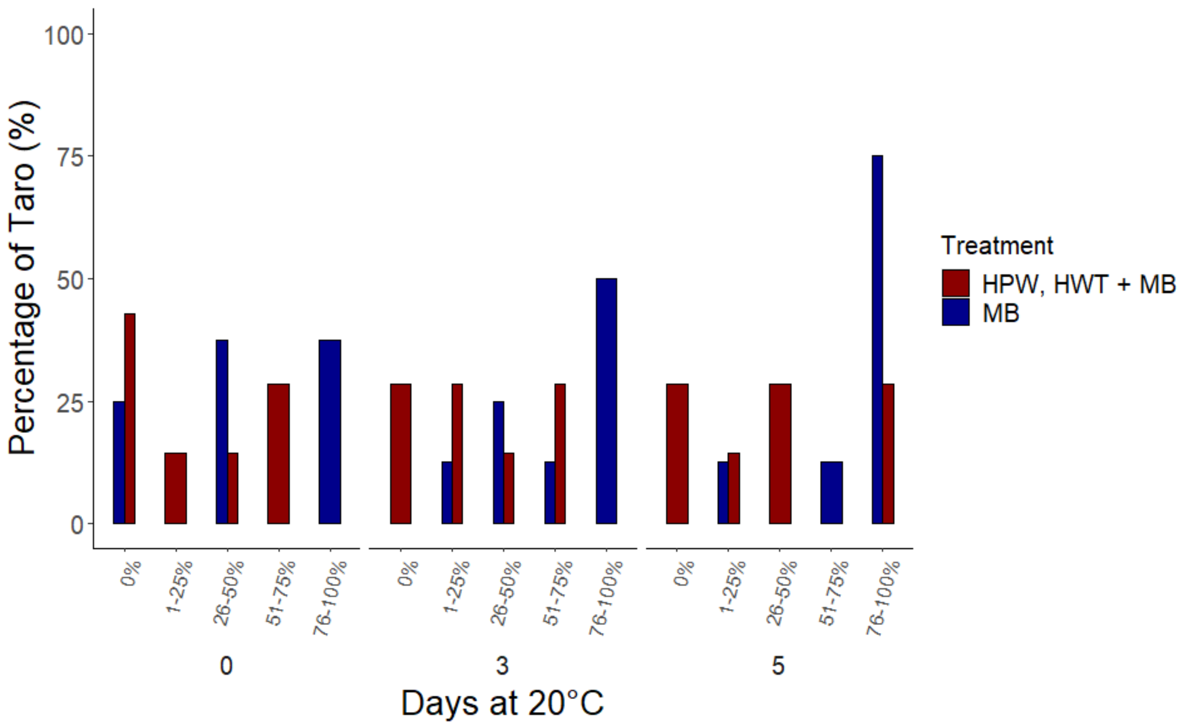


Figure 23. May 2021, cut base rots, additional storage. Proportion of the cut base with rots for each category (i.e. the proportion (%) of cut surface with rot expression) during shelf life (20°C) following shipping to New Zealand and one week of additional storage. HPW, HWT + MB: Taro were pressure washed (50 psi for 15 seconds) and hot water treated (48°C for 25 min) and fumigated with MeBr. MB: Non-treated (control) taro fumigated with MeBr on arrival in New Zealand.

General discussion

Rots on the body of taro corms during shelf life without further storage (i.e. marketed in the first week after ship arrival) were found to be lower in HPW+HWT-treated taro than in MeBr-only treated corms in most cases, and after 7 days of shelf life, were lower than in MeBr-only treated taro in two of the three trials. After an additional week of storage (i.e. marketed in the second week after ship arrival), HPW+HWT-treated taro were better quality (lower rots) than MeBr-only treated taro in all three trials, both at removal from storage and after 7 days. These are encouraging results from an importer's perspective, particularly given that Trial 3 included MeBr treatment of the HPW+HWT taro, which previously was thought to reduce quality.

Investigation of the rots on the cut base produced more mixed results, with some trials producing better quality and others less so. While rots on the cut base are not desirable, these are easily "fixed" by the retailer since they can be sliced off with little loss of product. Indeed retailers are likely to slice off the base as a part of the regular "refresh" when dried leaf petiole bases are removed. Body rots on the other hand are less easy to correct, and will significantly downgrade the quality of the taro.

The increase in rots during product storage for an additional week is an important result since this demonstrates the challenge of reaching more distant markets such as Australia where an additional 5 weeks of storage may be required.

For brevity's sake, results from other quality attributes have not been presented. Results for leaf petiole bases colour and quality (i.e. shrivel) were mixed between trials, with HPW+HWT being of lower quality in Trial 1, better in Trial 2, and the same in Trial 3 (data not shown). Firmness of the corm was found to be better for HPW+HWT in Trials 1 and 2, but the same in Trial 3 for both shelf-life scenarios (data not shown).

Conclusion

While there were some differences in results between trials – overall the rates of body rots were better for HPW+HWT-treated taro, and even the MeBr fumigation of HPW+HWT-treated taro did not significantly reduce quality. Rots on the cut stem were generally about the same between the two treatments, although these rots can be removed by trimming during display/retail sale. These results, along with the relatively small differences in other quality attributes (firmness and leaf petiole base), mean importers and retailers can have confidence in the out-turn quality of taro treated with the HPW+HWT scenario, even if these taro are subsequently fumigated owing to a quarantine failure.

Design and cost of commercial HPW+HWT unit

Our overall philosophy was to design a system that is one continuous process (not batch-based) that minimises staffing and the need to handle the taro. Thus, the system is designed to feed taro in one end of the process and produce a treated, cooled, dry, bagged product at the other end. Staff are required at some stages to carry out trimming, grading and bagging.

Outlining the system and throughput needed etc.

In consultation with Ah Liki by email and video conference, the information outlined below was obtained to provide a picture of current and future needs. This provided adequately robust information within which to design a HPW+HWT system.

General information

- Existing overall process system – harvest and cleaning in villages, transport, grading, drying and bagging: This information is summarised in Section 2.1.1.
- Current volume processed per fortnight, number of containers: Approx. 52 tonnes/fortnight, but demand is probably 30–40% greater than this.

- Timing of processing (over how many days): Generally 2–3 days/fortnight.
- Work hours and amount processed per day: Average of 16–17 tonnes/day, about 600 sacks (20 kg each) in an 8–12 hour working day. More staff are employed if more work is needed. Container contains ≈ 12 tonnes of taro, which over an 8-hour day equates to ≈ 1.5 tonnes/hour.
- What markets? New Zealand and the USA. Australia will only be opened if an acceptable treatment can be developed for leaf blight and accepted by DAWE (Department of Agriculture, Water and the Environment, Australia).
- Projected taro exports: Expect processing to increase by 50% over the next 2 years, and if the Australian market were to open, this would increase by a further 20%.
- Nature of processing system – automation vs manual labour: A reasonable degree of automation is needed. Overall, it was agreed to look at a relatively high degree of automation (conveyors etc.), and "working backwards" from this could be done depending on cost, for example, using passive drying (racks). Electrical start-up and operation is by manual control, but this could be automated with use of sensors, PLC controls (Program Logic Controller) and potentially remote monitoring.
- Factory size and product flow: Drawings were provided by Ah Liki, and the packhouse area is approximately 600 m^2. Length of product flow is 63 m, from initial trimming of taro to end of bagging conveyors.
- Water supply: Unlimited as the Ah Liki bottling plant is immediately beside the taro packhouse.
- Concrete floor quality: Forklifts are regularly driven over this, so it should be adequate as long as the waterbath load is spread adequately.
- Temperature of packhouse over the year: Local meteorological service information – There is relatively small seasonal variation in temperature in Samoa. The mean annual temperature ranges from 26 to 31°C. Night temperatures are pleasantly cooler in the dry season, when southeast trade winds dominate. Apia: Mean minimum temperatures drop to 22°C around July or August. Relative humidity (RH) is high – generally ≥80%. The high temperatures will assist drying, although this will be reduced by the high RH.
- Availability and capability of local engineering companies and/or in-house in terms of maintenance: All services are available, but the degree of expertise varies greatly.
- Potential energy sources for heating water: LPG is readily available in Apia.
- Monitoring of incoming product (e.g. weighing?): Not required, as payment is made in the villages.
- Understanding where Ah Liki currently source their food processing equipment (for their brewery, water-bottling plant etc.).

Characteristics of fresh taro corms

Owing to the inability to visit Samoa (i.e. COVID-19), a shipment of Samoan taro to New Zealand was used to examine additional factors such as:

- How taro floated in a waterbath: Because the petiole (leaf stem) bases remain on the top of the taro corm, taro have a high tendency to float with the stem end upwards (e.g. see
- Figure 6). However, if corms are held underwater by a mesh or similar structure, they tend to lie sideways (Figure 5).
- Area taken up by taro on a flat surface is approximately 50 kg/m^2. This may vary depending on variety.
- Shape and weight: Of the taro available for measurement in the 0.8 to 1.8 kg weight range, diameters varied from 100 to 140 mm, and length was 160 to 220 mm. A typical 1.2-kg taro is, on average, 120 mm diameter and 200 mm long.
- Density: from a small sample of four taro, density averaged at 0.975 kg/L (slightly buoyant – as reflected in the flotation trial).

Design scoping and refining

MECBES Design and PFR staff had a number of scoping and design meetings discussing such areas as the overall current process, experiments that had been carried out, likely design features. Discussion included:

- Truck unloading system. A low table at the same height of a truck tailgate could be used. This would mean taro are not being dropped onto the floor and staff are not handling taro from floor level. Taro could then be taken from here to the preparation tables in crates. If taro are in sacks, then the sacks could be more easily emptied onto the preparation tables.

- Trimming and grading. Current practice requires very little grading or handling at the packhouse. The trial shipments to New Zealand of HPW+HWT-treated taro has shown that the area of high risk is the base of the taro – the old corm or areas with crevices (Figure 1). Once this process was introduced, there were no interceptions (except the termites which were might have been found if more careful inspection had been instigated – as proposed by the use of a dedicated grading table).
- How to move taro reliably, particularly in the HPW and HWT steps, where treatment time is critical for efficacy and quality. In the case of the HPW and grading table (conveyor), a roller conveyor could be used to move the taro at a steady speed. In the HWT tank, a conveying method will be needed to hold the taro under the water and move them forward to provide a 25-minute hot water treatment time.
- High pressure washing system. The existing taro washer uses rotary brushes where incoming taro push the previous taro over the brushes toward the exit. Residence time is controlled by the rate of incoming taro. The taro rest in rows between adjacent brushes and are washed using rows of stationary nozzles mounted above each row of taro. A problem with bushes is their bristles become clogged with roots and debris that come with the taro. The new washer needs to move the taro in a steady manner with there is no taro on taro impact or pushing.
- Filtration systems. The HPW is where the main filtration is required, so the wash water can be recirculated and reused. The use of screen and cartridge filters was considered, along with disc and sand filters. Another alternative would be to develop a moving filter belt, and although effective in removing fibrous material, it could be costly.
- Drying options. Rotating drying brushes could be used but these would be expensive and could possibly damage the taro surface. It is proposed a roller conveyor and drying fans are used instead.
- The initial design concept (Figure 24) included a soaking step before the washer.
- The second simplified concept (Figure 25) eliminated the soaking step because of added cost, and that it is more cost-effective to clean the taro in the villages. For batches that are not adequately pre-cleaned, an existing flume/tank could be used.
- The cooling tank is half the length of the hot water treatment because (unlike the HWT tank where the taro are in a single layer) the taro can accumulate as two layers. The taro are moved by the recirculating water. Further cooling will also occur during the drying and bagging stages, removing the majority of the heat.
- For the final design, weighing of incoming product was not included as most suppliers are paid out in the village.
- Cooling rate. From observation temperature dataloggers in exported taro, a preliminary recommendation would be that open sacks be stood in a single layer in a container or coolstore for overnight cooling (minimum 12 hours, and preferably 18–24 hours). This should achieve temperatures approaching coolstore temperatures. Most importantly, leaving sacks open will allow any remaining heat and moisture to escape and thus avoid "sweating" inside the sacks. If insufficient coolstore or container space is not available, consideration should be given to the potential for "sweating" of sealed sacks and cooling at ambient temperatures (in the factory) be allowed for, again with open sacks.

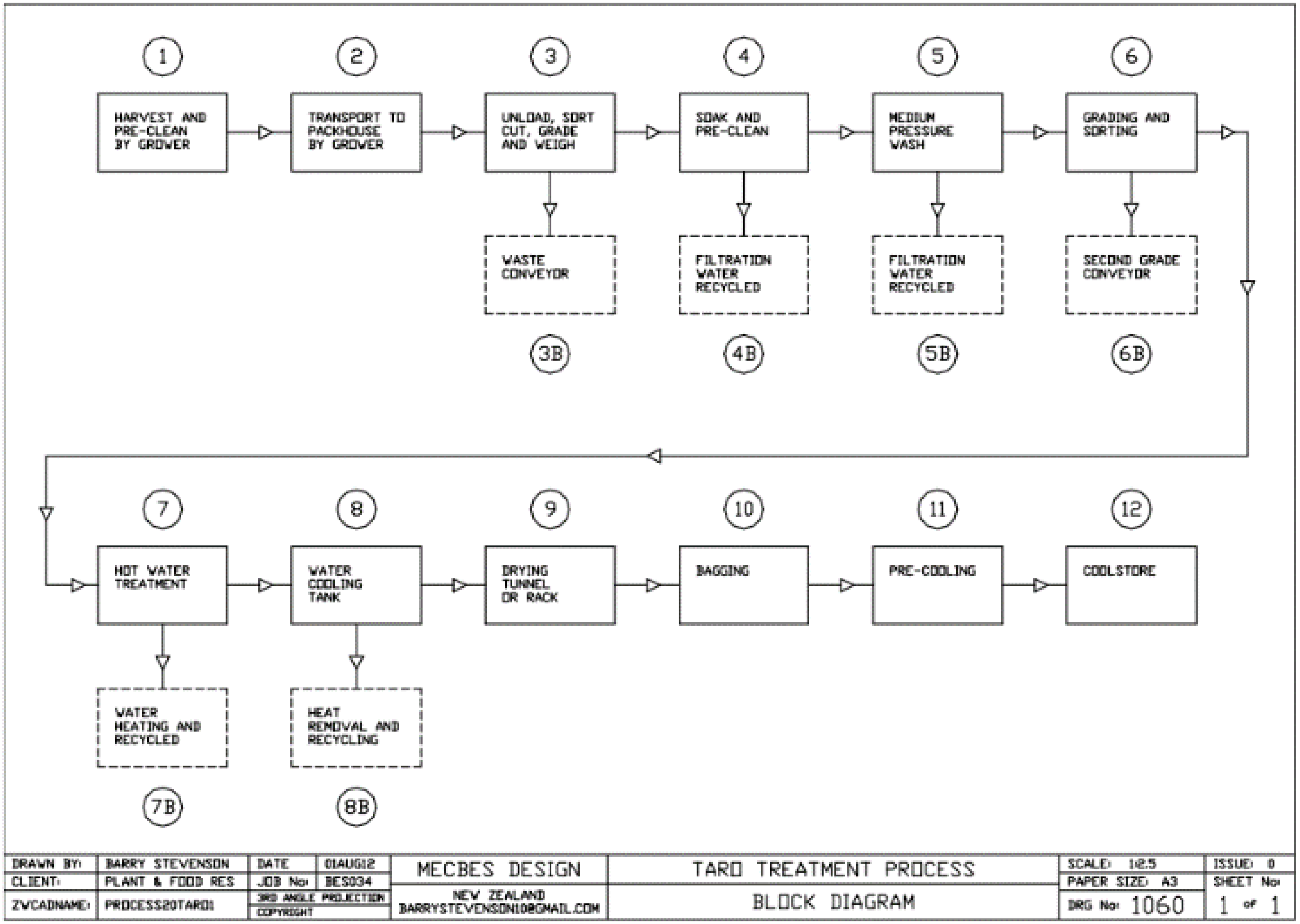


Figure 24. Initial design concept for commercial HPW+HWT unit, for discussion with Ah Liki.

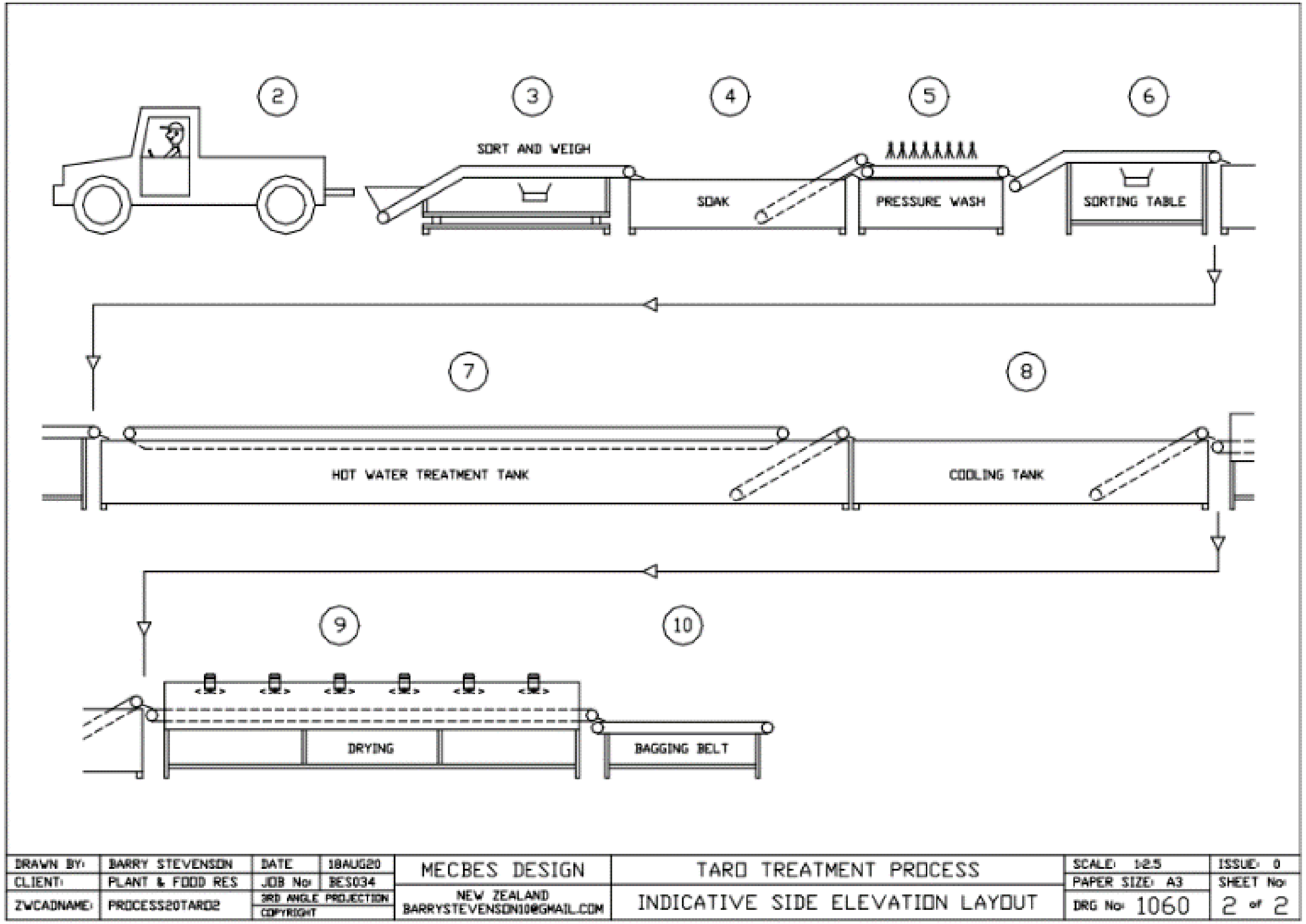


Figure 25. Second design concept commercial HPW+HWT unit – reduced number of steps.

Final design concept

Flow/steps

After discussion and some iterations, the following steps were developed in a continuous flow-through system (Figure 26):

Preparation tables where taro are trimmed and graded; pressure washing to clean the taro; followed by a grading step (to remove at-risk taro, e.g. holes that may harbour insects); then the hot water treatment step; a cooling water tank; then a forced air drier; and finally a bagging area. Between some of these steps, transfer conveyors help to move taro to minimise labour and provide consistent treatment times and thus out-turn.

The number of staff that may be required is indicated in Figure 27. These numbers will reduce or increase depending on the amount of product and the speed of packing required.

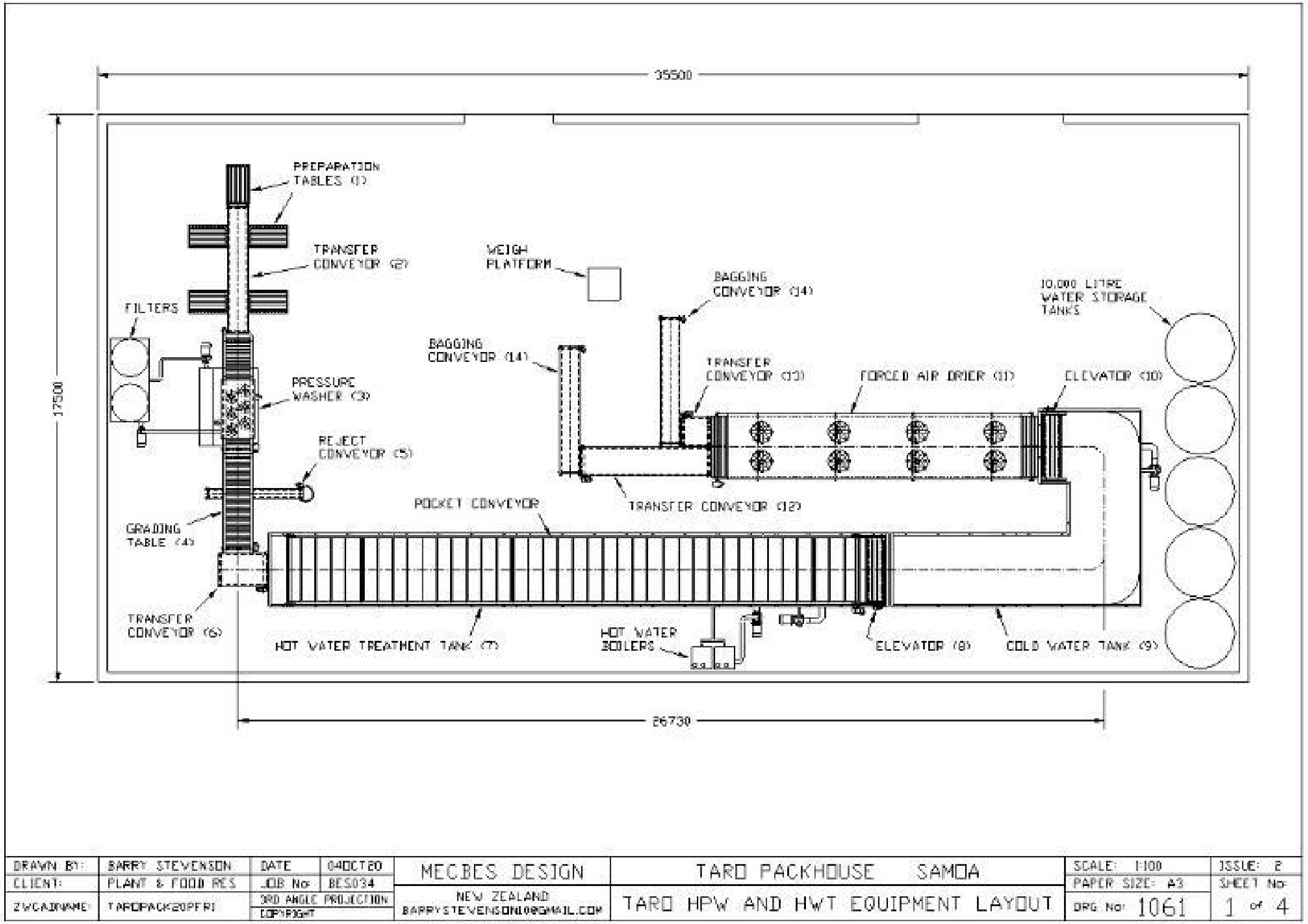


Figure 26. Overview of each of the stages in the taro cleaning process.

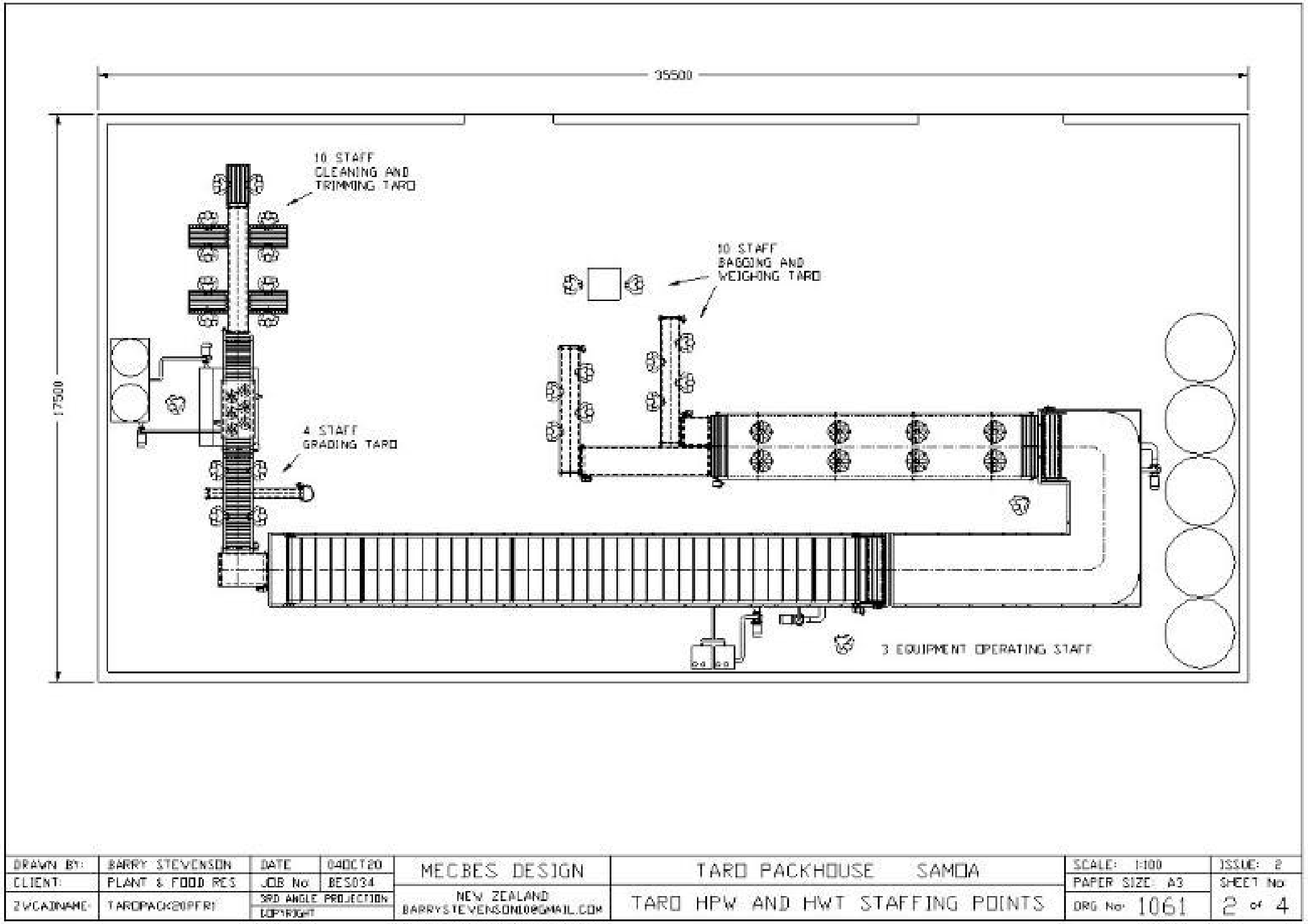


Figure 27. Overview of each of the stages with staff indicated. Staffing is for full production rat

Detailed steps

a. Preparation tables

This step is a very important one to ensure access to New Zealand is possible without fumigation. The key process is to trim the base of the taro (to reduce risk of rots and insects), and to grade out taro that might contain insects (e.g. holes with termites). Careful attention is required to ensure risk is minimised and after taro have entered the packhouse, they need to be taken to the five preparation tables to be trimmed and cleaned. The intention is for 10 staff, two per table, to prepare 62 kg of taro per minute. This is 3.7 tonnes/hour or 33.5 tonnes per 9-hour working day. Over a 3-day processing time, that is 100 tonnes ready for the fortnightly shipment.

On average, each staff member will be trimming 6 kg of taro/minute, or 3 to 8 taro/min depending on size.

The five tables have gaps in the timber top so that taro trimmings and rubbish can fall through to a catch tray underneath. The tray can then slide out for emptying.

b. Transfer conveyor

This conveyor belt carries trimmed taro from the five preparation tables to the pressure washer. The conveyor is 4 m long, 600 mm wide and has a belt speed of 13 m/min. At this speed, the belt will carry 8 kg taro per m^2 of belt surface.

c. High pressure washer

In the proposed pressure washer the taro will be carried on a roller conveyor under rotary spray heads (Figure 28). The rollers are made from 75-mm PVC tube, at 127-mm pitch. The roller conveyor travels at a rate of 36 rollers/min, or 76 mm/s, carrying approximately 25 kg of taro per m^2. The pressure washer has a total length of 3.7 m and a wash zone 1.8 m long.

The rollers will rotate owing to rubber friction carry bars, therefore causing the taro also to rotate as they are carried under the spray wash heads, giving a good overall clean. The washer drive motor is controlled by a VSD (Variable Speed Drive) so the conveyor speed can be slowed down depending on how dirty the taro are.

There are six rotary wash heads above the conveyor. Each head will have six nozzles, giving a total of 36, size 20 nozzles operating at approximately 3 bar or 45 psi. The pressure pump can deliver up to 400 L/min at 3 bar so there is sufficient capacity for more or larger nozzles. The rotary wash heads are motor driven via a VSD as well. This means the rotor speed can be varied to achieve optimum washing of the taro.

The spray water is captured via a tray and tank under the roller bed. Some dirt from the taro will settle in the bottom of this tank. The wash water will pass through a coarse screen filter to remove the larger fibrous debris and roots. This screen will require removal and manual cleaning. After the filter screen, the water will be pumped through twin disc filters into a header tank ready for reuse. The disc filters can filter the water down to 25 microns if required, and are self-cleaning.

As mentioned, a continuous filter belt could be developed to separate the fibrous material from the water, saving the need to monitor and manually clean the screen filter.

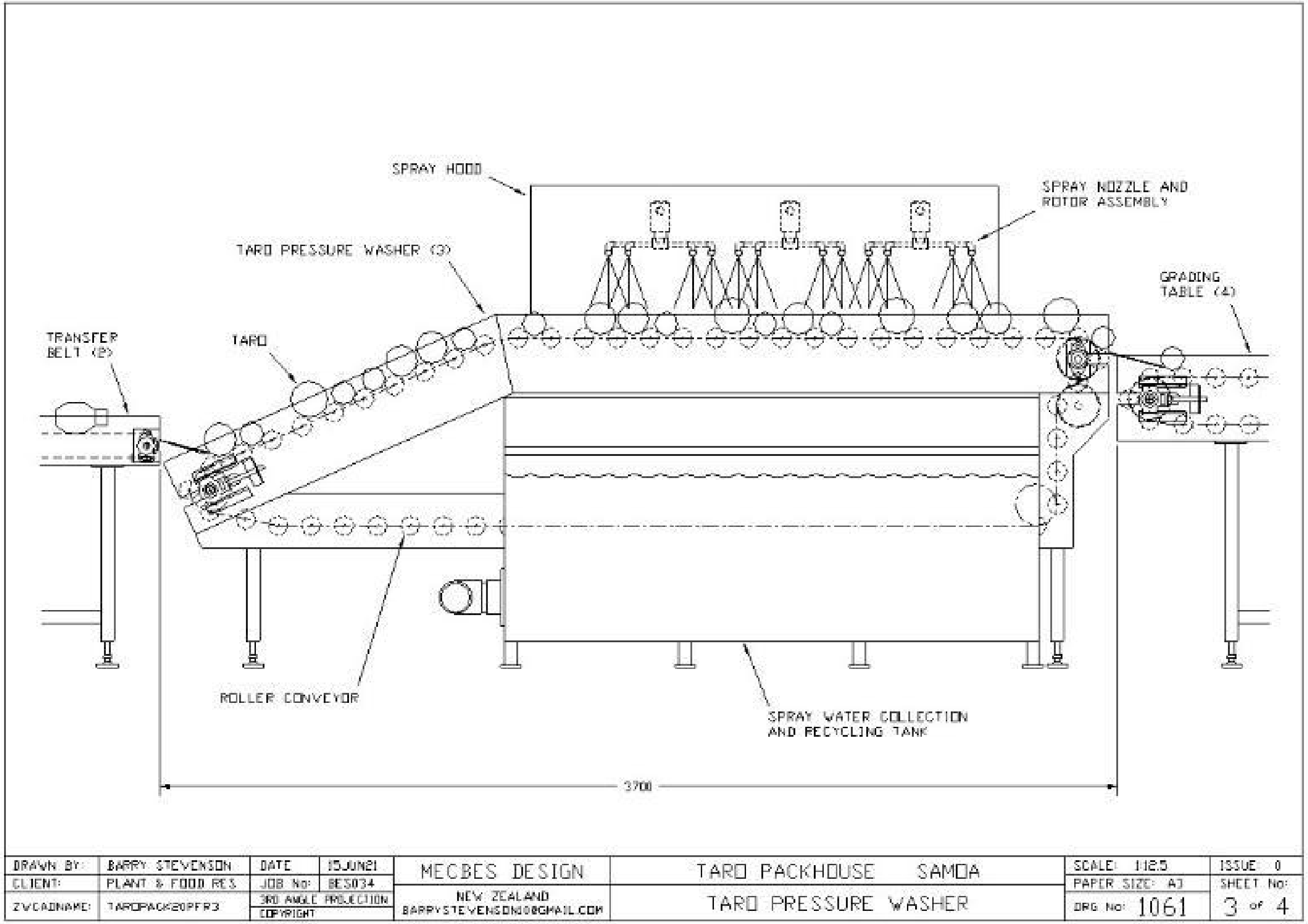


Figure 28. High pressure washer travelling rollers under rotary nozzles.

d. Grading table

The grading table is 3 m long, has the same rollers and travels at the same speed as the pressure washer roller conveyor so that taro do not accumulate at any point. Like the washer, the grading table speed is also controlled by a VSD should there be any need to slow down or speed up the grading process.

The intention is to have four staff checking the taro quality after the pressure washing phase. A bank of lights will be set up above the grading table to help with detection of unacceptable blemishes.

e. Reject conveyor

This belt conveyor sits at right angles under the grading table. Grading staff can place reject taro on this belt, which then carries them to a reject bin. A decision will need to be made whether these taro are returned to the preparation table for greater scrutiny, sent to the local market, or returned to the grower for disposal?

f. Transfer conveyor

This short belt conveyor is located at the end of the grading table to carry the taro to the hot water treatment tank. This belt travels at 19.5 m/min or 325 mm/s to pull the taro quickly away from the end of the grading table.

The transfer conveyor would be a good point to take quality control (QC) samples of taro before they enter the hot water treatment tank.

g. Hot Water Treatment Tank

The HWT tank is 19 m long and 2.14 m wide inside (Figure 29). The tank has sufficient capacity to hold taro for 25 minutes, coming into it at a rate of 62 kg/min. This means at any one time there is 1,550 kg of taro in the tank. To make sure taro spend 25 minutes in the tank to achieve a successful treatment, the passage of taro along the tank is controlled by a pocket conveyor. These synthetic and porous fabric pockets are moved along the tank via a chain and cross rod conveyor. The pockets move down the length of the tank at a rate of 1.6 pockets/min or 12.2 mm/s. Because taro float, the pockets both transport and keep the taro submerged in the hot water. The pockets are 457 mm long and 1,950 mm wide and each hold approximately 40 kg of taro, with 39 pockets submerged at any one time. The rod conveyor that supports the pockets is driven by a VSD-controlled geared motor. This means timing of treatment can be precisely controlled and varied should the need arise.

A recirculation pump moves 1,400 L/min water from the beginning to the end of the tank, which gives an even spread of heated water and will also help to move the taro and reduce the load on the pocket conveyor.

The water is heated by twin condensing boilers that are protected from tank impurities by a heat exchanger. Both boilers are used to preheat the tank, but only one boiler is needed during operation. To reduce costs, one boiler could be deleted, but this would slow the preheat time and give no back-up heating. The heating system provides sufficient water at 55°C to maintain tank temperature with 62 kg of fresh taro entering every minute. Initial heating of the tank (21,000 L) will take 6 to 8 hours.

The heating system comes as a kitset, so could be set up by local technical staff with direction from the supplier. A large LPG storage tank will need to be installed on site. This installation is not included in the price.

The water heating system has its own filter, but a separate pump and screen filter has been included in the pricing to help maintain water quality.

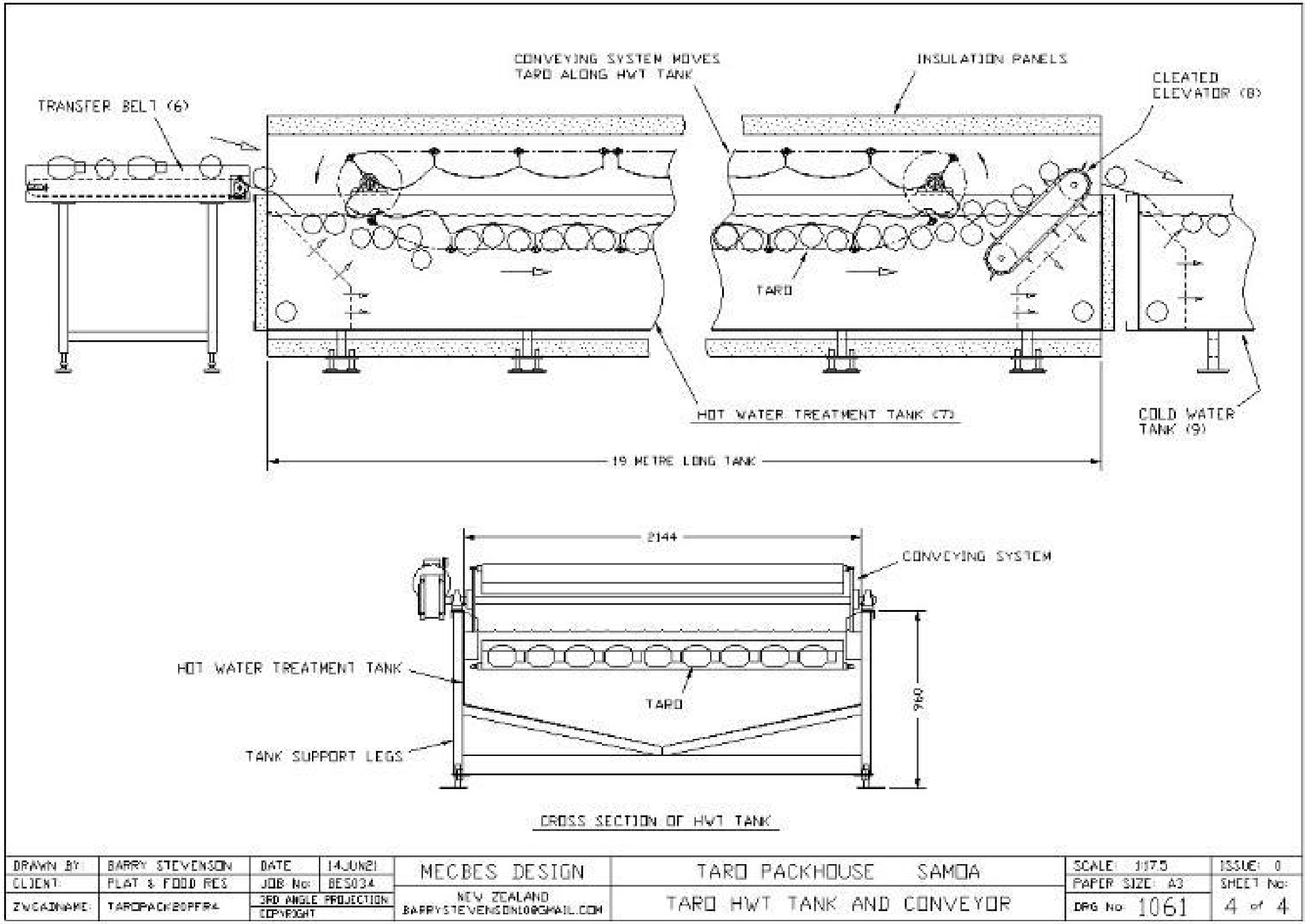


Figure 29. Hot water treatment bath. Note that the bath is 19 m long to allow for the 25-minute treatment time at 48°

h. Elevator

A plastic cleated belt elevator is mounted in the end of the hot water tank and is 1950 mm wide. The cleats help lift the taro out of the hot water and transfer them to the cold-water tank. The elevator drive runs at 6 rpm and 15 cleats/min. At this speed the cleats only need to be half loaded to move the 62 kg/min required. The geared motor driving the elevator has a VSD so speed can be varied to improve lifting of taro should this be an issue.

i. Cold water treatment tank

The cold-water tank has a centre length of 12.3 m and 2.14 m width. There is a recirculation pump to help move the taro from one end to the other. As in the hot-water tank, there is a separate pump and screen filter to maintain water quality.

j. Elevator

This is an identical plastic cleated belt elevator as used in the hot-water tank. It is used to lift taro from the cold-water tank and deliver them to the forced air drier. This elevator is also controlled via a VSD to fine-tune the removal speed.

k. Forced air drier

This drier incorporates a double-sided roller conveyor, 9.65 m long and 1.85 m wide across the rollers. The roller conveyor has eight 600-mm diameter axial fans mounted above it. These fans provide forced air movement to help dry the taro. No heating source has been included in the pricing, but pulling warm air from the ceiling space could be considered. A separate centrifugal fan and ducting could be installed in the ceiling space to assist with this.

The rollers speed is 23 rollers/min or 2.9 m/min. This means the taro will be in the drier for 3.3 minutes. If more time is needed, the drier conveyor is also controlled by a VSD so that it can be slowed down (or sped up).

l. Transfer conveyor

There are two transfer conveyors, one short and a longer one that pull the taro away from the outlet of the drying conveyor and transfer them to one of the bagging conveyors. These transfer belt conveyors have a fixed speed of 13 m/min.

m. Bagging conveyors

These two conveyors, like the transfer conveyors, also run at 13 m/min. They are spaced sufficiently apart for staff to work each side of them. Approximately eight staff will work taking taro off these belts and placing them into bags and taking them to the weigh platform.

The weigh platform is near the end of the bagging conveyors. Approximately two other staff will work at the weigh station checking bag weight and topping up or removing taro from the bags as required. They will need a table on which to place and to take taro from.

Heating systems

LPG was selected as the best option because of its ready availability in Samoa (e.g. Origin Energy Samoa). A permanent LPG storage tank will need to be installed on site to deliver LPG to the HWT tank boilers.

The water heating system comprises two Italtherm Timepower® condensing boilers fitted with LPG conversion kits. Each boiler has a 160 kW output (320 kW total), each consuming LPG at a rate of 11.5 kg/hour. The boilers are supplied as kitsets by Tubman Heating, Auckland, and can be assembled by local contractors with technical assistance from Tubman staff. The kitsets come with all necessary piping, temperature controller, expansion tank and a secondary pump and strainer. In particular, the water-heating circuits are protected by a heat exchanger that keeps potentially contaminated tank water separate from the boiler water, thus increasing the life of the boilers. These boilers also have an electronically controlled modulation pump with a 10:1 modulation range. This means the boiler controller senses the water rising to the set temperature and ramps back the power input so the temperature does not overshoot, or the boilers are not constantly turning on and off at 100% rating as the temperature drops. The boilers can automatically turn themselves down and just burn sufficient LPG to maintain temperature and overcome heat loss. For these reasons, the boilers are highly efficient, thus providing an excellent means of heating the water.

When initially heating the HWT tank water (21,000 L), both boilers will be in operation consuming 23 kg/hour of LPG, taking between 6 to 8 hours. Once in operation, only one boiler is needed, consuming 9.4 kg/hour (130 kW) to keep up with an input of 62 kg/min of taro. Allowing for some heat loss, this boiler will probably be operating close to its full capacity of 160 kW, using 11.5 kg/hour of LPG. Over a 3-day operating period, treating up to 100 tonnes of taro for shipment, it is quite possible 700 kg (1,370 L) of LPG will be used per fortnight. It is therefore reasonable to assume a 2- or 3-tonne LPG tank should be permanently installed on site to meet demand. These calculations are based on the assumption that we are raising the water and taro temperatures from an ambient of 25°C to 55 and 50°C, respectively, and the same water will be used over the 3 days of operation. If fresh water is to be heated for each day, then LPG usage may be closer to 1000 kg per fortnight.

It is proposed the HWT tank be enclosed within an insulating box or room. This enclosure would be constructed using rigid 1200-mm wide panels made from 100-mm thick EPS, clad in pre-painted steel skins. The underneath, sides and top of the HWT tank will be enclosed, with the ends partially open to allow for the input and output of taro. It is envisaged these openings will have some form of thermal curtaining to help retain heat; however, some heat loss will be inevitable.

It is assumed the water supply will be below an ambient temperature of 25°C. For this reason, several water tanks have been included to act as holding tanks to allow water temperature to equalise with the surrounding air temperature. To assist water temperature rise, a solar water heating system could be installed on the packhouse roof. This could be a commercially designed and installed system, or simply be a coil of black alkathene pipe laid out on the roof with a recirculation pump fitted with thermostat. There is also the possibility of designing a heat recovery system to extract heat from the cooling tank to help to preheat the water supply to the HWT tank. These options have not been investigated or priced into this proposal.

An upgrade to the power supply (i.e. transformer box) may be needed and this cost is not included.

Costing

To produce this costing, we initially had to establish what quantity of taro would need to be handled in the near future, allowing for industry growth (100 tonnes/fortnight). We had to choose what stages and types of equipment would be needed and in some cases develop new equipment concepts.

We then produced indicative drawings of what this equipment could look like (i.e. Figure 26, 27 & 28) how they would be made, their size and speed of operation. Detail drawings were made of some parts (rollers, tank sections, leg frames, support legs, conveyor sides, conveyor belts, etc.) and these were sent to manufacturers for quotes. These were also many items like pumps, geared motors, fans, and conveyor chain that had to be sized, selected and quoted on. A reasonable amount of design work was required sizing various stages to obtain fairly accurate quotes. The electrical power requirements (motors, pumps) also had to be determined to design the electrical control system accurately.

While accurate quotes were provided for specific designs and equipment, the overall costing needs to be seen as an indicative estimate of what this type of packhouse system may cost. This is because only a partial design has been done, and further design (and prototyping) will be needed before complete and accurate drawings and specifications can be produced for definitive quotations.

The summary of costs of each section of the HPW+HWT system from start to finish are summarised in Table 6 below, with NZ$989,393 for the equipment, and a further NZ$227,000 for other considerations (such as shipping, assembly and testing in Samoa), thus making a total of NZ$1,216,393 (WST2,180,000 / AUD$1,154,772).

The cost of each piece of equipment includes an estimate of time needed to complete the design, drawings, specifications and purchase of parts. Each individual equipment cost also includes a 15% company profit margin. Because of the developmental nature of this project, this profit margin could well be set higher to allow for unexpected design and manufacturing issues. Allowance has been made for prototyping (see Other Considerations – Section 4.3.1), which should help to reduce unexpected issues arising.

The electrical costing includes only manual start-up, where each piece of equipment is switched on individually. Speed adjustment via VSDs is also individual, not integrated. Approximately seven emergency stops have been included, should the need arise. This manual control is adequate, but more automated control may be desired or required with a PLC controlling start-up, sensing and monitoring the process operation. This degree of control, particularly the monitoring of temperature to guarantee a successful treatment, is preferred with this type of process; however, it will add approximately $25,000 to the electrical cost. This is still money well spent, in our opinion.

More detailed costing for each section can be found in Annex 2.

Taro Treatment Equipment Cost					
Item	Title	Quantity	Description	Length	Cost
1	Preparation Table	5	Timber Top	1.2 m	$7,285.00
2	Transfer Conveyor	1	PVC Belt	4 m	$14,228.00
3	Pressure Washer	1	Roller Conveyor	3.7 m	$109,780.00
4	Grading Table	1	Roller Conveyor	3 m	$34,970.00
5	Reject Conveyor	1	PVC Belt	3 m	$10,053.00
6	Transfer Conveyor	1	PVC Belt	1.5 m	$10,592.00
7	Hot Water Treatment	1	Pocket Conveyor	19 m	$409,718.00
8	Elevator	1	Plastic Cleated Belt	0.5 m	$23,216.00
9	Cold Water Tank	1	Moving Water	12.3 m	$96,055.00
10	Elevator	1	Plastic Cleated Belt	0.5 m	$18,616.00
11	Forced Air Drier	1	Roller Conveyor	10m	$152,738.00
12	Transfer Conveyor	1	PVC Belt	4 m	$14,509.00
13	Transfer Conveyor	1	PVC Belt	0.9 m	$9,378.00
14	Bagging Conveyors	2	PVC Belt	4 m	$24,304.00
15	Electrical		Supply and Installation		$53,951.00
			Sub Total		$989,393.00
Other Considerations					
1	Prototyping aspects of the Hot Water Treament Equipment, etc				$60,000.00
2	Assembly and Testing of Equipment in New Zealand				$24,000.00
3	Disassembly, Packing for Shipping to Samoa				$16,000.00
4	Re-Assembly and Testing of Equipment in Samoa				$30,000.00
5	Training, Initial Production Runs, and Hand-over				$16,000.00
6	Supply of Spare Parts and Maintenance Training				$24,000.00
7	Freight Costs and Shipping to Samoa. Port to Port. No Customs etc.				$57,000.00
			Total		$227,000.00

Table 6. Overview of costs of each of the steps in the HPW+HWT system and “Other considerations”.

Other considerations

Other than design and building the equipment, there are other ancillary costs – "Other considerations" and the cost of these is shown at the bottom of Table 6.

The handling of taro on conveyors, particularly roller conveyors, which has not been used before and thus some preliminary prototyping could be beneficial e.g. to optimize the design of the washer. This is more so for the HWT tank conveyor. The proposed HWT pocket conveyor is a new concept and how well it will work (or not) should be prototyped on a small scale before going to a full-scale design. Not only would this confirm the concept, but allow the chance to refine the design for reliable operation.

In the HPW, rotary spray wands have been used. While this wash method has been used successfully with other crops (apple, avocados, dragon fruit), taro are a new crop and some trial work should be undertaken. The existing washer uses brushes where the taro rest between adjacent brushes until further taro enter the washer and push the existing taro further along the brushes. Because the taro rest in fixed rows between brushes, the wash nozzles can also be fixed or stationary above the rows of taro. In the proposed new washer the taro are constantly moving and rolling on the roller conveyor. Because the taro are constantly moving, the nozzles also have to move and this is the reason rotary wands are proposed. Prototyping their use will help optimize their use on taro.

It should be noted that roller drive belts could be added into the washer and grading table. These would allow control over how quickly the taro would rotate while under the spray nozzles or while being inspected. The cost of these drive belts has not been included, but these belts could prove beneficial or a necessity during development and prototyping. Space for these to be retrofitted should be considered during the design stage.

Possibilities for reducing costs

Probably the most significant reduction in costs could be achieved by using the current system to dry taro – i.e. leaving taro on mesh tables, sometimes with the use of fans. This is cheaper, but clearly involves more labour, and delays in bagging. The cooling water bath might also be eliminated, but if so, at least some minimum water immersion (approx. 5 min) will be needed to reduce the high temperatures of the corms.

Some of the equipment could be made from mild steel, and painted or galvanised. While savings of 20% could be made on the preparation tables by doing this, we would expect savings of only 10% or less overall. Keeping in mind Samoa has high humidity, it would be better to use stainless steel for manufactured parts. However, if necessary, mild steel (galvanised or painted) could be used for the belt conveyors that do not get wet.

If a solar system is used to generate hot water (stored in one of the water tanks overnight), this would reduce or even eliminate the need for the second heater system, although this would need to be balanced with the cost to set up the solar system. Clearly running costs would be reduced by less use of LPG.

The treatment process has a design capacity of 33 tonnes per 9-hour day. The intention is that 3 days of operation will achieve the 100 tonnes/fortnight target. If overall capacity or daily output were less, then some savings could be made by building smaller equipment. However, savings may not be that great because many parts would remain the same or similar. Therefore it may be better to retain the extra capacity for the future.

Electrical supply to site

It is assumed that a three-phase 400 V, 50 Hz, multiple earth neutral (MEN) supply is available of at least 100A per phase. Ah Liki runs a water bottling plant immediately beside the taro packhouses, so water availability is not a limiting issue – although conservation is worth considering. Collection of rainfall from into tanks from the packhouse roof might be one option.

General discussion

This modest-sized project has been able to make some important steps towards commercialising a non-fumigation treatment of fresh taro for export to New Zealand, and possibly even Australia.

We have shown that a HPW+HWT system can meet MPI quarantine requirements, with demonstration on a full 600-taro lot that export to New Zealand is possible in nine out of 10 cases. The only failed consignment was an internal nest of termites in one taro that could have been detected with more careful grading. This emphasis on grading during packing, and the design of a post-HPW grading station (Figure 27) is an example of the higher standards and a strong systems approach to market access that we are recommending (Jamieson et al. 2018). This approach is what is used by the New Zealand apple industry where control points are used at all stages of the supply chain, i.e. preharvest sprays and monitoring, harvest timing, grading, pressure washing, QC stations, and market selection based on available information.

Consultation with commercial partners has shown that this treatment could be implemented in the current commercial process and site. However, the high "peak packing" time that the shipping systems cause (i.e. one ship/fortnight) may pose significant problems given that the overall aim is to minimise harvest time prior to packing and shipping. Weekly shipping alternatives would be helpful, preferably to different markets, to spread supply and maintain staffing and workflows.

The successful design of a full commercial treatment system will be one that allows continuous treatment, grading, drying and bagging of taro at a throughput that should meet future growth potential.

The cost of a relatively "gold-plated" full commercial system is significant (over $NZ1 million), and is a considerable investment. While there are ways to reduce this cost (lower quality materials, alternative manufacturers, more labour input), this is not an unreasonable cost for a multistep treatment system with good automation/flow. For example, high pressure washing systems in the apple industry in New Zealand cost $1–1.5 million for washing and flume systems alone (i.e. no HWT). As noted previously, fumigation with MeBr is the most cost effective and broadly efficacious treatment available, although it can result in reduced product quality. Unfortunately, all alternative solutions have negative aspects such as duration of time to apply, logistical challenges, more complex treatments and/or are more expensive to apply (including significant capital and running costs). Potential for development funding may be possible from agencies such as ADB (Asian Development Bank), DFAT (Australia), WB (World Bank) and/or PHAMA PLUS.

While this treatment HPW+HWT system has been shown to be an effective alternative to MeBr fumigation in a commercial setting, it does have other negative aspects such as energy use (with related carbon footprint impacts), and water use. However, mitigation of these could be achieved by use of alternative technologies such as solar heating from the packhouse roof and more extensive water recycling.

It should be noted that one benefit of this system over MeBr fumigation is that it will reduce the time taro spend at the importer since, after MPI inspection (and the 100% failure rate thus requiring fumigation), fumigation can take a day or two to carry out depending on time of the week and service provider. Also, the need to carry out MeBr recapture after fumigation will add time, maybe another day. Thus, HPW+HWT could result in an improvement of 2–3 days, all time where quality is reducing (on addition to the negative impact of MeBr).

The presence of leaf blight (Phytophthora colocasiae) in Samoa stops access to the Australia market (Fullerton et al. 2019). A significant potential benefit of the HPW+HWT system is the potential use of this system for taro leaf blight control and thus access the Australian market. This may open up a new market for fresh taro and clearly provide significant potential fiscal benefit to Samoa by increasing fresh exports (currently frozen taro is exported to Australia). Preliminary results show effective control of Phytophthora colocasiae-inoculated taro by the HWT used in this work (Molimau-Samasoni et al. 2021).

Anecdotal evidence suggests that HPW+HWT-treated taro might be of better flavour, or could be preferred by consumers because of their non-toxic fumigated status. A market out-turn and consumer preference workstream could be carried out in conjunction with relevant staff from MAF and SROS and the PFR Consumer and Sensory Team. However, as noted by Ah Liki, New Zealand consumers of taro are very cost sensitive and these potential benefits may not result in much of a premium.

Conclusion

This project has demonstrated that a pilot-scale, high pressure washer treatment followed by hot water treatment (HPW+HWT) can provide taro that reliably pass New Zealand MPI inspection at importation, for a standard 600-taro sample. The shelf-life quality of HPW+HWT-treated taro was generally as good as, or better than that of MeBr-treated taro, even if HPW+HWT-treated taro were subsequently MeBr treated. This has given the importer confidence in the quality from a supply chain perspective. In consultation with the key Samoan commercial exporter, a system was designed and approximately costed using New Zealand suppliers. While the cost is significant (>$NZ1 million), there are potential ways to reduce costs, or obtain funding. Overall, this project has confirmed the potential for HPW+HWT as an effective replacement for MeBr fumigation to access New Zealand, and even potentially Australia should control of leaf blight be proved effective.

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Annex 1: User manuals and signage

Annex 1.1: Experimental protocol for taro treatment and shipment.

Introduction

- To date the work we have carried out has determined the best treatment combination (of high pressure washing and hot water treatment) that cleans and disinfests taro so that they have the best chance of passing MPI inspection without fumigation.
- We need to carry out as many exports as possible in order to test the treatment combination with MPI inspection
- Main aim is to export control (non-high pressure washed or "standard" treatment) and treated (HPW and HWT) taro after export to NZ. MPI will inspect and PFR will determine product quality on a sub-sample.

Methodology

Taro:

- High quality taro without holes, wounds, rotten areas (particularly the base of the taro), and taro with a "waist" shape. Trim / cut off rots or misshapen bases.

Rotten base of taro – Unacceptable

Narrow "waist" unacceptable – Trim/cut off

Narrow "waist" unacceptable – Trim/cut off

Unacceptable quality

Control (untreated):

- Taro of standard export quality and treatment
- Place bags into standard sacks (with holes)
- Labelling – spray paint the bag

Treated (HPW+HWT):

- 600 taro (≈ 30-40 sacks)
- Treat taro through the HPW at correct rate – ≈ 15 seconds – about 2 taro every seconds
- After washing check quality again (now that the taro are cleaned and holes etc can be easily seen)
- Treat taro in HWT (25 mins – see above for temps)
- Cool taro in a cool waterbath
- Dry taro overnight
- Place into cotton bags and seal with cable tie (see photo)
- Place bags into standard sacks
- Labelling – spray paint the bag

Phytosanitary certification:

- Ensure there are <u>two</u> phytosanitary certificates – one for the control (standard taro export) and the treated taro (HPW+HWT)

Refrigerated container:

- Place sacks into container – preferably near the door
- Dataloggers. If dataloggers have been provided include in a sack (discuss with PFR)

GAFATAULIMAINA O TALO

Aotelega o le galuega

- O le tulai mai o lenei glauega talu lona faatinoina sa faamautinoaina ai le lelei atoatoa o lenei metotia (faogaina o le saoasaoa o le masini vai palasa e fufulu ai talo, ma le faogaina o le vai vevela) e fufulu ma tapeina ai iniseti ina ia mafai ona pasia e maketi fava o malo e aunoa ma se faaasuina.
- E manaomia I lenei galuega le tele o ni talo e auina atu I fafo ina ia mafia ai ona faogaina lenei metotia I sona aotelega mo le siakiina e le MPI
- O le naunautaiga o lenei suesuega o le fia auina atu lea I Niu Sila o talo (e lei gafataulimaina) ma talo (ua gafataulimaina) mo le iloiloina e le MPI ae o le PFR latou te faia le faaiuga I le tulaga lelei atoatoa o talo

Metotia

Talo:

- O talo lelei atoatoa e leai ni ava po'o ni pupu, manu'a, pala (I le muli talo) ma e lautele le pito I lalo. Tipi ese ni pito pala toe patupatua I le pito I lalo.

Pala le muli talo – le taliaina

Lauiti le pito I lalo – tipi ese

Tulaga ma foliga o le talo e le taliaina

Talo e lei gafataulimaina

- Talo lelei atoatoa mo maketi I fafo ma le gafataulimaina
- Toe fafao lesi taga I totonu o taga masani ua uma ona faapupu
- Maka ma faanumera – vali i fagau lulu (spray paint)

Treated (HPW+HWT)

- 600 Talo (30-40 taga)
- Fufulu talo I le masigi vai palasa I le malosi e fetaui lelei – 15 sekone – 2 talo I le 2 sekone
- Toe siaki foliga ma tulaga lelei o le talo pea maea ona palasa e le masini (o lea la ua mama atoatoa le talo ma ua mafai foi ona iloa lelei ni vaega o lo'o pala ma ava)
- Faamagoto talo I le vai vevela (25 minute – seti le vevela o le vai I le 49.0 tikeri)
- Tu'u ai talo mo se 25 minute,
- Ave ese talo ma faamalu I se tapu vai malu
- Faamago lelei I le po atoa
- Fu'e I taga ie ma nonoa I se uaea saisai (vaai I le ata)
- Toe fafao taga I totonu o lesi taga
- Maka ma faanumera – vali I fagu vali lulu (spray paint)

Pepa Faaasu (PC)

- E 2 pepa faaasu e tapenaina, pepa mo talo ua maea ona gafataulimaina (treated) ma le pepa mo talo e lei gafataulimaina (untreated)

Pusa Ea malulu

- Faatulaga taga talo I totonu o le pusa ea malulu – faalatalata I le faitotoa
- Masini e ao ai faamaumauga (Loggers)

Annex 1.2: Instruction manual for High Pressure Washer unit

Instruction Manual

Plant & Food™ Research
Rangahau Ahumāra Kai

High Pressure Washer

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Contents

Before operation

Fill the reservoir with water

DO NOT turn the machine on until both water reservoirs have been filled

DO NOT empty the water reservoirs until the machine has been turned off and unplugged

DO NOT allow the machine to run with less water than indicated on the side

Ensure the power supply is safe

DO NOT allow the power cable to be driven over

DO NOT place anything heavy on the power cable

DO NOT get the electrical cabinet wet

Operational Tips

- Ensure the main electricity cord is connected to power point on the wall properly (secure connection via screwed in locking mechanism)
- Emergency button is located on main control panel to completely shut down unit
- Ensure doors into the main electrical switch board inside machine are fully and properly closed before running the unit
- Do not reach to areas on brush bed (with hands – use long tools) when the unit is running
- Always, at minimum, **2 people** should operate this machine.

PPE Required

- Ear muffs
- Gum boots or non-slip footwear
- PVC gloves – taro can cause skin irritation

Associated Hazards

- Pinch injury possible around the moving brush bed belt. Keep hands off the sample collection area
- Remote chance of electric shock – do not touch control panels with wet gloves
- High pressure from water washing jets
- Falling over when walking around machine, slip and trip due to wet work area.

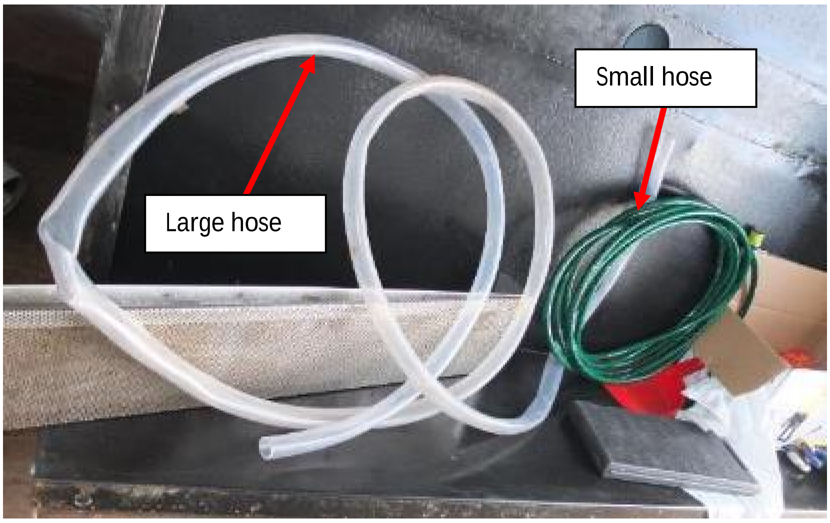
Cleaning before use

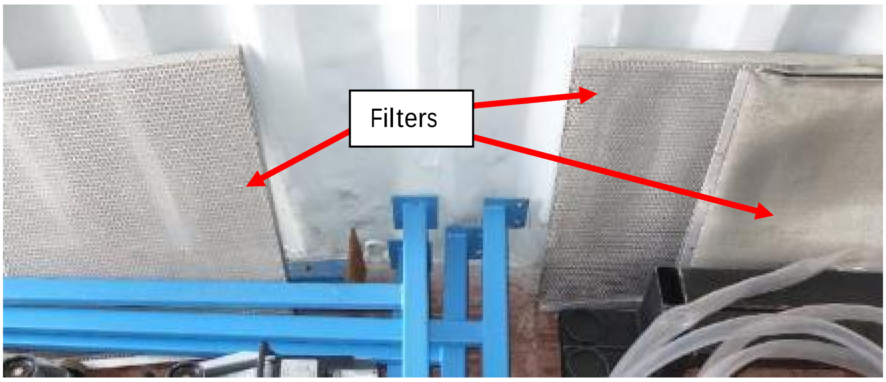
- Open the drains in the main reservoir and small reservoir

- Use the water blaster to clean the reservoirs and the pressure washing area
- DO NOT spray at the brushes when they are not turning. The water blaster will damage the brushes unless they are moving
- Once clean, close both drains
- Remove the side panels and check the chains for rubbish. Remove any rubbish and put panels back on. DO NOT remove the side panels while the machine is powered and in operation

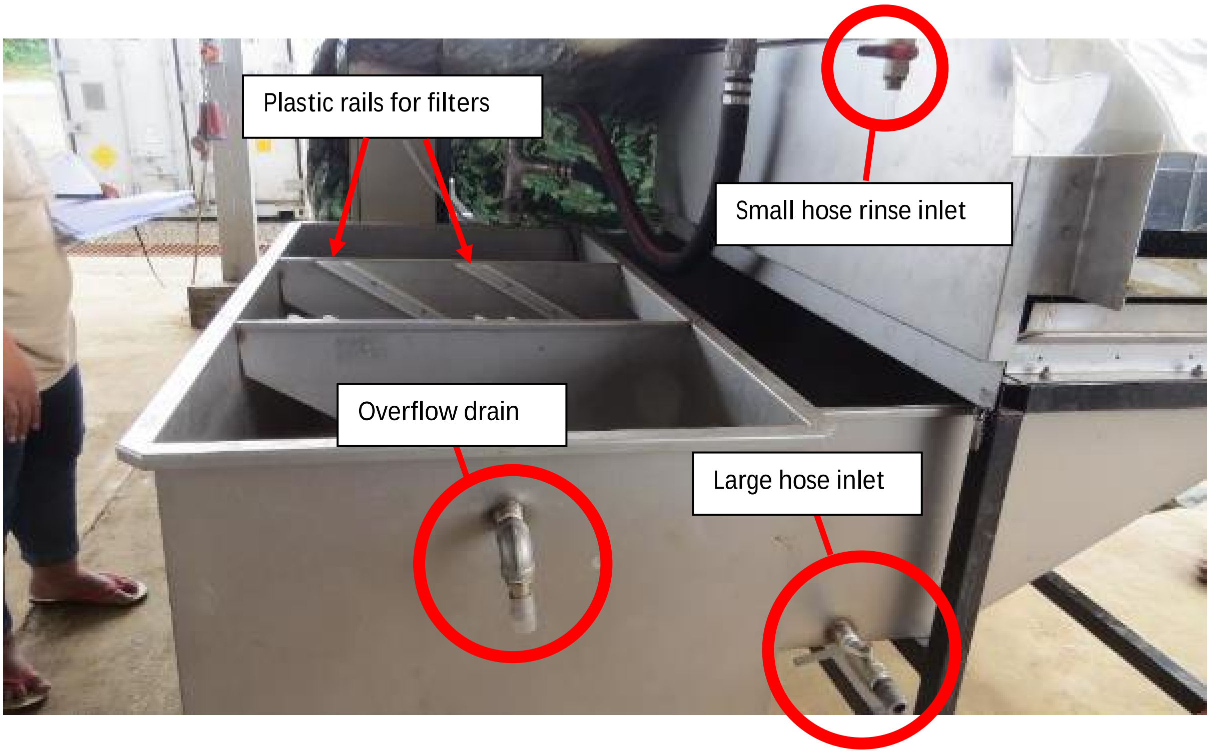
Setting up

- Items needed:
  - Small hose: for the freshwater rinse
  - Large hoses: for draining water and initial fill
  - End boards: for holding crates
  - Pusher: for pushing produce through the machine
  - Filters: 3 large mesh and 1 small mesh (small mesh is rarely used)

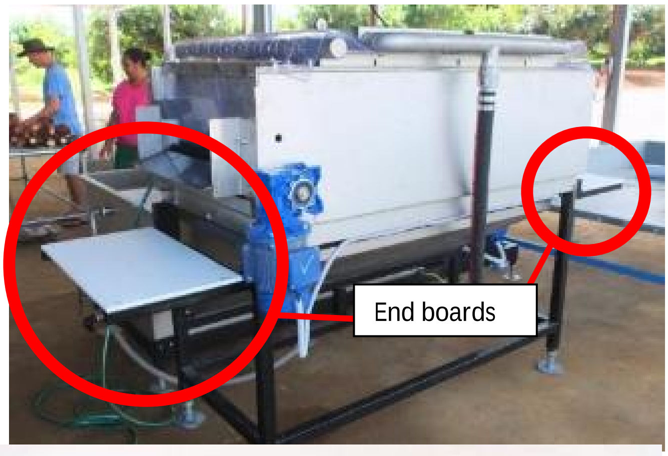


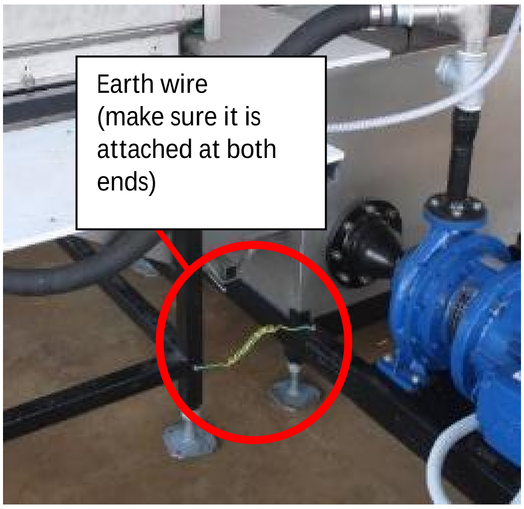


- Fill the reservoirs by attaching a large hose to the side of the small reservoir (large hose inlet), then connecting to the water tank. Then connect a small hose to the rinse inlet and to a mains pressure outlet tap



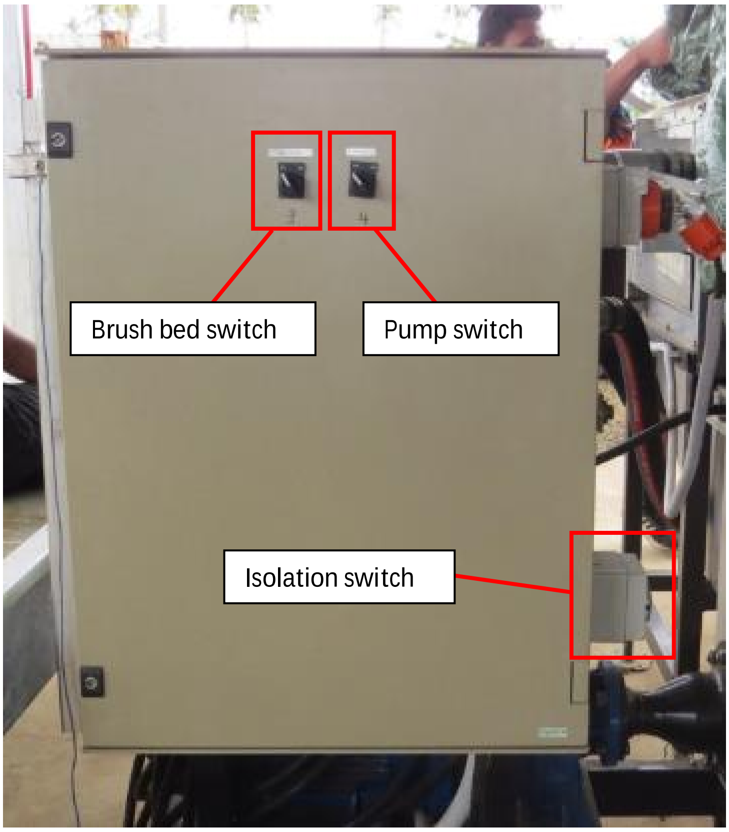
- Attach a large hose to the overflow drain on the large reservoir
- Attach the end boards
- Insert the filters on the plastic rails
- Make sure that the earth wire is connected to both frames





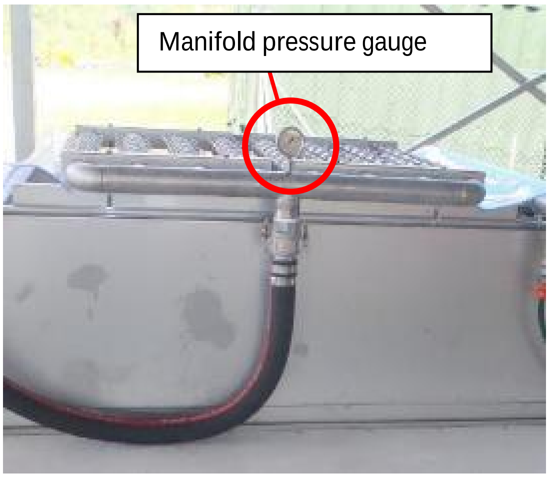
Running the machine

1. Plug the machine into a 4-pin, 32A, 3-phase outlet and turn the switch on (same plugs as containers)
2. Turn on the isolation switch
3. Turn on the brush bed rollers
4. Turn on the pump
5. Turn on small inlet hose for fresh water rinse



Adjusting pressure:

- The pump needs to be running during this process, this allows you to check the pressure is set correctly
- Open the electrical cabinet. DO NOT GET IT WET!
- Adjust the Hz knob slowly. The digital readout will not adjust instantly, wait until the numbers stop changing before turning the knob again



- Adjust until the digital readout matches the desired Hz
- Check the pressure gauge on the washer manifold for the desired pressure
- Close the cabinet. MAKE SURE IT IS CLOSED PROPERLY

Running a treatment

Settings for Plant & Food experiment:

1) Pressure gauge (on gantry) MUST read 50 psi
2) Roller rotation speed = 18 Hz
3) Treatment time in the washer = 15 seconds (feed in 2 taro every 2 seconds)
4) The nozzles must be continually unblocked during treatment as well as the filters being cleaned

Translation to Samoan:

Sekiina o masini a le Plant & Food:

1) Fua Mika (malosi) = tatau na faitau 50 psi
2) Saoasaoa o taamiloga o lola = 18Hz
3) Taimi e fufulu ai totonu o le masini = 15 sekone (tai 2 talo I le 2 sekone)

Gutu paipa e tatau ona ola ma aua nei poloka, ma ia mama lelei ia faamama

Treatment time - speed to place taro into the washer:

Treatment time = 15 seconds (2 taro every 2 seconds)

Translation to Samoan:

Taimi e fufulu ai talo – o le saoasaoa e tu'u ai talo totonu o le masini

Taimi e fufulu ai talo = 15 sekone (tai 2 sekone ma tuu i totonu talo e 2)

Cleaning after use

Cleaning after use:

1) Empty both tanks
2) Clean all filters
3) Waterblast the rollers to remove as much taro material as possible
4) Hose out the tanks so they are clean
5) Cover the washer with tarpaulin after use

Translation to Samoan:

Fufuluina pe a uma ona fa’aaoga:

1) Fa’agaogao uma tane (aua nei iai ni mea i totonu)
2) Fufulu mama uma ia faamama vai
3) Fufulu mama lola i le palasa vai e aveeseina ai otaota mai talo
4) Faoga fagaau e fufulu ai tane
5) Ufiufi lelei tane i se tapoleni pe a uma ona faaoga

Machinery Specifications

Dimensions	3.3m x 2.3m
Power socket required	3-phase, 4-pin, 32A, 500V
Length of power cable	18m
Current drawn under maximum load	21A
Spray nozzles	Promax® QuickJet® Spray Tips (QPTA-25-20)
Rinse nozzles	Promax® QuickJet® Spray Tips (QPTA-40-05)
Number of spray rows	8
Number of spray nozzles	64 (8 per row)
Maximum spray pressure	110psi
Water reservoir capacity	1.4m^3 (1400L)
Large mesh filter size	30x30 squares/inch (0.55 mm aperture)
Small mesh filter size	100x100 squares/inch (0.15 mm aperture)

Water pump/motor

Power	3-phase, 50 Hz, 15kW
Centrifugal pump	238mm diameter
Water flow	28m^3/h (467L min^{-1})
Variable speed drive (VSD) range	5-50 Hz (over 30 s period to minimize current surge)
Start-up time	30 seconds
Stopping time	1 second

Conveyor motor

Power	3-phase, 50 Hz, 1.5kW
Gearbox	15:1 worm and wheel gearbox
Variable speed drive (VSD) range	5-50 Hz (5 Hz matches taro loading speed)
Start-up time	1 second

Annex 1.3: Instruction manual for Hot Water Treatment unit

Instruction Manual

Plant & Food™ Research
Rangahau Ahumāra Kai

Hot Water Treatment unit

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Contents

Before operation

Fill the bath with water

DO NOT turn the machine on until the water bath has been filled

DO NOT empty the water bath until the machine has been turned off and unplugged

DO NOT allow the machine to run with less water than indicated on the side

Ensure the power supply is safe. Make sure the power cable isn't coiled

DO NOT allow the power cable to be driven over

DO NOT place anything heavy on the power cable

DO NOT get the electrical cabinet wet

Operational Tips

- Ensure the main electricity cord is connected to power point on the wall properly (secure connection via screwed in locking mechanism)
- Emergency button is located on main control panel to completely shut down unit
- Ensure doors into the main electrical switch board inside machine are fully and properly closed before running the unit
- Always, at minimum, **2 people** should operate this machine.

PPE Required

- Gum boots or non-slip footwear
- PVC gloves – taro can cause skin irritation

Associated Hazards

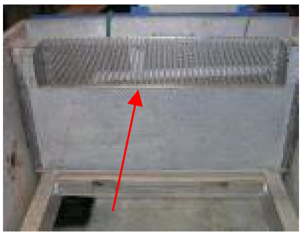
- Remote chance of electric shock – do not touch control panels with wet gloves
- Falling over when walking around machine, slip and trip due to wet work area.
- Potential crush injury from the crate holder. Ensure that hands and feet are kept clear when moving and lowering the crate holder
- Hot water and hot elements. Keep hands out of the water when machine is running
- Unguarded water inlet for pump. Keep hands out of water near the filters when pump is running. High suction may cause injury

Cleaning

- Remove plastic cover from the bath
- Open the drain underneath the tank. This drain is to the right of the cabinet. On the opposite side of the tank to the pumps
- Use the water blaster or a hose to rinse out the inside of the tank
- Close the drain

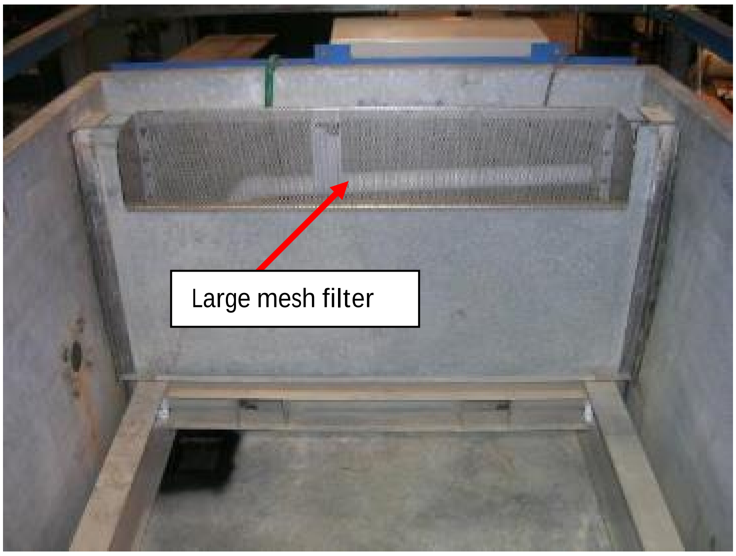
Setting up

- Remove following items from storage:

			
Mesh filter	Chain block	Square metal mesh	Adjustable tie-down

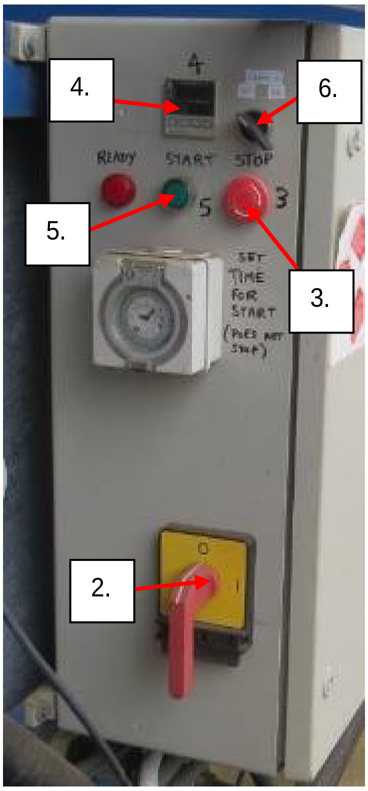
- Attach the chain block to the crate holder
- Lift the crate holder out of the bath using the chain block and lower it to the ground outside the bath
- Make sure the drains are closed

- Insert the large mesh filter and fine mesh filter
- Fill the bath with water to the line marked “GOOD



- Plug the HWT bath into the wall socket
  - Ensure that there is enough power available!
  - At the time of Plant and Food’s last visit, the max capacity was 100A
  - The bath uses a 50A plug (this means it has a max loading of 50A but it will use less than this when running)
  - The refrigeration containers at Atele should have a max loading of 25A. But check the back of the unit to make sure
  - Check what is plugged in and make sure that when added together, these machines do not exceed the max amp loading of the circuit board.

Running the machine



1. Switch the power on at the wall
2. Switch the power on at the machine (turn large red switch from O towards I)
3. Turn the safety switch (red button) in direction of arrows (clockwise) until the switch pops out
4. Set the desired water temperature using only the middle two buttons (up arrow and down arrow)
5. Press the green "Start" button. This will start the pump
6. Switch the "element 2" switch on (right/clockwise)
7. Wait for the bath to reach the target temperature

Hot water treatment of taro:

Note: The target temperature is 48°C at the water "return", i.e. coldest position (coming over the weir/filter) – the following conditions have been verified using a calibrated temperature probe.

1) Set temperature to 50°C using buttons in panel 4 (in this photo)
2) Note: Time to heat water bath is ≈ 3 hours
3) Load taro into 12 crates. Cover and strap metal grid over the top
4) Switch on the second element (top right switch - # 6 in this photo)
5) Immerse the taro completely under water then set the temperature to 49.0°C and turn off the second element
6) Leave for 25 minutes
7) Remove and place in the next water bath for 25 minutes and then leave out to dry overnight
8) Place taro in cloth bags – cable tie them shut - THEN into standard sacks
9) Mark the sacks

Translation to Samoan:

Faamagoto talo i le vai vevela:

1) Seti le vevela o le vai i le 50 tikeri e faaoga ai ki i le pusa 4 (i totonu o le ata)
2) Manatua: Taimi e faavevela ai le tapu vai pe a ma le 3 hours
3) Fue talo i pusa e 12. Tapuni le pito i luga i le uamea valavala ma saisai ia mau
4) Ki le elemeni lona 2 (tamatau pito I luga, #6 i totonu o le ata)
5) Faamagoto lelei pusa talo ma toe seti le vevela i le 49.0 tikeri (#4 i totonu o le ata) ona tape lea o le elemeni lona 2
6) Tu'u ai mo se 25 minute
7) Ave ese mai ma tu'u i totonu o le isi tapu vai mo se 25 minute, ona faaea laia ma fa'amago i le po

8) Fu’e talo i taga ie, nonoa mau ini uaea saisai, ona tu’u lea i totonu o atigi taga masani
9) Maka ma faanumera taga

Running the treatment

Loading the crates

- Load the fruit/vegetables into the grey crates
  - Make sure fruit isn’t loaded higher than the black handles
- Load the crates into the crate holder
  Lift the crate holder to max height using the chain block
- Once the crate holder is at max height, position it so that the square metal mesh can be fitted on top of the crates
- Tie down the metal mesh with an adjustable tie-down
- Move the crate holder into position above the bath
- Check the bath temperature before continuing
- Carefully lower the crates into the water, make sure the crates don’t get stuck on anything
- Start timing the treatment once the top crate is fully submerged

Unloading the crates

- o Once the treatment time is up, lift the crates out of the water using the chain block
- o Move the crates to a position where the mesh can be removed and remove the mesh
- o Do not remove the crates until the crate holder is on the ground
- o Lower the crate holder to the ground and remove the crates

Between treatments

- o Remove the fine mesh filter and rinse out any dirt by hosing it from the underside then return the filter to the tub

- After treatment

- o Turn off the machine by pressing the safety switch (Red button)
- o Turn off the main switch on the machine (large red switch)
- o Turn off the power at the wall and unplug the cable
- o Attach a hose to the secondary drain and open the valve

- o Drain most of the water through the secondary drain, unless it is OK to flood the floor then use the main drain
- o Once the water stops draining out of the secondary drain, open the main drain underneath the bath
- o Once the bath is empty, hose out any dirt left at the bottom

- Packing up

- Using the chain block, lift the crate holder into the empty bath

- Detach the chain block
- Remove the fine mesh filter and large mesh filter
- Store the chain block, filters, square metal mesh, and adjustable tie-down in the container
- If the HWT bath is not being used for a while, cover the bath with a plastic sheet

Machinery Specifications

Dimensions	
Power socket required	3-phase, 5-pin, 50A, 500V
Length of power cable	
Current drawn under maximum load	
Chain block load capacity	1 tonne
Water reservoir capacity	1.2m^3 (1200L)

Water pump specs

Power	3-phase, 2.4kW
Water flow	32.1m^3/h (535L min^{-1})

Annex 2: Detailed costing of HPW+HWT system

Item	Description	Part	Description	Material	Height (mm)	Quantity	Cost	Total Cost	Notes	Lower Cost
1	Preparation Table	(a)	Wooden Table Top	Treated Pine	900	5	$325			$325
		(b)	Leg Frame	S/Steel		5	$3,850		Stainless Design. Materials + Labour	$2,696
		(c)	Catch Tray	Treated Pine		5	$280			$280
		(d)	Fasteners and Sundries			5	$200			$140
		(e)	Manufacture and Assembly			5	$780			$780
		(f)	Design and Draughting			1	$500		5 hours	$400
		(g)	Management and Production Support			1	$400		Admin, Purchasing, Stores, Freight	$400
						Sub Total	$6,335	$6,335		$5,021
2	Transfer Conveyor	(a)	600 wide x 7980 endless length Belt	PVC Apple Green	900	1	$689		Transmission House. A section strips	$689
		(b)	616 wide x 4000 long Conveyor Frame	S/Steel		1	$1,373		Supreme Sheetmetals. Laser cut & folded	$887
		(c)	Leg Frame	S/Steel		3	$1,350		Stainless Design. Materials + Labour	$1,150
		(d)	Geared Motor	Motovario		1	$1,021		Transmission House	$1,021
		(e)	Drive and Idle Rollers	S/Steel		2	$1,320		Fraser Gear. Materials + Labour	$1,100
		(f)	Support Rollers	S/Steel		12	$1,128		Dyno Conveyors. Materials + Labour	$720
		(g)	Bearings and Housings	S/Steel & Cast		4	$249			$147
		(h)	Fasteners and Sundries			1	$442			$176
		(i)	Manufacture and Assembly			1	$1,600			$1,600
		(j)	Design and Draughting			1	$2,400		3 days	$2,400
		(k)	Management and Production Support			1	$800		Admin, Purchasing, Stores, Freight	$800
						Sub Total	$12,372	$12,372		$10,690
3	Pressure Washer	(a)	Roller Conveyor. Chain C2050SS-8.1	S/Steel	1308	15.8m	$1,289		Sprocket NZ.	
		(b)	890 x 3644 Conveyor Frame	S/Steel		1	$3,772		Supreme Sheetmetals. Laser cut & folded	
		(c)	PVC Rollers. 127mm Pitch	PVC		62	$5,766		Dyno Conveyors. Materials + Labour	
		(d)	Leg Frame	S/Steel		3	$1,650		Stainless Design. Materials + Labour	
		(e)	Geared Motor	Motovario		1	$1,336		Transmission House	
		(f)	Drive, Idle shafts and Sprockets	S/Steel		4	$4,720		Sprockets NZ. Materials + Labour	
		(g)	Chain Guides	uhmwpe		4	$456		Supply Services	
		(h)	Bearings and Housings	S/Steel & Cast		8	$761			
		(i)	Spray Nozzles and Rotor Assembly	Rotoflux & S/S		36	$9,294		6 nozzles per rotor. Rotors motor driven	
		(j)	Rotor Drive Motor and Assembly	Motovario		2	$2,250		Transmission House	
		(k)	Spray Array Support Frame	S/Steel		1	$1,295			
		(l)	Spray Hood	S/Steel		1	$246			
		(m)	Waste Water Collection Tank	S/Steel		1	$1,992			
		(n)	Pressure Pump	Gould GIS 50x32-160		1	$3,940		Brown Brothers Ltd	
		(o)	Filtration Pump	Lowara CO-500/22		1	$1,989		Brown Brothers Ltd	
		(p)	Filtration and Pressure Piping and Tank			1	$4,511			
		(q)	Filtration and Recirculation System	FiltMaster		2	$9,310		Irrigation Express. Twin auto disc filters	
		(r)	Fasteners and Sundries			1	$884			
		(s)	Manufacture and Assembly			1	$18,000			
		(t)	Design and Draughting			1	$16,000		4 weeks	
		(u)	Management and Production Support			1	$6,000		Admin, Purchasing, Stores, Freight	
						Sub Total	$95,461	$95,461		
4	Grading Table	(a)	Roller Conveyor. Chain C2050SS-8.1	S/Steel	1154	12.2m	$998		Sprocket NZ.	
		(b)	900 x 3000 Conveyor Frame	S/Steel		1	$2,231		Supreme Sheetmetals. Laser cut & folded	
		(c)	PVC Rollers. 127mm Pitch	PVC		48	$4,464		Dyno Conveyors. Materials + Labour	
		(d)	Leg Frame	S/Steel		2	$1,325		Stainless Design. Materials + Labour	
		(e)	Geared Motor	Motovario		1	$1,336		Transmission House	
		(f)	Drive, Idle shafts and Sprockets	S/Steel		2	$2,360		Sprockets NZ. Materials + Labour	
		(g)	Chain Guides	uhmwpe		4	$360		Supply Services	
		(h)	Bearings and Housings	S/Steel & Cast		4	$374			
		(i)	Chain Cover	S/Steel		2	$318			
		(j)	Reject Shutes	S/Steel		2	$392			
		(k)	Standing Platforms	Steel, Plywood		2	$720			
		(l)	Fasteners and Sundries			1	$331			
		(m)	Manufacture and Assembly			1	$6,000			
		(n)	Design and Draughting			1	$6,000		1.5 week	
		(o)	Management and Production Support			1	$3,200		Admin, Purchasing, Stores, Freight	
						Sub Total	$30,409	$30,409		

Item	Description	Part	Description	Material	Height (mm)	Quantity	Cost	Total Cost	Notes	Lower Cost
5	Reject Conveyor	(a)	300 wide x 5980 endless length Belt	Cleated PVC	Angled	1	$385		Transmission House. A section strips	
		(b)	316 wide x 3000 long Conveyor Frame	S/Steel		1	$903		Supreme Sheetmetals. Laser cut & folded	
		(c)	Leg Frame	S/Steel		2	$650		Stainless Design. Materials + Labour	
		(d)	Geared Motor	Motovario		1	$739		Transmission House	
		(e)	Drive and Idle Rollers	S/Steel		2	$1,120		Fraser Gear. Materials + Labour	
		(f)	Support Rollers	S/Steel		8	$504		Dyno Conveyors. Materials + Labour	
		(g)	Bearings and Housings	S/Steel & Cast		4	$249			
		(h)	Waste Bin			1	$60			
		(i)	Fasteners and Sundries			1	$332			
		(j)	Manufacture and Assembly			1	$1,400			
		(k)	Design and Draughting			1	$1,600		2 days	
		(l)	Management and Production Support			1	$800		Admin, Purchasing, Stores, Freight	
						Sub Total	$8,742	$8,742		
6	Transfer Conveyor	(a)	1000 wide x 3080 endless length Belt	PVC Apple Green	1042	1	$490		Transmission House. A section strips	
		(b)	1016 wide x 1500 long Conveyor Frame	S/Steel		1	$688		Supreme Sheetmetals. Laser cut & folded	
		(c)	Leg Frame	S/Steel		2	$1,150		Stainless Design. Materials + Labour	
		(d)	Geared Motor	Motovario		1	$739		Transmission House	
		(e)	Drive and Idle Rollers	S/Steel		2	$1,620		Fraser Gear. Materials + Labour	
		(f)	Support Rollers	S/Steel		6	$684		Dyno Conveyors. Materials + Labour	
		(g)	Bearings and Housings	S/Steel & Cast		4	$249			
		(h)	Fasteners and Sundries			1	$190			
		(i)	Manufacture and Assembly			1	$1,400			
		(j)	Design and Draughting			1	$1,200		1.5 days	
		(k)	Management and Production Support			1	$800		Admin, Purchasing, Stores, Freight	
						Sub Total	$9,210	$9,210		
7	Hot Water Treatment	(a)	Water Tank Sections including Legs	S/Steel	960	5 sections	$59,157		Supreme Sheetmetals. Materials + Labour.	
		(b)	Inlet and Outlet Plenum	S/Steel		2	$1,834			
		(c)	Adjustable Sliding Foot	S/Steel		40	$5,200			
		(d)	Roller Conveyor. Chain C2060SS-8.1	S/Steel		74.4m	$9,416		Sprocket NZ.	
		(e)	Drive, Idle shafts and Sprockets	S/Steel		2	$3,620		Sprockets NZ. Materials + Labour	
		(f)	Geared Motor	Motovario		1	$2,533		Transmission House	
		(g)	Bearings and Housings	S/Steel & Cast		4	$716			
		(h)	Conveyor Cross Rods	S/Steel		80	$6,720		Materials + Labour	
		(i)	Pocket Conveyor	Breezeway Extra		8 sections	$8,240		Hamilton Canvas. 10 pockets/section	
		(j)	Conveyor Support and Cover Frames	S/Steel			$15,340			
		(k)	Conveyor Side Covers	S/Steel			$5,952			
		(l)	Conveyor Chain Guides	uhmwpe		72m	$2,304		Supply Services	
		(m)	Transfer Plate	S/Steel		1	$271			
		(n)	Circulation Pump	Gould GIS 100x65-200		1	$4,673		Brown Brothers Ltd	
		(o)	Bypass Filter and Pump	80mm Amiad Screen		1	$2,467		Irrigation Express. ScanAway cleaner kit	
		(p)	Circulation and Hot Water Piping	ABS Pipe & Fittings			$10,225		Capital Valves	
		(q)	Hot Water Condensing Twin Boiler	Italtherm		1	$76,070		Tubman Heating. Includes Heat Exchanger	$58,070
		(r)	Hot Water Pump	Gould GIS 100x65-250		1	$5,384		Brown Brothers Ltd	(1 Boiler)
		(s)	Thermal Insulation Tunnel	PIR Panel		200 m2	$27,442			
		(t)	Water Holding Tanks	10,000 litres each		3	$8,700		RX Plastics	
		(u)	Filter, Pump, Tank Base Frames	S/Steel		4	$5,448			
		(v)	Fasteners and Sundries			1	$2,564			
		(w)	Manufacture and Assembly			1	$48,000			
		(x)	Design and Draughting			1	$28,000		7 weeks	
		(y)	Management and Production Support			1	$16,000		Admin, Purchasing, Stores, Freight	
						Sub Total	$356,276	$356,276		
8	Elevator	(a)	Conveyor Frame	S/Steel		1	$2,169		Elevator out of Hot Water Tank	
		(b)	UNI MPB K600 Plastic Belt	Polyethylene		1	$2,308		Transmission House	
		(c)	Sprockets and Retaining Rings	Polyethylene		1 set	$1,901		Transmission House	
		(d)	Geared Motor	Motovario		1	$1,336		Transmission House	
		(e)	Bearings and Housings	S/Steel & Cast		4	$249			
		(f)	Drive and Idle shafts	S/Steel		2	$260			
		(g)	Conveyor Side Guides	S/Steel		2	$364			
		(h)	Belt Supports	uhmwpe		8	$160			
		(i)	Transfer plate	S/Steel		1	$201			
		(j)	Fasteners and Sundries				$440			
		(k)	Manufacture and Assembly				$4,000			
		(l)	Design and Draughting				$6,000		1.5 weeks	
		(m)	Management and Production Support				$800		Admin, Purchasing, Stores, Freight	
						Sub Total	$20,188	$20,188		

Item	Description	Part	Description	Material	Height (mm)	Quantity	Cost	Total Cost	Notes	Lower Cost
9	Cold Water Tank	(a)	Water Tank Sections including Legs	S/Steel	960	4 sections	$39,472		Supreme Sheetmetals. Materials + Labour.	
		(b)	Inlet and Outlet Plenum	S/Steel		2	$1,834			
		(c)	Adjustable Foot	S/Steel		26	$2,470			
		(d)	Circulation Pump	Gould GIS125x100-200		1	$5,027		Brown Brothers Ltd	
		(e)	Circulation Piping			1	$1,826			
		(f)	Bypass Filter and Pump	80mm Amiad Screen		1	$2,467		Irrigation Express. ScanAway cleaner kit	
		(g)	Water Holding Tanks	10,000 litres each		2	$3,800		RX Plastics	
		(h)	Fasteners and Sundries			1	$630			
		(i)	Manufacture and Assembly			1	$10,000			
		(j)	Design and Draughting			1	$10,000		2.5 weeks	
			Management and Production Support			1	$6,000		Admin, Purchasing, Stores, Freight	
						Sub Total	$83,526	$83,526		
10	Elevator	(a)	Conveyor Frame	S/Steel		1	$2,169		Elevator out of Cold Water Tank	
		(b)	UNI MPB K600 Plastic Belt	Polyethylene		1	$2,308		Transmission House	
		(c)	Sprockets and Retaining Rings			1 set	$1,901		Transmission House	
		(d)	Geared Motor	Motovario		1	$1,336		Transmission House	
		(e)	Bearings and Housings	S/Steel & Cast		4	$249			
		(f)	Drive and Idle shafts	S/Steel		2	$260			
		(g)	Conveyor Side Guides	S/Steel		2	$364			
		(h)	Belt Supports	uhmwpe		8	$160			
		(i)	Transfer Plate	S/Steel		1	$201			
		(j)	Fasteners and Sundries			1	$440			
		(k)	Manufacture and Assembly			1	$4,000			
		(l)	Design and Draughting			1	$2,000		2.5 days. Same as hot water elevator	
		(m)	Management and Production Support			1	$800		Admin, Purchasing, Stores, Freight	
						Sub Total	$16,188	$16,188		
11	Forced Air Drier	(a)	1995 wide x 9650 long Conveyor Frame	S/Steel	1100	1	$13,576		Supreme Sheetmetals. Laser cut & folded	
		(b)	Leg Frame	S/Steel		6	$4,172			
		(c)	Adjustable Foot	S/Steel		12	$1,140			
		(d)	Roller Conveyor. Chain C2050SS-8.1	S/Steel		59.8m	$4,895		Sprockets NZ. Includes Middle Chain	
		(e)	PVC Rollers. 127mm Pitch	PVC		314	$29,202		Dyno Conveyors. Materials + Labour	
		(f)	Geared Motor	Motovario		1	$1,795		Transmission House	
		(g)	Drive, Idle shafts and Sprockets	S/Steel		2	$2,750		Sprockets NZ. Materials + Labour	
		(h)	Bearings and Housings	S/Steel & Cast		4	$460			
		(i)	Chain Support Guides	uhmwpe		2	$1,500		Supply Services	
		(j)	Chain Cover	S/Steel		2	$1,591			
		(k)	Air Deflector Panels	S/Steel		1	$2,320			
		(l)	Fan Support Frame and Cover	S/Steel		1	$5,991			
		(m)	Axial Flow Fans			8	$3,944		Rotating Machinery Supplies	
		(n)	Fasteners and Sundries			1	$1,480			
		(o)	Manufacture and Assembly			1	$36,000			
		(p)	Design and Draughting			1	$16,000		4 weeks	
		(q)	Management and Production Support			1	$6,000		Admin, Purchasing, Stores, Freight	
						Sub Total	$132,816	$132,816		
12	Transfer Conveyor	(a)	900 wide x 7980 endless length Belt	PVC Apple Green	950	1	$844		Transmission House. A section strips	$844
		(b)	916 wide x 4000 long Conveyor Frame	S/Steel		2	$1,502		Supreme Sheetmetals. Laser cut & folded	$976
		(c)	Leg Frames	S/Steel		3	$1,650		Stainless Design. Materials + Labour	$1,150
		(d)	Geared Motor	Motovario		2	$1,021		Transmission House	$1,021
		(e)	Drive and Idle Rollers	S/Steel		2	$1,540		Fraser Gear. Materials + Labour	$1,100
		(f)	Support Rollers	S/Steel		12	$1,368		Dyno Conveyors. Materials + Labour	$873
		(g)	Bearings and Housings	S/Steel & Cast		4	$249			$147
		(h)	Fasteners and Sundries			1	$442			$176
		(i)	Manufacture and Assembly			1	$1,600			$1,600
		(j)	Design and Draughting			1	$1,600		2 days	$1,600
			Management and Production Support			1	$800		Admin, Purchasing, Stores, Freight	$600
						Sub Total	$12,616	$12,616		$10,087

Item	Description	Part	Description	Material	Height (mm)	Quantity	Cost	Total Cost	Notes	Lower Cost
13	Transfer Conveyor	(a)	900 wide x 1880 endless length Belt	PVC Apple Green	950	1	$329		Transmission House. A section strips	
		(b)	916 wide x 900 long Conveyor Frame	S/Steel		2	$542		Supreme Sheetmetals. Laser cut & folded	
		(c)	Leg Frames	S/Steel		2	$1,100		Stainless Design. Materials + Labour	
		(d)	Geared Motor	Motovario		2	$739		Transmission House	
		(e)	Drive and Idle Rollers	S/Steel		2	$1,540		Fraser Gear. Materials + Labour	
		(f)	Support Rollers	S/Steel		3	$342		Dyno Conveyors. Materials + Labour	
		(g)	Bearings and Housings	S/Steel & Cast		4	$249			
		(h)	Fasteners and Sundries			1	$114			
		(i)	Manufacture and Assembly			1	$1,200			
		(j)	Design and Draughting			1	$1,200		1.5 days	
		(k)	Management and Production Support			1	$800		Admin, Purchasing, Stores, Freight	
						Sub Total	$8,155	$8,155		
14	Bagging Conveyors	(a)	600 wide x 4000 long Belt	PVC Apple Green	900	2	$1,378		Transmission House. A section strips	
		(b)	616 wide x 4000 long Conveyor Frame	S/Steel		2	$2,746		Supreme Sheetmetals. Laser cut & folded	
		(c)	Leg Frame	S/Steel		6	$2,700		Stainless Design. Materials + Labour	
		(d)	Geared Motor	Motovario		2	$2,042		Transmission House	
		(e)	Drive and Idle Rollers	S/Steel		4	$2,640		Fraser Gear. Materials + Labour	
		(f)	Support Rollers	S/Steel		24	$2,256		Dyno Conveyors. Materials + Labour	
		(g)	Bearings and Housings	S/Steel & Cast		8	$498			
		(h)	Weigh Platform	Pallet Scale		1	$790		Arrow Warehouse	
		(i)	Fasteners and Sundries			2	$884			
		(j)	Manufacture and Assembly			2	$3,200			
		(k)	Design and Draughting			1	$800		1 day.	
		(l)	Management and Production Support			1	$1,200		Admin, Purchasing, Stores, Freight	
						Sub Total	$21,134	$21,134		
15	Electrical	(a)	Design, Supply and Installation				$46,914	$46,914	B.T. Developments	
16	Equipment Production Cost							$860,342		
17	Equipment Sales Price		15% Profit Margin					$989,393		
				Other Considerations						
1	Prototyping aspects of the Hot Water Treament Equipment, etc						$60,000			
2	Assembly and Testing of Equipment in New Zealand						$24,000			
3	Disassembly, Packing for Shipping to Samoa						$16,000			
4	Re-Assembly and Testing of Equipment in Samoa						$30,000		Plus Airfares, Accomodation etc	
5	Training, Initial Production Runs, and Hand-over						$16,000		Plus Airfares, Accomodation etc	
6	Supply of Spare Parts and Maintenance Training						$24,000		Plus Airfares, Accomodation etc	
7	Container Hireage and Shipping to Samoa (Port to Port)			5 x 40 ft containers			$57,000		No Internal Freight or Customs	
							$227,000	$227,000		
						Project Total		$1,216,393		

Report for:

DT Global Australia PTY Limited

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