FINAL PROJECT REPORT

Postharvest loss and food safety risks in Samoa's fruit and vegetable value chains

August 2015

Prof Steven J.R. Underhill
Faculty of Science, Health, Education and Engineering
University of the Sunshine Coast
MAROOCHYDORE DC, Q, 4558
Australia
Email: sunderhi@usc.edu.au

OBJECTIVES OF PROJECT:

Undertake an evaluation of postharvest loss and food safety risk in Samoa's fruit and vegetable chains.

To support of the work of FAO in strengthening smallholder market linkages and sustainable value chain development in Samoa, this research sought to assessed post-harvest loss and food safety risk in selected fruit and vegetable chains in order to assist the development of practical recommendations to reduce loss.

EXECUTIVE SUMMARY

- Current commercial postharvest loss in Samoa was 12-15%, with postharvest losses more prevalent in fruit crops (banana, papaya, avocado, pineapple and breadfruit)[1]. This level of postharvest loss is less than anticipated and reflects comparatively short transport distances and limited inter-island supply[2]. There were numerous incidences of high postharvest loss, the worst being 52% postharvest loss observed in consignments into the Fugalei markets.
- The postharvest handling and marketing of fruit and vegetables in Samoa is highly vulnerable to external shock. In simulated market storage condition, any delay in the transport logistics or rate of market throughput is anticipated to lead to extensive postharvest losses (>30%).
- In this study, we undertook a detailed assessment of seven horticultural postharvest value chains. Value chains assessed are listed on page 9. All the postharvest horticultural chains assessed lacked basic postharvest infrastructure and had limited understanding of good postharvest handling practices.
- The main contributor to postharvest loss was the slow municipal market throughput – particularly evident in the Vaitele and Fugalei markets, where it was common for market vendors to take 4-5 days to sell a consignment with product continuously held at ambient temperatures (24-32C).
- Significant differences in postharvest losses were recorded between the various municipal fruit and vegetable markets on Upolu and Savaii.
  - Vaitele municipal markets (26% loss)
  - Saleimoa road side market (18% loss)
  - Afega community market (17% loss)
  - Fugalei municipal markets (13.8% loss)
  - Taufusi private markets (9% loss)
  - Savaii market – insufficient number of vendors to analyse
- While market through-put efficiency was the primary reason for different levels of postharvest losses between markets, there were also a series of local value-adding enterprises linked to the Taufusi market (i.e. over-ripe product being sourced by home bakeries) and vendor trading practices (i.e. bulk packing and discounting) that further reduced overall postharvest losses. Comparatively low

[1] Crops specific postharvest losses will be published is a pending technical journal article

[2] Much of the horticultural product traded through the municipal markets, were transported from farm to market within 2 to 6 hours of harvest, and involved distances of less than 50km. The notable exception being product source from Savaii, and taro value chains sourced from smallholder farmers who were often reliant on local bus transport logistics.

postharvest losses in the Taufusi market is also attributed to greater consumer convenience at the Taufusi markets (i.e. drive-through design, no need to park, and convenient location). Market design and placement relative to the degree of consumer convenience provided, had a major impact on market trading efficiency.

- A food health and safety audit was undertaken by SROS for three of the assessed value chains and is reported separately.
- Postharvest losses were notably lower (often <5%) in those value chains selling directly to retail outlets or structured around contractual farming agreements (i.e. direct selling to supermarkets, restaurants or hotels). This was due to more rapid supply logistics (removing the risk of prolonged municipal market storage). Strategies to promote contractual farming and associated value chain relationships are likely to have a positive impact in terms of further reducing postharvest losses.
- Most value chain stakeholders recognised the need to improve their postharvest handling, but were unclear on practical ways to achieve this. In the case of commercial farms, most were employing postharvest handling practices unable cope with the larger supply volumes.
- Common postharvest handling issues/challenges included:
  - Limited access to appropriately priced plastic field crates - leading to excessive re-packing and elevated food safety cross contamination.
  - No access to over-night cool storage capacity at the municipal markets- leading the product being held at ambient temperatures until sold.
  - Lack of harvest and maturity indices – variable product on display with over-ripe product causing further consignment spoilage.
  - Poor on farm hygiene – creating significant food health and safety risk.
  - Limited postharvest handling knowledge of market vendors – some of the practices used by vendors are likely to shorten product shelf-life.
  - High incidence of pre and postharvest diseases.
- The road conditions and handling practices were assessed through impact and vibration events along the chain. The road conditions were relatively good, with the exception of the secondary farm roads in the Alesia region[3].
- In most value chains assessed there was no access or use of refrigerated storage. Even when present, cool chain management was poor or inconsistently used.
- In terms of high-risk commodities, potential postharvest losses in highly perishable crops (water cress, leafy vegetables) were mitigated through vendors only selling small volumes and focusing on high-volume days (i.e. Friday and Saturday trading)[4]. This is an important point, in that it provides evidence of deliberate restricted supply volumes to reduce vendor postharvest losses, and that postharvest losses are influence the wider supply chain.
- The reasons for the comparative slow throughput trading at the municipal markets needs to be further examined. It would appear horticultural marketing in Samoa is in transit towards a de-centralised structure based on more consumer conveniently located micro-markets and increased retail-shop trade.

[3] The number an severity of impact and vibration events were worst in the commercial Aleisa farms, than in product being sourced from Southeastern parts Upolu of transported by public bus.

[4] In the case of watercress, product was sourced from local creeks and rivers in the greater Apia region and commonly sold on Saturdays by day traders (harvested and sold by late morning).

KEY RECOMMENDATIONS

1. There is an urgent need for postharvest capacity building in Samoa. To be effective, training needs to focus on providing practical postharvest handling strategies relevant to existing production and market dynamics. Training should focus on the following industry stakeholder groups and practices:
    - Smallholder farms - harvesting, handling and transport (community-based training).
    - Commercial scale farmers - pack-house design and training of on-farm labour[5] (on-farm training).
    - Municipal market vendors - product handling and storage (in-market training).
2. There was a universal lack of understanding of food health and safety risk factors in all of the value chains assessed, as such there is an critical need for food safety training and capacity building. While training is required across the industry, priority should be given to the larger commercial farms and those farms using organic fertilisers. Further microbial testing of horticultural value chains is also recommended, due to the limited number of chains assessed in the current study.
3. Chemical residue testing was not included in this project. A preliminary audit of chemical residue for a range of horticultural products should be undertaken to fully document food health and safety compliance and risk.
4. Strategies and options to reduce postharvest losses along the value chain need to be commercially evaluated. These could include:
    - Evaluation of low energy cool storage structures on farm and/or at the municipal markets.
    - Better access to affordable plastic crates and cartons – focused primarily on the commercial growers.
    - Use of polystyrene cartons for market storage – focused on vendors.
5. As contractual marketing-orientated value chains had a lower incidence of postharvest loss, strategies to better promote and support contractual farmers in Samoa need to be developed.
6. Postharvest value chains from the Island of Savaii and those associated with horticultural value-adding products, were not assessed in the current study. Based on strong stakeholder interest additional postharvest assessments targeting these chains are recommended.
    - A series of horticultural value chains from Savaii needs to be assessed with the view improving existing intra-island trade.
    - Breadfruit and organic banana are important value-added horticultural crops traded in Samoa, where industry stakeholders are currently seeking technical assistance. Associated postharvest handling practices needs to be evaluated, key risk factors identified and strategies to improve the value chain developed.
7. There is a critical lack of applied postharvest expertise in Samoa. A local horticultural researcher or extension officer or academic needs to receive intensive training in applied postharvest handling practices and associated technologies.

[5] It would be desirable that any potential postharvest training involved local training providers (USP, National University of Samoa) so content can be mainstreamed within local horticultural curriculum.

BACKGROUND TO THE STUDY

Commercial postharvest handling of vegetable crops in the Pacific Island Countries (PICs) results in significant wastage and reduction in the amount of marketable product available to commercial supply chains (Underhill 2013). While a lack of cold storage and poor marketing infrastructure are often cited as the most significant causes of postharvest losses along the vegetable value chain in the PICs, subsequent research has identified that postharvest losses were primarily the result of poor on-farm practices. Poor road infrastructure, product handling and consignment loading have been shown to be major contributors to postharvest wastage in other less developed countries (LDCs) (Tomlinset al., 2000, 2002; Sahayand Mohan, 2003; Aba et al., 2012). In the Pacific, this is particularly relevant where low-input farmers have transitioned from growing traditional root and tuber crops to more sensitive species such as leafy vegetables, tomatoes, eggplant and other similar high-value western crops. In addition a lack of awareness of the importance of proper load configuration and product stack height in reducing resultant fruit damage is often poorly understood.

Postharvest wastage due to poor management of on-farm ripening and storage, is a major contributor to product losses. Farmers often pick product at colour break or pre-ripe and seek to ripen on farm, in order to reduce losses resulting from pests. However unhygienic ripening and storage facilities often lead to an increase in presence of pathogens, and limited fruit sorting to remove rotten fruit, contributing to high rates of on-farm product spoilage. Often overlooked is the underlying issue of food safety risk based on microbiological contamination when postharvest wastage is discussed in the postharvest literature in the context of LDCs. While product may present itself as having acceptable visual quality, potential food contamination can easily be overlooked, in effect creating hidden postharvest wastage.

The Government of Samoa (GOS), through the Ministry of Agriculture and Fisheries (MAF), lacks the capacity in terms of technical skills and major resources to undertake to develop and implement agricultural evidence gathering and policy analysis. Both are critical to improving the development of evidence-based food security policy, and reducing food and nutritional insecurity in Samoa.

The use of action value chain analysis (i.e. following the product along the chain) will involve value chain actors in the horticultural chain in participatory research, in order to identify opportunities for improving efficiencies. As a result it is far more effective at gathering real marginal cost data necessary to carrying out accurate analysis; as well as providing a more effective mechanism for communicating the results of research to value chain participants.

Given the proposed introduced of the new Samoan Food Bill (2013) which introduces some rather new requirements for farmers, processors and retailers, there was a significant need for technical assistance to identify the potential pathways of introduction of biological and toxic contaminants into a number of food chains – particularly those where products were eaten ‘fresh,’ such as lettuce, tomatoes, capsicum, chinese cabbage, head cabbage and watercress. This research will be important to inform the design of a follow-up capacity building interventions, which will be developed next year following the completion of this activity

METHOD

- A project pre-research consultation workshop was held with Ministry of Agriculture and Fisheries (MAF), Scientific Research Organisation of Samoa (SROS), Samoan Farmers Association (SFA), Samoa Chamber of Commerce and Industry, FAO stakeholders, World Bank and consultants supporting the *Samoa Agriculture* Competitiveness Enhancement Project, and SFA-invited farmers. This workshop was used to present the proposed value chain methodology and refine the target value chains for assessment.
- The resultant research methodology involved four key activities:
    1. A rapid survey of the market vendors in terms of industry perceptions of current levels of postharvest loss.
    2. Detailed assessment of seven horticultural value chains to document current postharvest handling practice and identify key risk factors.
    3. Quantification of postharvest losses in the Fungalei municipal markets
    4. An audit of food health and safety risk along three value chains, supported by microbial assessment at key points along the chain.
- The market vendor survey (undertaken by SROS researchers) involved vendors identifying their three worst crops and their overall level of commercial postharvest loss. A total of fifty vendors were interviewed across all the municipal and roadside markets on Upolu. Repeat interviews were undertaken in the Taufusi markets to validate data.
- In each of the seven value chains assessed, the physical risk factors and transport logistics were determined using a series of TinyTag Tansit-2 temperature and humidity, and TinyTag vibration and impact loggers, (Gemini Dataloggers, United Kingdom) placed within the consignment. Truck speed and route were concurrently recorded using a Super Trackstick® Telespial Systems Inc California with global position system (GIS) referencing uploaded onto Google Earth™. All loggers and global positioning equipment were time synchronized to allow a spatial and temporal cross-referencing of truck speed, temperature, humidity, vibration and impact data. Postharvest losses were determined for selected crops, with product held at market storage conditions (temperature) at SROS lab for 3-5 days and product-assessed daily. In each value chain the postharvest handling practices were observed from point of harvest, through to point of retail consumer purchase (with the except of Tahitian Lime export value chain). A photographic series of operations was collected for each value chain.
- Quantification of postharvest losses in the Fungalei markets was based on the recording the weight of product per consignment removed from trading by market vendors on a daily basis over the full trading week, in Feb, March and April 2015. In total, twenty vendors and twenty commodities were assessed. Commodity specific results are not presented in this report, but will published in a scientific journal.
- The food health and safety audit was undertaken by SROS, with key findings are presented separately.
- Key findings and recommendations were presented back to key stakeholders in a workshop coordinated by the Samoa Chamber of Commerce and Industry at the end of the project. For each value chain assessed an individual report was prepared and emailed to the relative industry contact, and in all but one of the value chains assessed we also met with the growers and discussed practical strategies to reduce losses and improve product quality.

Figure 1a**.** Spatial summary of the seven horticulture value chains assessed (red lines indicate the transit routes of the value chains assessed)

Figure 1b. Spatial summary of the seven horticultural value chains assessed - northern Upolu

Table 1 Summary of the horticultural postharvest value chains assessment

Chain	Assessment date (2015)	Crop	Chain descriptor
1	17 - 20 Feb	Tahitian limes	Semi-subsistence farm contract farmer in Solaua (NE Upolu). Fruit were picked in the afternoon (during rain) by the exporters workers, transported immediately to MAF cool room, held for two days, before air-freight to NZ
2	24 March – 1 April	Taro	Small-scale taro farmer in Lepa (SE Upolu), product was harvested in the late afternoon, product stored o/night on farm, and transported by bus to Fugalie the traded over a 2 day period.
3	31 March – 8 April	Salad rocket	Community-based and NGO supported protective production grown product (Poutasi, SE Upolu). Product was picked in the early morning, transported in ice cool esky container the same day to a network of restaurants in Apia, then stored in fridge for 2 days
4	20 – 23 May	Chinese cabbage (Bok choy)	Private-commercial scale farmer, (Aleisa, Upolu) product was picked early in the morning, washed on farm and then transported in a open truck to a network of small retail outlets in Apia where it was displayed in ambient conditions and traded over a 1 day period
5	21 May –	Lettuce	Private-commercial scale farm that owned by one of the resorts (Central, Upolu). Product is wet before harvest, harvested, washed and placed in plastic trays under a tree overnight, then transport to a cool storage facility in Apia, held for overnight and then transported in non-cooled truck to resort on the far western Upolu, then placed in restaurant cool storage fridge
6	22 May –	Chinese cabbage (Bok choy) Head cabbage	Large commercial retailer own farm (Aleisa, Upolu). Product was picked early morning, transport within a few hours to the retail shop, where it was weighed (cabbage) or counted (chinese cabbage), repacked, moved to the cool preparation area, washed, and placed in larger cool storage facility. Cabbages were shrink-wrapped and Chinese cabbage place in plastic sleeve and displayed in chilled fruit and vegetable display areas.
7[6]	26 May	Salad rocket Kale leaves	Community-based and NGO supported protective production grown product (Poutasi, SE Upolu). Product was picked in the early morning, transported in cool container the same day to a network of restaurants in Apia, then stored in the SROS Fridge in sealed plastic bags at 10C.

[6] This value chain was a replicate assessment of the value chain assessment 3 in terms of product and handling practices, but with a different leafy vegetable. Value chain 7 results are not presented in this report - as key finding and recommendations are all consistent with those presented in value chain 3.

VALUE CHAIN 1: PRIVATE COMMERCIAL FARM SUPPLYING A SMALL RETAIL OUTLET

Commodities assessed: Tahitian lime

Descriptor of chain: Product was sourced from a smallholder farmer near Solaua Village [North East Upolu], packed into 5kg plastic crates, and transported to a central packing shed using an open tray vehicle. Project was graded, inspected, packed in cartons, and held in a refrigerated cool room prior to export consignment to New Zealand. Product was transported to the airport in an air-conditioned taxi and loaded immediately into airfreight contains at which point the assessment was ceased (Fig 2 & 3)

Distance farm to airport arrival: 52.4 Km
Time from harvest to airport departure: 39hr
Losses (due to grading) 8 %
Max storage temp 28C
Min storage temp 6C

Figure 2**.** Tahitian Lime transport logistics from farm to airport

Temperature

- Fruit had a core temperature of 27C at picking and increased to 29C prior to being placed in the cool storage (Fig. 4a).
- Fruit were held in the pack house at ambient temperature to dry for 28 hr. Once in the cool room it took fruit 12hr to reach a core temperature of 10C and a further 12hr to reach 7C. There was an increase in fruit temperature at 12pm on 20 Feb for about 15-30 min consistent with the cool room being turned off or a power failure. Fruit had a core temperature of 9-10C during loading at the airport.
- It is important to note that it is taking 24hr from when fruit are loaded into the cool room to reach 6C.
- Ideally it would be good to reduce the time between the fruit arriving in the packing shed to loading into the cool room. I realize this allows for drying of the fruit, but be aware the fruit are being held at around 28C during this period.

Transport and handling

- Based on the incidence of vibration and impact (Fig. 4 b,c), there was little evidence of rough handling during the harvesting and transport to the packing shed, sorting or transport by taxi to the airport. This result is consistent with the use of a 4-wheel drive and mini-bus to transport product. The transport along an unsealed dirt road between the farm and the main east coast road at Lufi-Lufi (2.3 Km) had little effect.

Possible postharvest strategies to improve the efficiency of the chain:

- Overall postharvest loss was 8% based solely on grading and sort (field blemish, size and colour).
- The harvesting of the fruit during rain can make the fruit more sensitive to various forms of skin damage, though the latent (delayed nature of this injury) is such that it would only be evident post-arrival in New Zealand.
- Depending on what happens to (out-of-grade) product, you might wish to consider storing and transport this product to the airport; but then retaining for 5-7 days, so that if fruit quality issues do arise in New Zealand, you have can product to draw some point of comparison.
- I assume the storage temperature in the sea-freight container was set at somewhere between 5-7C. If not, may wish to monitor temperature.
- Product was harvested in the rain, without the use of postharvest fungicides. It is important to be aware of rain can influence fruit postharvest behavior, making the fruit more prone to physical damage associated with poor handling. Wet fruit particularly when stored in warm temperatures are also more prone to postharvest disease deterioration.
- It might be worth considering using some form of carton liner

Figure 3. Visual representation of the value chain

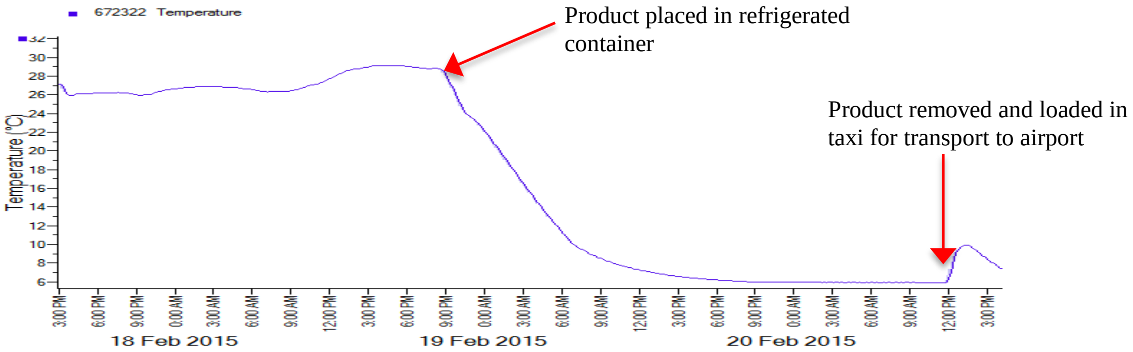


Figure 4a. Internal fruit temperature from point of harvest to arrival at the airport

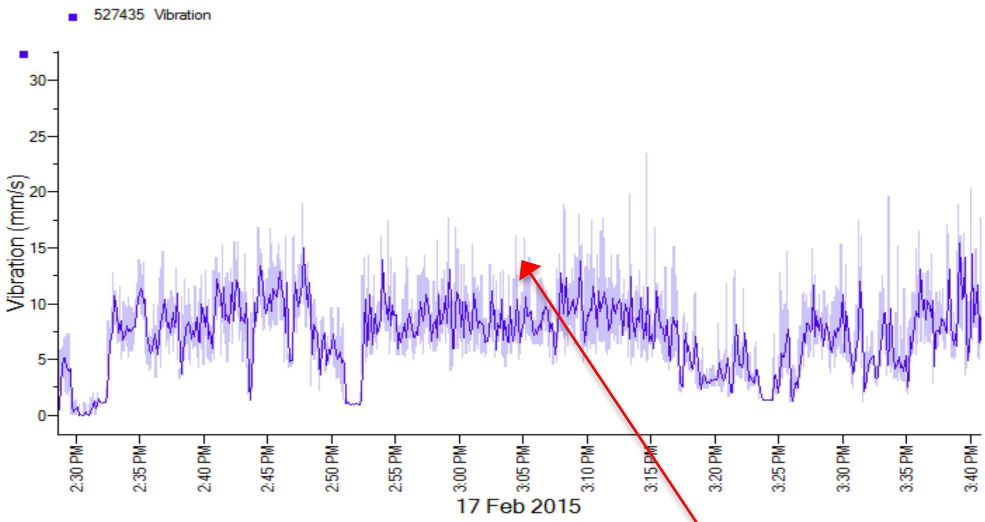


Figure 4b Vibration events from farm to shed

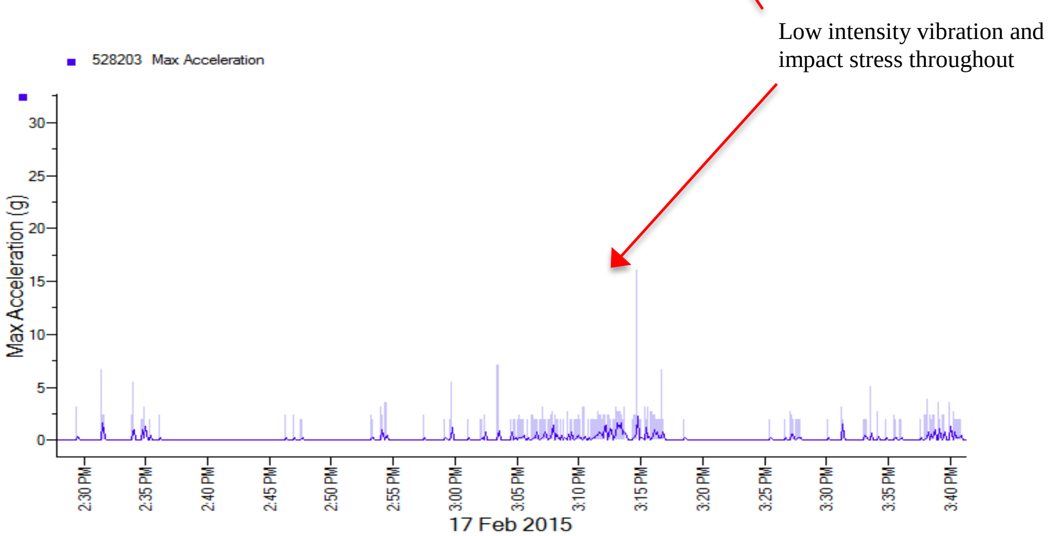


Figure 4c Impact events from farm to shed

CHAIN 2: SMALLHOLDER TARO VALUE CHAIN

Commodities assessed: Taro

Descriptor of chain: The taro postharvest supply chain was assessed between 27 March and 2 April 2015, based on a smallholder farmer in Lepa (the southern eastern end of Upolu) supplying 150 Kg of taro into the Fugalei municipal markets in Apia (Fig. 5). Transport was via the local commuter bus, which took 2:09 h inclusive of 6 stops and a total transport distance of (farm to Fugalei markets) of 55.62 Km. It took 17 h 35min from point of harvest to arrival at the Fugalei municipal market. This was typical of smallholder taro farmers supplying the domestic market in terms of small-scale production, volume, packing and transportation mode and distance.

Figure 5a & b Taro supply chain route from Lepa village farm to Fugalei markets

- 70 taro corms were purchased and transported as part of the commercial consignment, held at the market for two days (consistent with the normal commercial trade period) and then relocated to SROS where they were held at ambient conditions for a further four days. Ten corms were then assessed for internal damage, at point of arrival at the Fugalei markets, after 2 days retail display, and then daily for four days. To assess the effective harvest practices on the level of postharvest lsss, 10 taro corms were carefully harvest and replaced with the consignment at point to loading of the sacks. Results are presented in Table 4.

Figure 6a & b. Taro chain. Farm (above) and arrival at the central markets (below)

Figure 7. Visual of the taro value chain

Product was harvest at 3:00pm, packed into 50Kg sacks on the side of the road and held over-night. Product was then transported by public bus to the municipal markets following morning and stored in the sun at the market (2-3 days) until sold. Product was also relocated to the SROS lab in Apia after 2 days and held in comparable ambient conditions to those of the central markets and assessed daily of internal damage (*bottom left hand photo*)

Results and key findings

- The harvesting practices observed displayed little care and attention, with taro often thrown >5 m. The severity of the harvesting was such that a small trial was undertaken to assess the implication of this handling on the resultant incidence of damage. Preliminary data (Table 4, Fig 8) would suggest that harvest practices are an important contributor to potential postharvest loss in taro.
- Taro postharvest loss was 0% on arrival at the markets, and at 2 days of trading, but with a further 1 day post-market storage increased to 20% of the corm with detected 1-2cm lesions consistent with bruising type damage and stem-end disease (Table 4). Postharvest damage increased to 40% of all corms at 3 days post-market storage with lesions increasing to cover 25-30% of the cut surface area of the corm.
- The use of heavy sacks (approx. 50 kg) while standard practice necessitated some rough handling in terms of loading and unloading.

Table 4. Post-municipal taro shelf life during ambient storage

Time	Percent of corms where internal damage was observed (%)	Comment
At point of arrival at the Markets	0	Nil
After 2 days of market storage	0	Nil
+ 1 day	20%	Injury was due to a combination of 1-2 cm internal bruising. And stem end damage possibly due to pre/postharvest pathogens
+ 2 days	30%	
+ 3 days	40%	Stem end damage was 25-35% of the total area of the product.
+ 4 days	40%	
+ 4 days (corms carefully harvested)	10%	Little damage

Sample size: 70 medium size corms, with ten corms internally assessed each day.
This preliminary data is based on whole corm numbers. A more accurate assessment of actual postharvest loss will be determined based on proportional of corm damage.

- Taro were harvested mid-afternoon (temperature was 30C). Once packed the temperature within the sacks remained relatively constant at 27C. At the municipal markets taro were stored at 24 -29C reflecting diurnal temperature ranges (Fig 9).
- Internal temperature within the taro corm was between 27.5- 30C between packing and arrival at the municipal markets the next day (Fig 10).
- Based on the incidence and severity of vibration (Fig. 11) and impact (Fig. 12) events the key points of concern are during harvesting and in transit
    - The impact events during harvest were one of the worst observed in similar Pacific chain studies.
    - While the taro sacks were loaded at the rear of the bus and therefore potentially exposed to ongoing vibration stress from farm to market, actual values of vibration were comparative low, with the exception of a portion of the trip 0.56Km past the Village of Salelesi (Fig. 12).

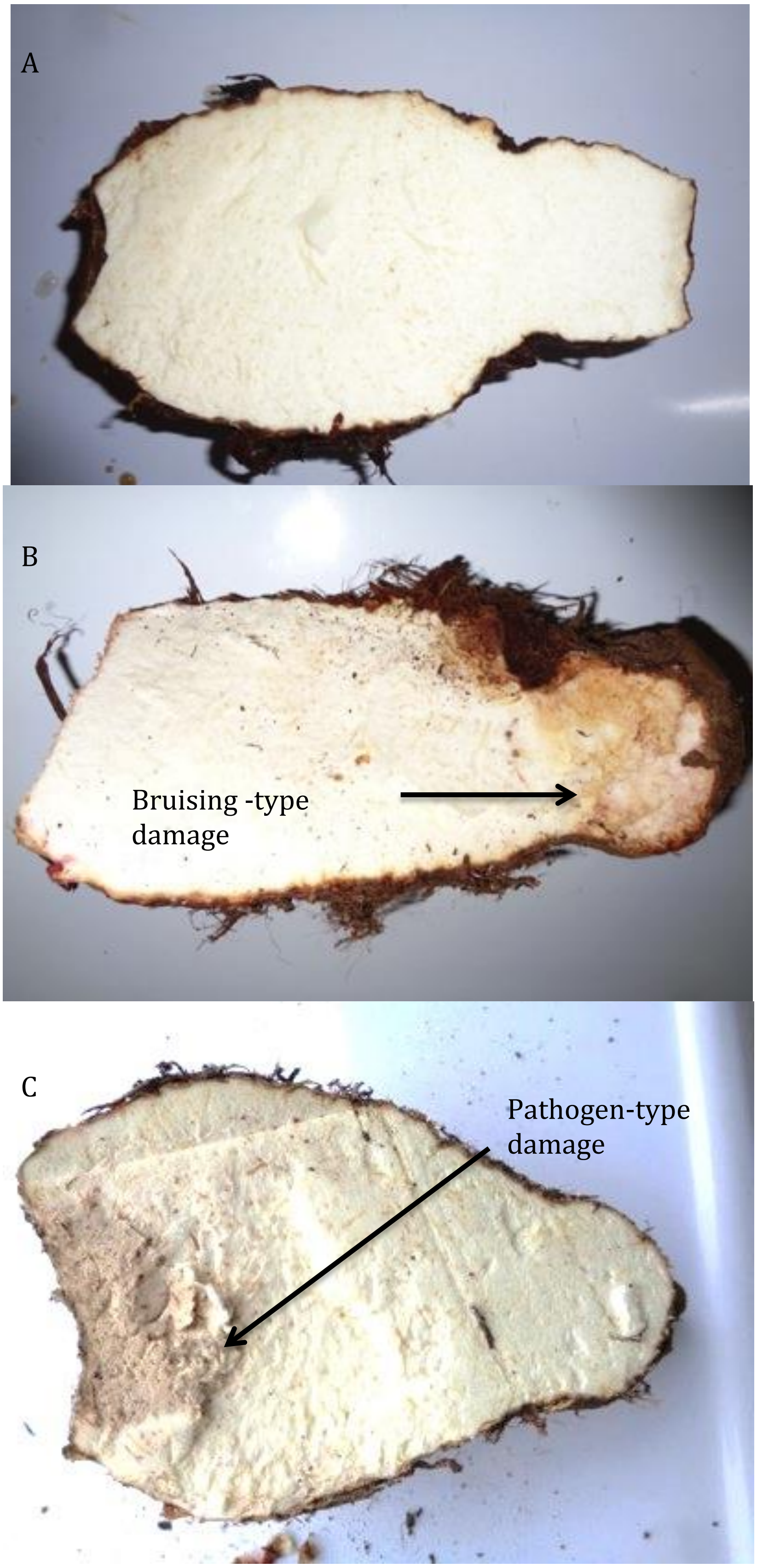


Figure 8. Internal corm damage during market and post-market storage
(a) On point of arrival at the municipal markets,
(b) At two days of market storage.
(c) At +1 day post market storage

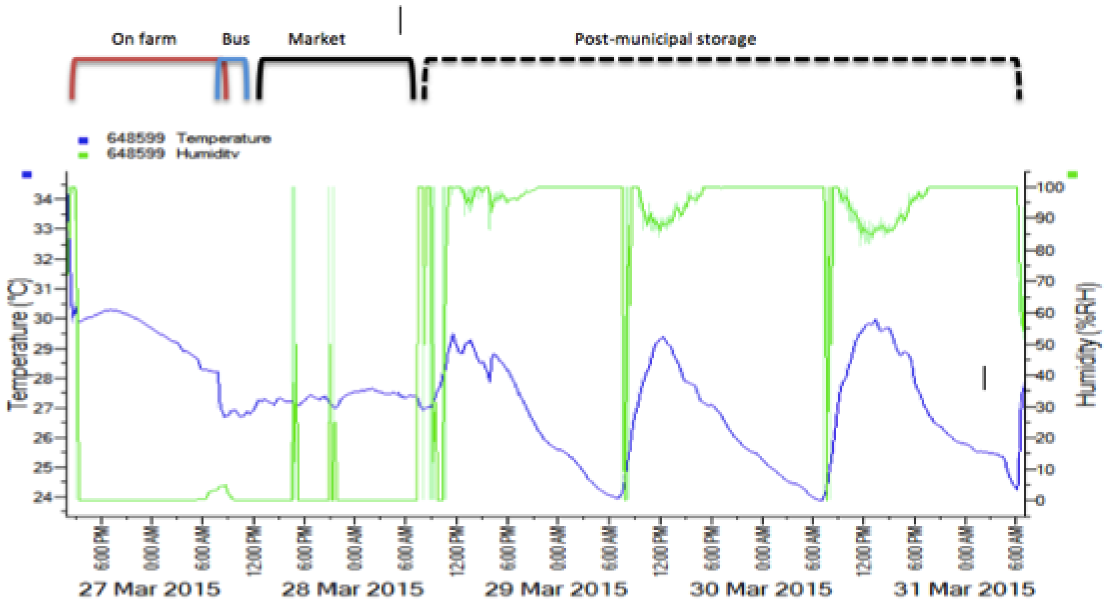


Figure 9. Air temperature and humidity during harvesting, within the consignment (inside the sack, and during trading at the Municipal markets)

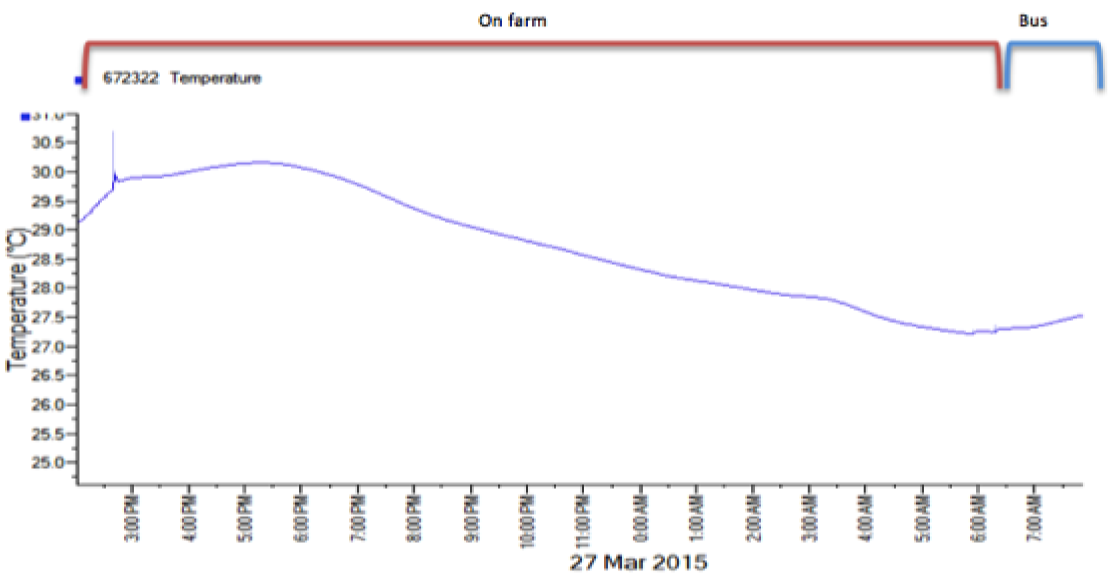
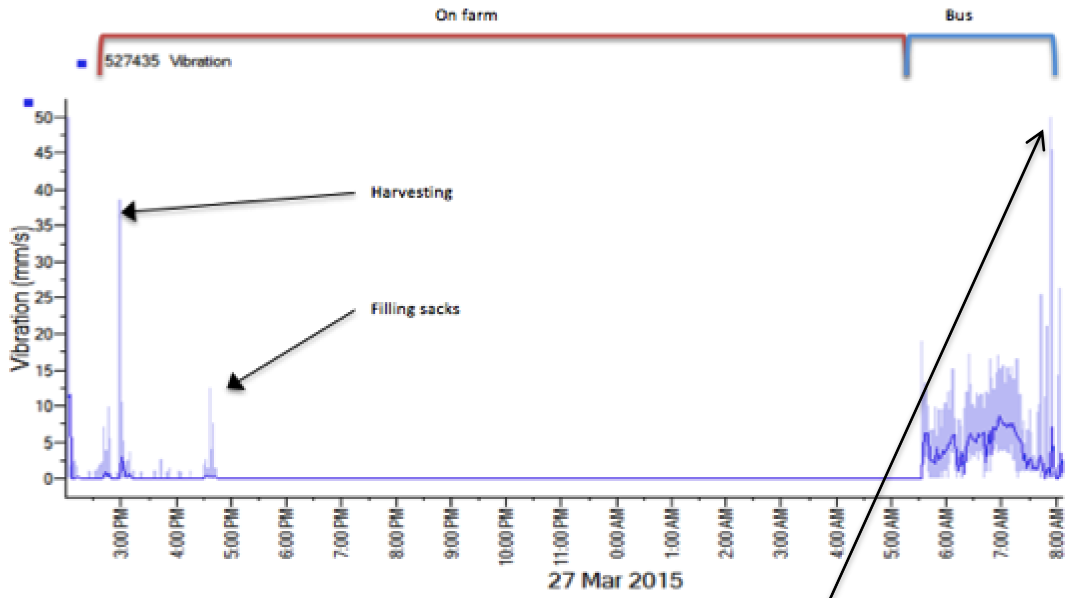


Figure 10. Internal corm temperature (from point of harvest to point of arrival at the municipal markets)

Figure 11. Incidence of vibration from point of harvesting to point of arrival at the municipal markets



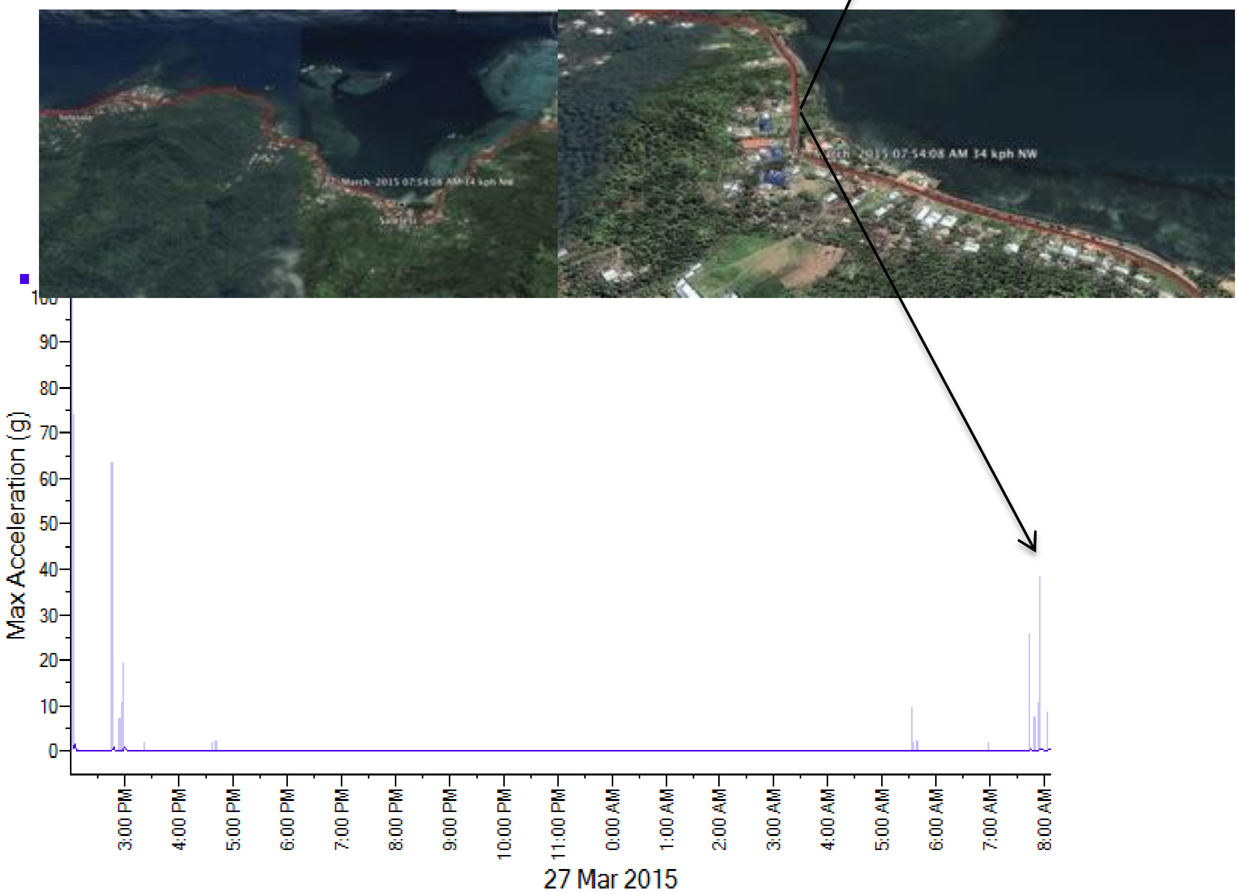


Figure 12. Incidence of impact from point of harvesting to point of arrival at the municipal markets

VALUE CHAIN 3: LEAFY VEGETABLE PROTECTIVE CROPPING VALUE CHAIN SUPPLYING APIA RESTAURANTS

Commodities assessed: Salad rocket

Descriptor of chain: Product was grown under a protective cropping systems, using plastic and over-head irrigation and packed 2.5Kg LD plastic bags using in a multiple-purpose open shed immediately adjacent to the protective cropping structures. Product was sorted, packed in LDPE plastic bags and then placed in esky containers with ice blocks. It took 6:01 h from point of harvest to product arrival at the restaurant end-point. Transport from farm (by private van) to restaurant took 4:06 h (with a further 2 h for harvesting, picking and sorting on farm). Transport distance from farm to restaurant was 47.67 Km

Figure 13 a & b. Visualisation of the transport route from farm to the various retail outlets

Figure 13c & d. Visualisation of the transport route to the various retail outlets

Method for quantifying postharvest loss

- Postharvest loss was based on a sub-sample of five x 2kg plastic bags of salad rocket (*Eruca sativa*) each containing approximately 250-300 individual leaves. Product was commercial picked, sorted, packed, and transported in large 25kg insulated plastic crates with ice, using a commercial van directly to a series of restaurants. On arrival at the restaurant, product was stored for 24 hrs in their commercial fridge, consistent with normal handling practices.
- After one day of storage at the restaurant, the product (still in the plastic bags) was removed and relocated to the FAO office where they were stored for a further 7 days in a domestic refrigerator. Product was visually assessed on arrival at FAO office and then daily for a further 7 days based on visually assessing individual leaves and recording the number of individual leaves per bag that were deemed “loss” (colour, disease and/or physical damage). Rejected leaves removed to negate cross-contamination. A different plastic bag was assessed each day.








Figure 14. Visualisation of the leafy vegetable value chain from farm to retail outlet

Table 5. Postharvest losses of salad rocket leaves from point of harvest up to 7 days storage

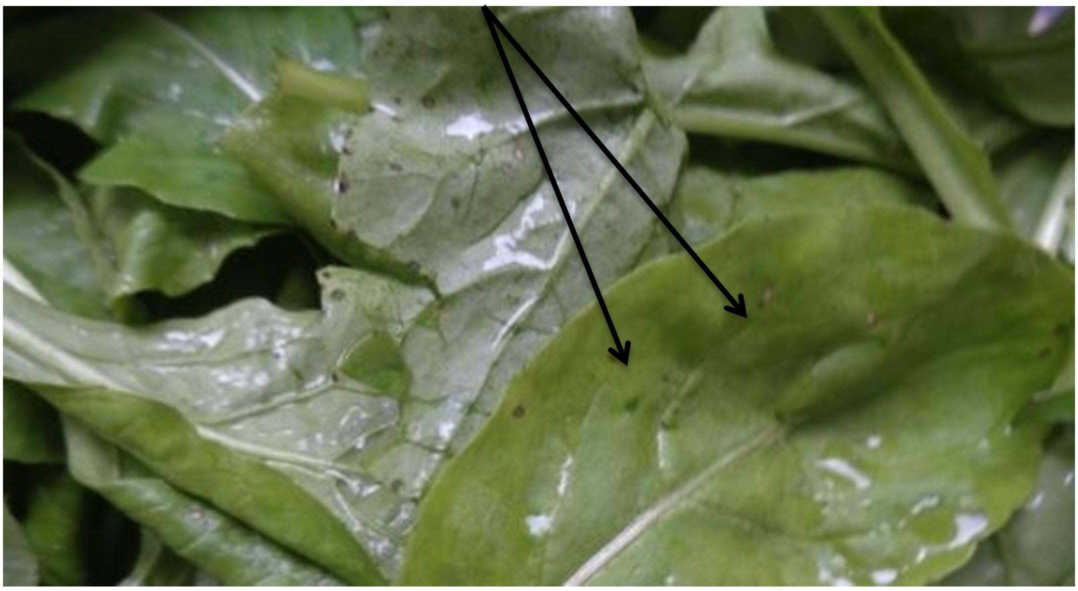
Time	Percent of corms where internal damage was observed (%)	Comment
At point of arrival at the Markets (Tues)	-	Not assessed.
After 1 days of storage (Wed)	0.9%	Storage in the commercial fridge at the restaurant in under-opened plastic bags
+ 2 day (Thurs)	3.86%	

All samples unless specifically mentioned were stored in plastic bags

Results

- There was negligible postharvest loss at 24 h after harvest (0.9%), which progressively increased to 3.86% after 2 days (the point at which all the product was normally used by the restaurant). While postharvest loss data was obtained for the subsequent 7 days – resultant high losses (27%) were attributed to the comparatively low temperatures (1 to 3C) in the FAO fridge.
- There were few impact events and those detected were not likely to be problematic (Fig 16). Interestingly the main impact events detected were all while the van was in Apia in the 2:15-2:45pm period, presumably where it was waiting the opening/delivery time for the restaurant.
- The transport conditions, in terms of vibration events were generally good (Fig. 17), and interestingly were comparable to those in observed in the taro public bus chain (Fig. 12). The notable difference was the much quick speeds (i.e. van speed between Poutasi and Si'umu was 54-74Km/h (compared to the public bus speed 38-56Km/h associated with the taro chain).
- In terms of identified risk factors associated with this chain.
    - The use of a multi-purpose shed to sort and pack product, and the close proximity to (adjacent to a soil and seedling planting benches, is likely to create a food health and safety risk in terms of capacity to kept surfaces and equipment clean. Ideally sorting and packing sites should be separated from potting and planting benches.
    - Once picked, there was around 1.5 h before product was placed in ice coolers. This is not a major concern given product was stored in the shade, could be improved by having the van arrive earlier and product placed in ice cooler at the packing shed immediately after packing.

Figure 15. Assessment of plastic bag verse solid plastic contain packaging (the later recommended by the grower) was inconclusive because storage temperature in the FAO fridge was 1C during experiment. Interestingly chilling injury was more prevalent in product in the sealed containers, compared to plastic bags. Small lesions were also observed (below) on the leave at the commencement of storage – indicating field-based pathogen damage



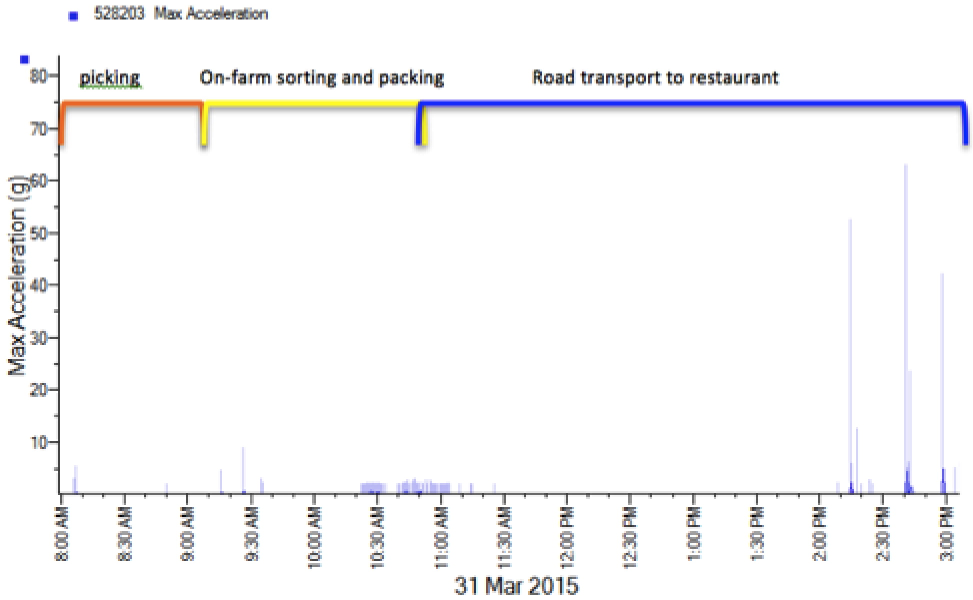


Figure 16. Impact events along the transport chain for salad rocket, from point of harvest to point of arrival at the restaurant

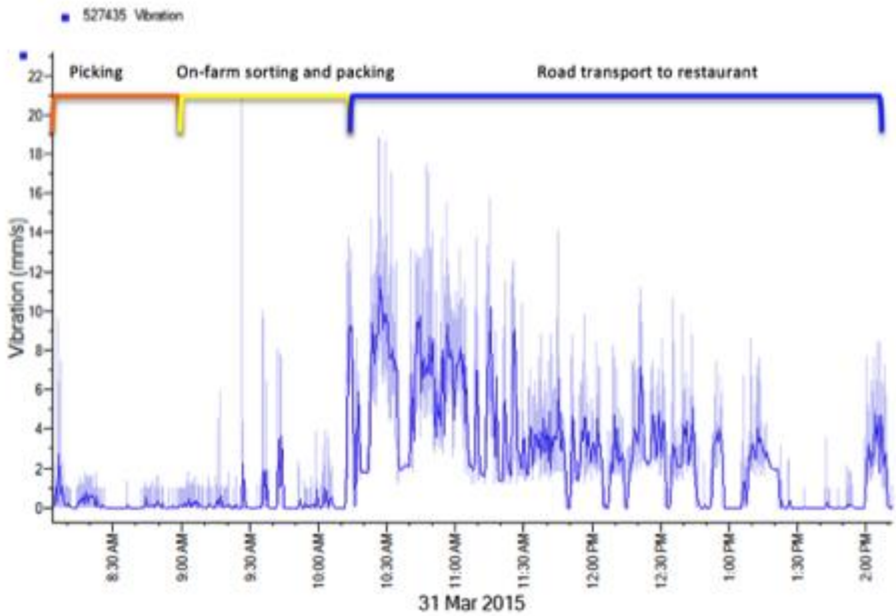


Figure 17 Vibration events along the transport chain for salad rocket, from point of harvest to point of arrival at the restaurant

VALUE CHAIN 4: PRIVATE COMMERCIAL FARM SUPPLYING A SMALL RETAIL OUTLET

Commodities assessed:	Chinese cabbage (*Bok choy* or *Pak choi* (Brassica rapa subsp. chinensis)
Descriptor of chain:	NOTE - the product had already been harvested on arrival at 7:00am. Product was placed directly into shallow plastic crates, washed and replaced into the same crates and then transported in an open-sided truck to a series of retail outlets in Apia. The retail store displayed the product at the rear of the store (ambient temp). A sample of product was purchased at point of arrival at the retail store and transferred to the SROS lab to determine ambient shelf-life
Time sequence:	On the assumption of a 6:30 harvest time, there was 3 hr from point of harvest to retail delivery. Transit time from farm to 1hr 23min – with 5 delivery stops. All product sold by 9pm same day, nil commercial postharvest loss

Figure 18. Visualisation of the transport route from farm to retail outlet

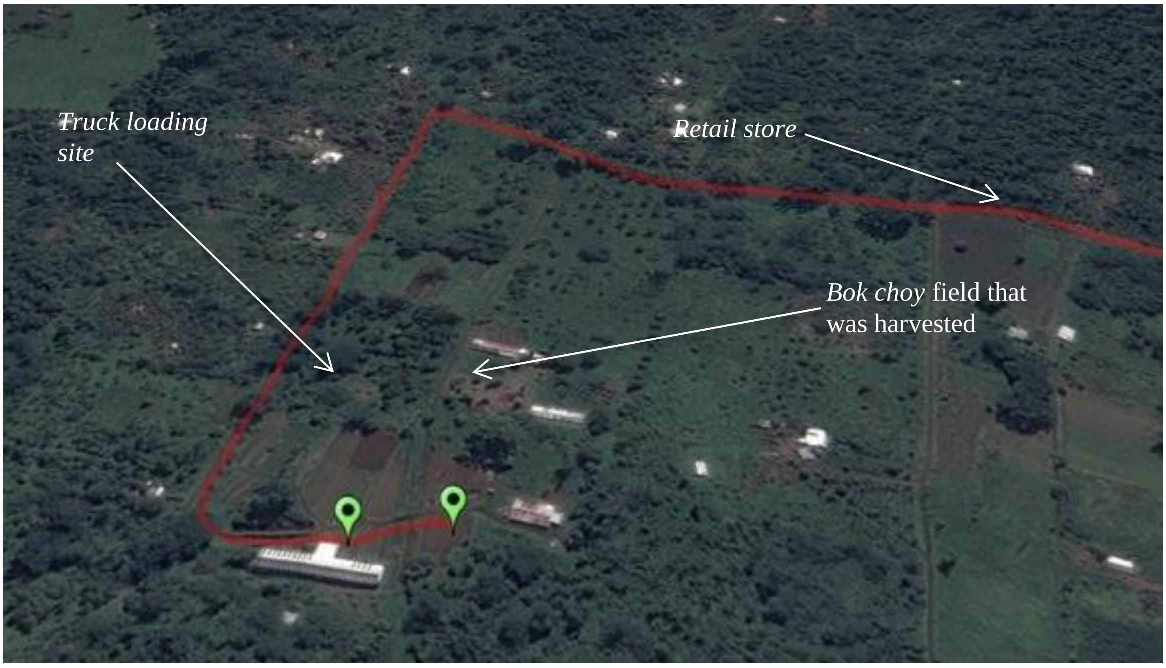
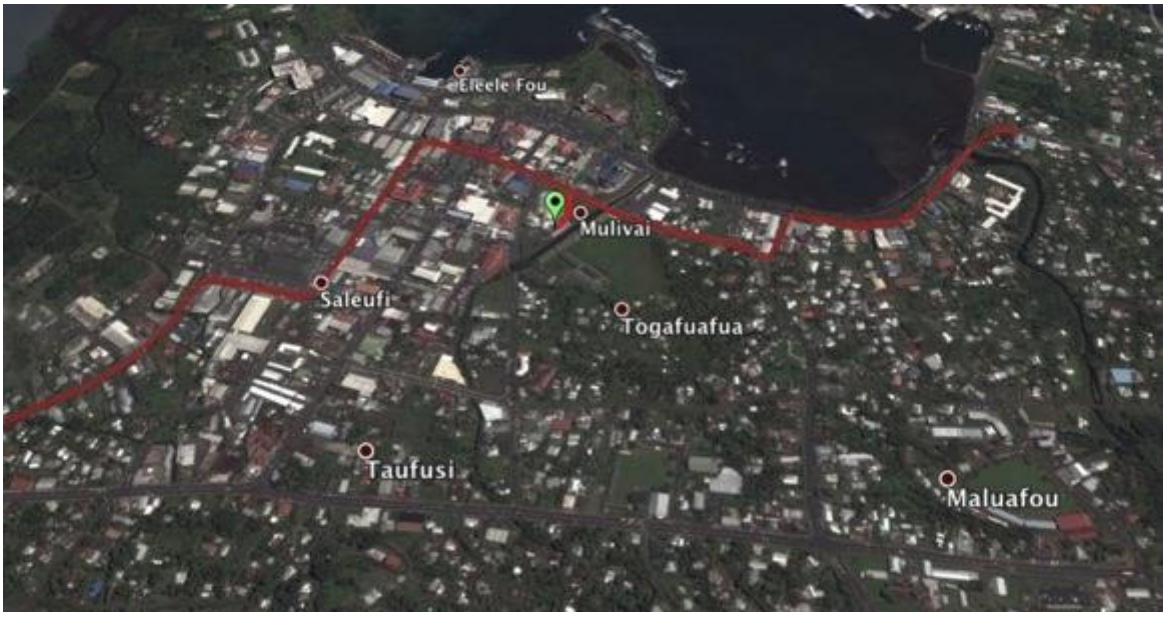


Figure 19 a & b. Transport route. Farm to retail outlet (above) and delivery at the retail outlet (below)



Recommendation and key observations

1. Given the product was harvested in the early morning (before 7am), transported directly to the retail stored where it was on display within 3hr of harvesting and all sold on the same day (within 12 h), there is little inherent likelihood of postharvest loss in this chain.
2. The stem–lesions were the only observed defect (Fig. 21), with damage noted in most >70% plants. While resultant product quality did not lead to postharvest loss (at the traded retail price), quality was notable lower than in other *Bok choy* supply chains assessed in Upolu.
3. Once harvested the product temperature increased from 22 to 26C, decreasing while the product was transport to Apia (Fig. 22). While far from ideal for leafy vegetables, the potential postharvest loss is negated through direct supply to the retail outlet and rapid on selling to consumers.
4. To determine, potential postharvest losses if product needed to be stored longer than 12 h, a simulated ambient storage experiment was undertaken. Postharvest loss was determined based on the number of leaves considered inedible due to deterioration, relative to the total number of leaves (20 plant sample size) over a three-day period. Stems lesion and wilting was not included as a postharvest loss; determination based on visual assessment of each leaf by a Samoan national.
    - 24 h after harvest – 7.7% loss
    - 48 h after harvest – 26 % loss
    - 72 h after harvest – 59% loss
5. A separate food health and safety audit was undertaken on this value chain by SROS and is reported separately

Strategies to improve the postharvest handling practices observed

- After the product was washed it appeared to be placed back into the same plastic containers that were used for harvesting? If so, this is a potential source of microbial cross-contamination.
- While not an issue in terms of causing detectable postharvest loss, the incidence and severity of impact shocks and vibration in-transit (farm to shop) was the worst so far measured in Upolu. The issue was not really the poor road conditions adjacent to the farm, but rather a high incidence of vibration and impacts once on the sealed road. I suspect this is possibly due to the lightweight of the consignment causing the product to bounce around in the back of the truck, but it might also highlight a fault with the truck (possible worn suspension).
- If you are planning to set up a hydro-cooling system on your *Bok choy*, you really need to first consider getting a suitable sized packing shed in place. Be aware that unless you can control the post-hydro-cooling storage temperature of the product, the benefits associated with rapid reduction of field heat can quickly be undone elsewhere along the chain.

Figure 20. Visual overview of the postharvest supplied chain

Figure 21 Product quality

Left. Bok choy at point of harvest

Below left. Product on point of harvesting

Below right. Magnified view of stem lesions.

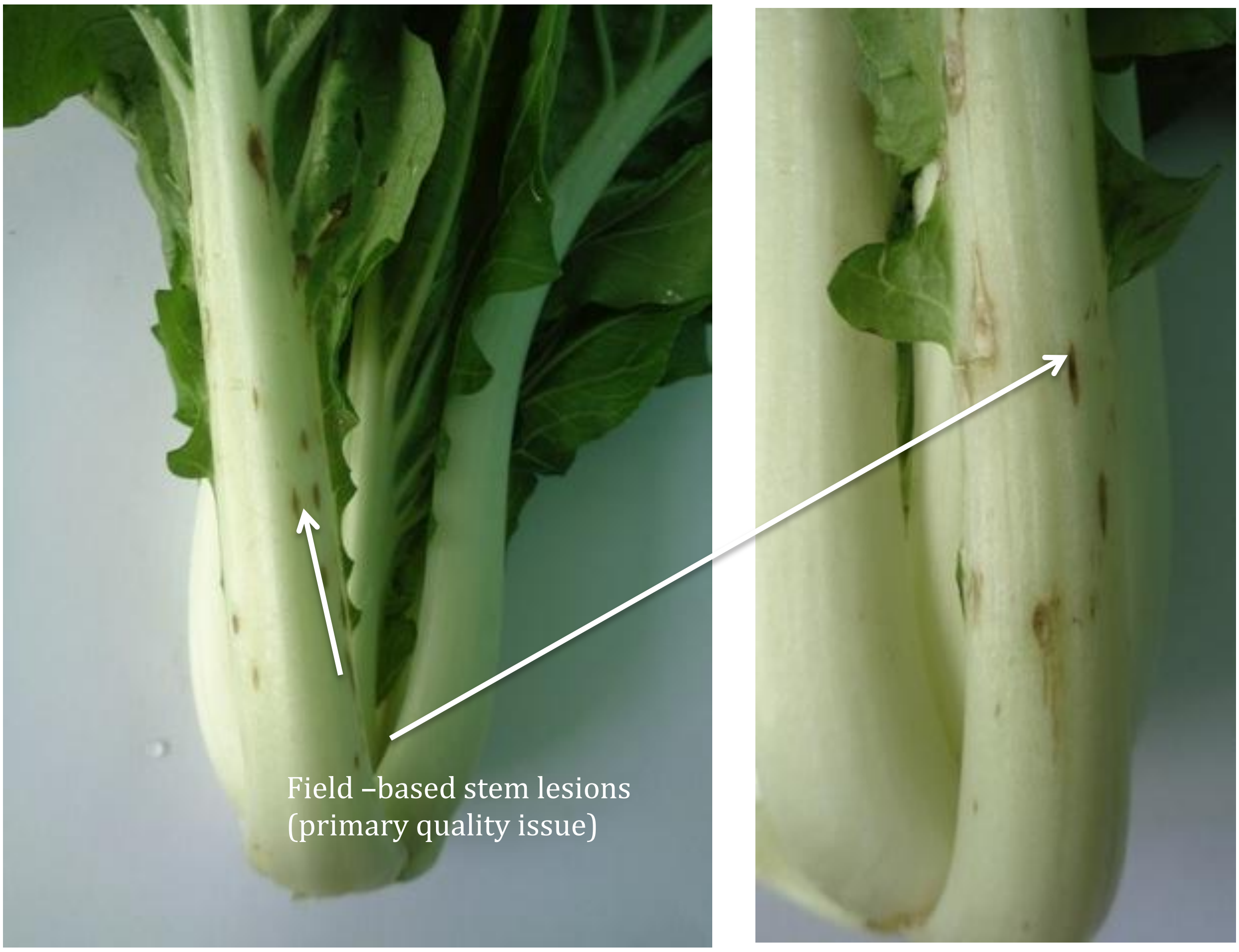
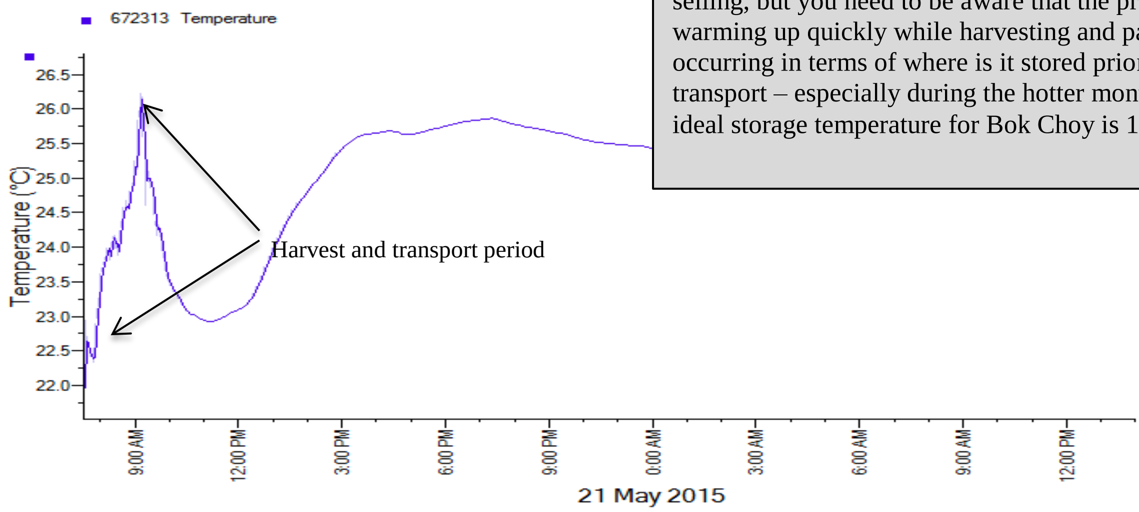
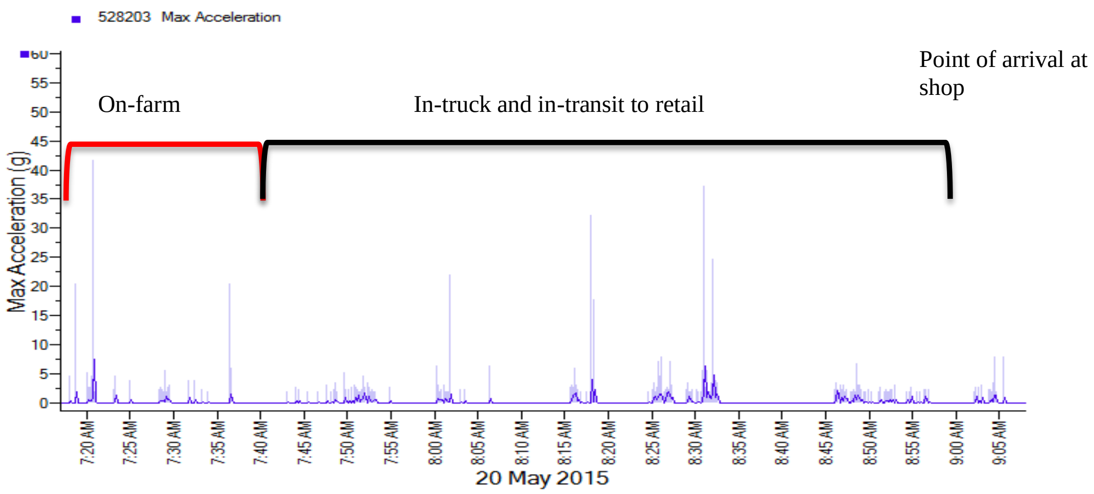


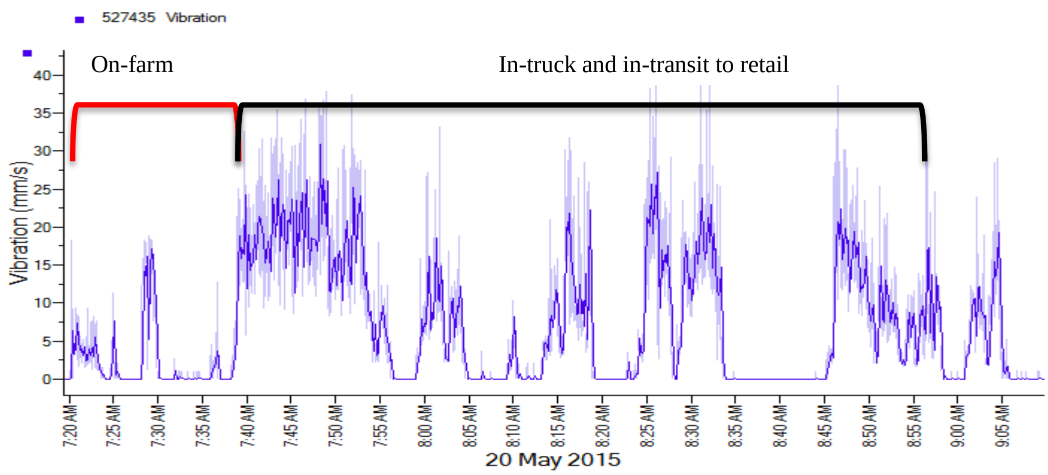
Figure 22. Internal core temperature



So what does this tell us? The temperature of the product was 22.5C at point of harvest but increased to 25C during transit. This is ok given the rapid on-selling, but you need to be aware that the product is warming up quickly while harvesting and packing is occurring in terms of where is it stored prior to transport – especially during the hotter months. The ideal storage temperature for Bok Choy is 1to 5C

Figure 23 a & b Impact (below) and vibration (bottom of page) from farm to retail





shop

So what does this tell us? Compared to the other supply chains assessed, there was a lot more vibration and impact shock observed, which is a indicator that the consignment was moving around in the back of the truck in transit. While this is not unexpected given the road conditions near the farm, I suspect another contributor is the lightweight of the consignment.

VALUE CHAIN 5: PRIVATE COMMERCIAL FARM SUPPLYING ONE OF THE RESORTS ON UPOLU

Commodity:	Lettuce
Descriptor of chain:	Product was sprinkled with water prior to harvesting (which commenced at 1:29 pm). Product was picked (1:35pm), trimmed in field and packed and placed directly into clean shallow plastic trays, and immediately transferred to an under-cover shed (also used to stored fertilisers and potting mixture) (1:40pm). Product was washed and then relocated to a series of raised shelves near the main house (2:05pm) in the shade. At 4:26pm it appears to have been moved to a storage area where it was held for 15h 47 min. Product left the farm at 8:13am 22 May and arrived at Apia bottling at 8:33am. It was held over night in a cool room and then transferred to the resort restaurant. It took 52 h from harvest to arrival at the resort restaurant some 40 Km from the farm.
Time sequence:	There was 18h 14 min between point of harvesting and when the consignment left the farm (i.e. picked in early afternoon and transported to Apia early morning the next day). Product was then stored in a cool room for a further 30 h 16 min before being transported to the restaurant. Total time (from point of harvest to arrival) = 48h 30 min Total distance (from point of harvest to arrival) = 42.54Km

Figure 25 a. Leafy vegetable transport route

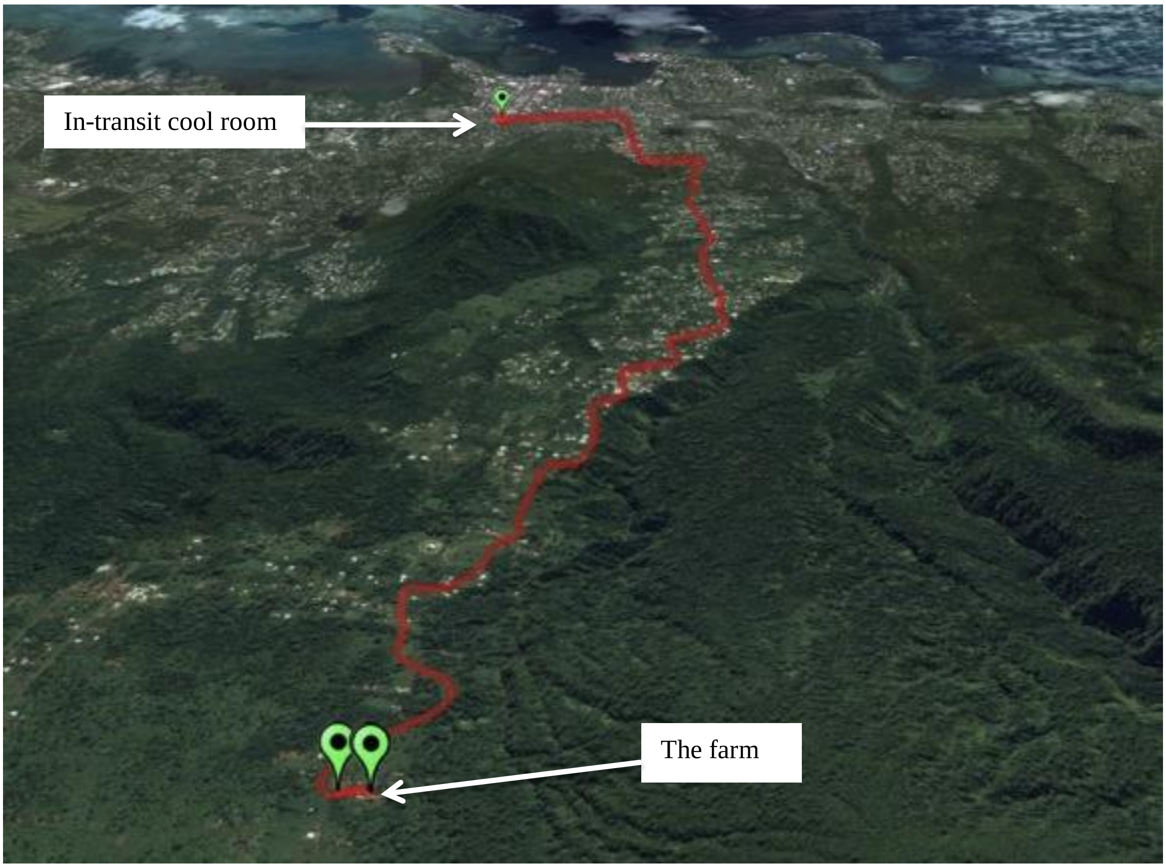


Figure 25 b & c. Leafy vegetable transport route, farm to in-transit cool room (above) and In-transit cool room to retail outlet (below)

Key observations

1. While this supply chain had access to a refrigerated storage in Apia as well as cool storage facilities at the restaurant, ambient storage temperature in-transit results in the product rapidly warming up in transit [6 to 20C] (Fig 28].
2. The product was picked in the late afternoon, and held on farm until the next morning. While this seemed to be due to availability of picker and limited access to a truck to transport product, the farm was in close proximity to Apia (7 Km). The scheduling of harvest, transport and supply demand were not ideal and inconsistent with the fact that this chain vertically integrated.
3. In terms of time from harvest to arrival at the restaurant (just over 2 days) this was the slowest supply chain assessed. The primary concern was the delay between harvesting and the product leaving the farm.
4. Quantification of postharvest loss was not undertaken for this value chain, due to the ability to trim product.

Strategies to improve the postharvest handling practices observed

- Why was the product harvest at 1pm (when field heat is worst) if the product was then going to held on farm until the following morning? Better to harvest on the same day of transport or as late as possible in the afternoon.
- You might wish to check of chemical application schedule to ensure appropriate dosage and withholding periods. Most of the lettuce in the field appeared to have white residue on the leaves. Conversely there was a lot of insect damage on the lettuce assessed. The practice of sprinkling the crop with water prior to harvest may lessen this risk, but better to make sure your chemical applications protocol are checked.
- While this farm had a packing-shed, this was also used for potting and fertilizer storage, both of which create the risk food safety contamination. Better to store all fertilizer and chemicals in a different area or better still in a purpose-build area.
- There was an obvious use of organic fertilisers (possibly chicken manure), which if not probably decomposed can create a food health and safety contamination risk. SROS assessments undertaken during this trial should help confirm whether remediation is required.

The in-field quality of the lettuce was not good with both insect and disease damage. Might be good to seek advice on your current pest and disease control strategies.

Figure 26. (Above) Photograph on the left is lettuce at point of harvest in farm. Photograph on the right is the same product after 1½days in cool storage in Apia, and a further two days at 10C (4 days). (Below) postharvest handling practices.

Observed key risk factors

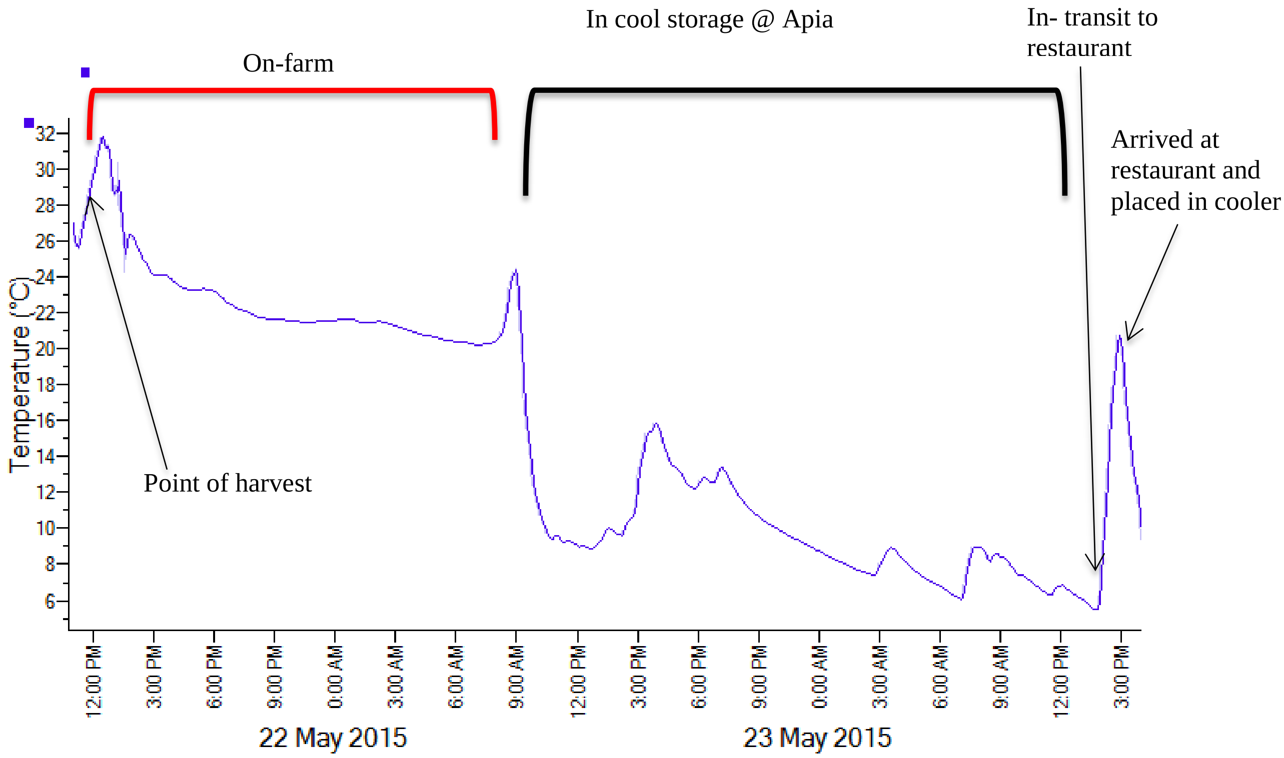
The sort and trimming work was done in a shed in close proximity to seedling and soil potting. This does create a food safety risk – better to have the potting soils and chemicals well away from where the product is being trimmed; or having a table dedicated to only postharvest handling.

Once the product was washed (not observed) it was place under a large tree, and held there for 15 hour before being picked up and relocated to the cool storage.

Why such long on-farm storage period?

Figure 27. Visual overview of the postharvest supplied chain

Figure 28. Lettuce core temperature from point of harvest thru to the restaurant cool room



So what does this tell us? By harvesting the product in early afternoon the lettuce was almost 28C at point of harvest. This would suggest that while pre-watering of the product before harvest may have reduce the incidence of leaf wilting it had little effect on product temperature, with product increasing to 32C before being placed in the shade. While prolonged on farm storage is far from ideal, the product was 21-24C during this period. The temperature in the cool room fluctuated between 6-16C suggesting there was a lot of product being moved in and out.

While the lettuce was stored in Apia it was 5 to 6C, the transport to the restaurant was obviously in a non-refrigerated vehicle with product temperature increasing to 22C during the approx. 45 min trip. Once arriving at the restaurant it was immediately placed in a cool storage.

Value chain 6: Private commercial farm supplying a major retail outlet

Commodities assessed: Chinese cabbage (*Bok choy* or Pak Choi (Brassica rapa subsp. chinensis) and head cabbage

Descriptor of chain: *Bok choy* was picked (started @ 7:36am) and either placed on the soil or packed directly into small plastic trays, relocated to an enclosed truck, where it was repacked into a large wooden crate, and then transported on-farm for head cabbage harvesting. Head cabbage harvesting involved swamp taro leaves being placed on the floor of the truck and cabbage loosely packed (picking started at 9:35am). The truck left the farm at 11:00am and arrived at the Vaitele retail store at 11:11am. The cabbage was repacked into large 25 Kg sacks for weighing then tipped into the wood crates, readily for trimming, washing and packing. The *Bok choy* was counted and placed into trays for similar washing, trimming and packing. Product was held in a general cool storeroom, then displayed for sale in refrigerated display cabinets. Product sold within 48 hr.

Time sequence: Head cabbage: 1hr 52 min from point of first harvesting to point to when truck unloaded at the Retail shop. Time to harvest: 1hr 41 min. Transit time 11min.
Bok choy: 3hr 51 min from point of first harvesting to point to when truck unloaded at the Retail shop. Time to harvest 2hr 38min. Total transport distance (farm to shop) = 7.34Km

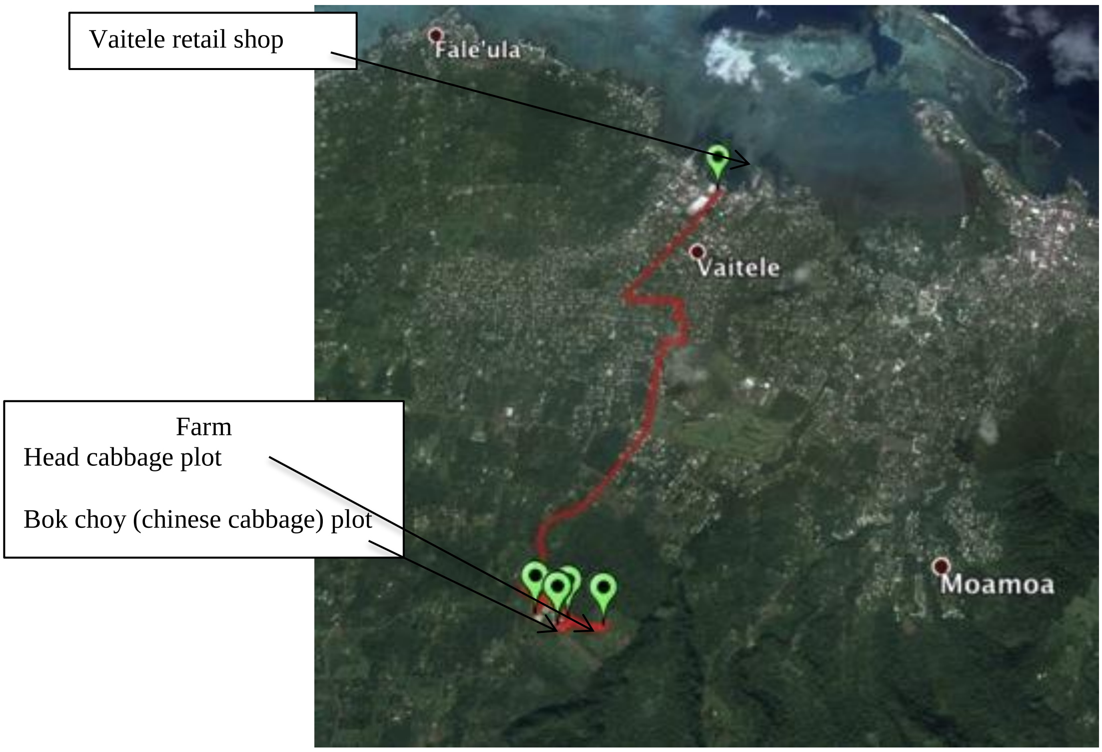


Figure 29. Transport route from farm to retail outlet

Figure 30. Transport route of truck on the farm (below) and on-route to the retail outlet (Bottom photo)

Recommendation and key observations

1. Based on the size and scale of the farm operations, the absence of any postharvest packing infrastructure was notable, though typical of the situation in Samoa. If you are going to scale up operations, you should consider constructing an on-farm packing and trimming facility, where product can be centrally washed, packed and weighed.
2. There were a series of postharvest handling practices observed on-farm that are likely to create food health and safety risks and pathogen-based spoilage.
    - Product was occasionally being picked and then placed on the soil prior to packing. This creates the risk of soil borne pathogen contamination of the product. **Better to pick and place directly into the plastic crates.**
    - If you are using organic fertilizers (i.e. chicken manures) as a soil additive, you need to be especially careful as to how this is being applied, in terms of avoiding contact with the leaves. Your current practice of in-store washing will lessen the risk, but given product is washed in the same area as meat and other products this will create a cross-contamination risk. **Better to have the product washed on-farm, rather than bring in potential dirty and contaminated product into your retail store preparation room.**
    - The picking crates had not been adequately cleaned before use. This creates the risk of soil borne food safety contamination or elevated postharvest spoilage. **Best to clean all the crates each day when in use.**
    - The use of large 44 Gallon drums to wash product, is not ideal because after a few water quickly became very dirty, creating a food safety risk. **A purpose-built washing area within a pack-shed would be much better option.**
    - The speed of picking and packing was comparatively slow. I think one key contributor was the fact that the product was re-packed (transferred to and from different containers) numerous times.
    - There was considerable unnecessary multiple handing of the product on-farm particularly the Chinese cabbage. For example, product was placed into plastic crates at harvest, then repacked into large wooden crates in the truck, on arrival at the retail outlet replaced back into the same plastic crate during counting. Each time this occurred product was being damaged. I reason for all the packing and unpacking was simply due to not having enough plastic packing crates. **Best to just get more packing crates so as to avoid unnecessary repacking.**
    - Loose packing of any product into the back of a truck – as currently occurs in head cabbage – is not ideal. **Better to use the large wooden crates currently used for the Chinese cabbage, or conversely the 25 kg sacks –especially given product needed to be packed into these sacks on arrival at the retail shop so they could be weighed.**
    - The large wooden crates had a few exposed nails and rough edges all of which can damage the product. **Better to remove or line the crate (but be aware any lining needs to be kept clean).**
    - Some of the crates had fallen over when the truck arrived at the retail shop. This could be avoid by have one standard packing crate – that is easier to stack.
3. The handling practices were generally good, but there is a need to look at how the product is unloaded and weight and re-packed on arrival at the retail store as most of the rough handling occurred at this point in the supply chain.

Figure 31. Observed postharvest handling practices

Figure 32. Identified risk factors associated with current postharvest handling practices

Chinese cabbage is harvested and then placed back on the dirt creating food safety contamination risk

In-field washing, but the method used meant that water quickly became dirty (contamination risk). Afterward washing product was placed on dirty mats or product was placed back on the ground (contamination risk)

Due to the lack of packing boxes in the field, the product was re-packed into a large wooden crate (not ideal for leafy produce as product can be damaged), product also packed and re-packed numerous times (each time causing damage)

Because the product was packed into many different types of cartons, as well as loose packed and a large in-field picking bin, the load moved around in transit – causing damage

All the field-picking crates used were dirty and had not been cleaned. If washed product is placed back into these crates as occurred, there is a contamination risk

The large wooden field crates had a few exposed nails, which will damage product as well as being a safety risk to pickers

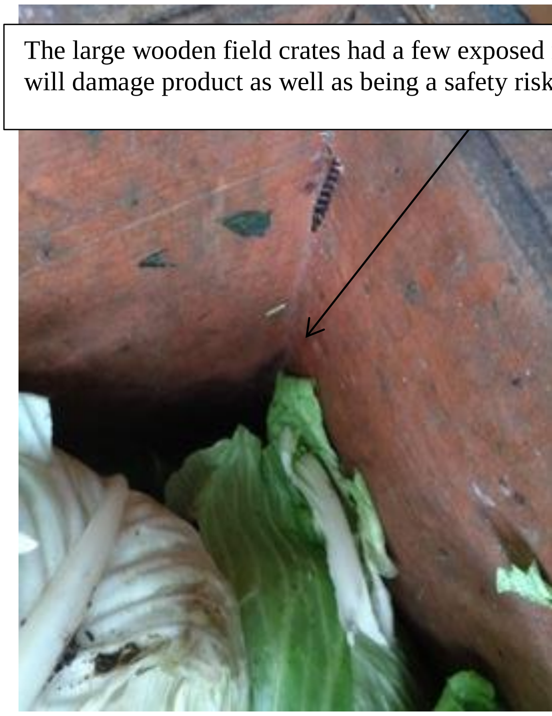


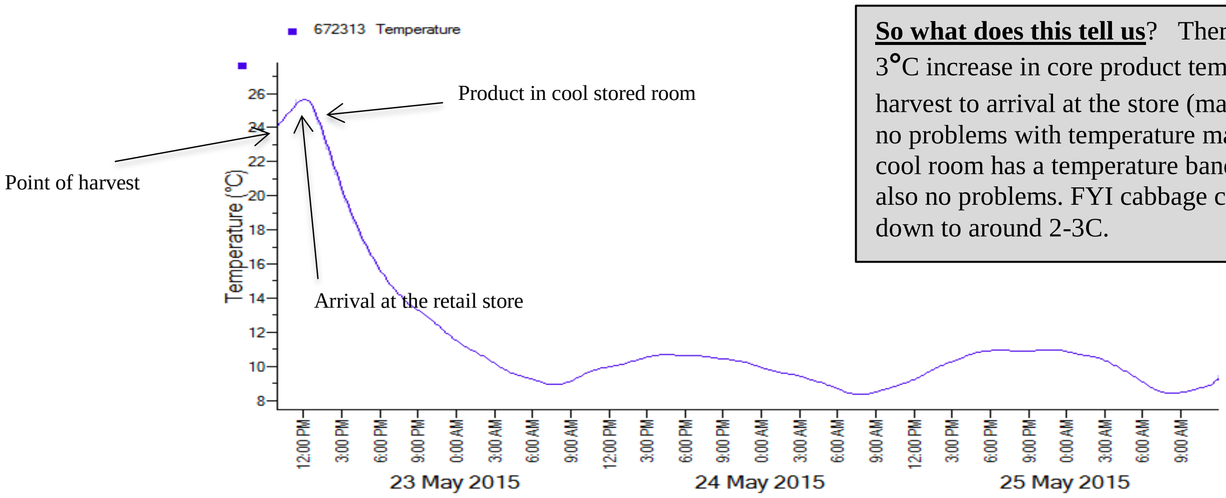

Figure 33. Above. Head cabbage. Left-hand photograph is the product at point of harvest; the right-hand photograph is of the product after trimming, 3 days in the Vaitele cool room; plus a further 2 days at 10C.

Below. Chinese Cabbage. Left-hand photograph is the product at point of harvest; the right-hand photograph is the product after trimming, 3 days in the Vaitele cool room; plus a further 2 days at 10C.


The head cabbage was still in good condition after 5 days, and where quality issues were observed (insects inside the out layer of the product or slight leaf discoloration) this was all pre-harvest in nature, and resolved with further leaf trimming.

In terms of the *Bok Choy* -Chinese cabbage, after 5 days the leaves were severely wilted but there was no evidence of yellowing. The main source of damage observed was broken stems and leaves all of which are likely to be caused by excessive packing and re-packing prior to going into the Vaitele retail store.

Figure 34. Internal core temperature- head cabbage



<u>So what does this tell us</u>? There is only 2 to 3°C increase in core product temperature from harvest to arrival at the store (max temp 26°C) so no problems with temperature management. The cool room has a temperature band of 8-12C, so also no problems. FYI cabbage can be stored down to around 2-3C.

Figure 34. Impact from point of harvest to arrival at the retail store

<u>So what does this tell us</u>? The harvesting, loading practices and road transport are fairly good. However, the under loading /weighting of the product on arrival at the store, especially where head cabbage is poured into the wooden crate caused a series of impact events that could cause damage product or shorten shelf-life.

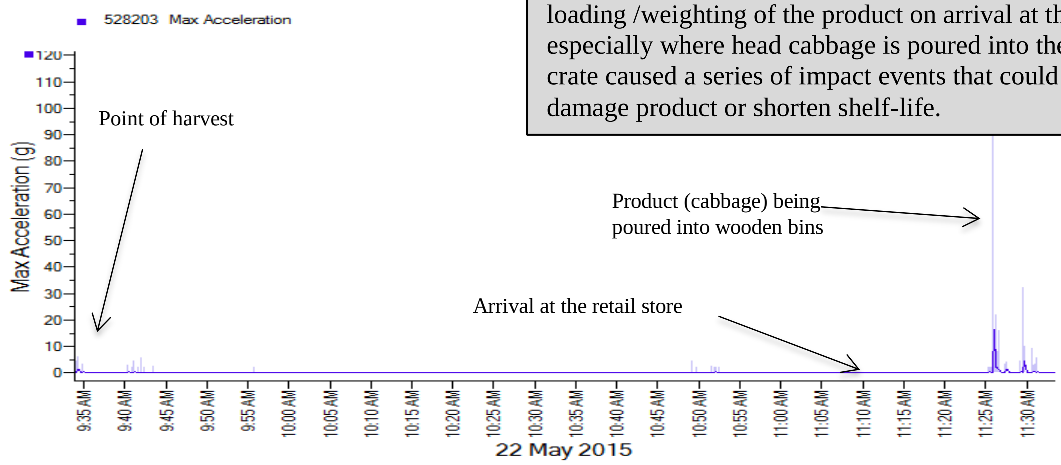


Figure 35. Vibration from point of harvest to arrival at the retail store

<u>So what does this tell us</u>? In terms of careful handling of the product, unloading and weighting of product on point of arrival at the store is where greater care is needed.