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Improving non-communicable disease remediation outcomes in Tonga: the importance of domestic fruit production systems: an analysis

Steven J. R. Underhill [a,b,*], Lila Singh-Peterson [a,b]

[a] *Faculty of Science, Health, Education and Engineering, University of the Sunshine Coast, Maroochydore DC 4558, Queensland Australia*
[b] *Queensland Alliance for Agriculture, Food and Innovation, The University of Queensland, St Lucia, Brisbane, 4000, Queensland, Australia*

Abstract

Non-communicable diseases (NCD) are the leading cause of mortality in the Pacific Island nation of Tonga. Current remedial strategies have focused on promoting healthy food choices based on increased intake of fruits and vegetables. While researchers seek to overcome complex social, gender and cultural practices that impede dietary transition, discontinuous domestic fruit supply chains undermine this effort. With the view to supporting a more holistic approach to NCD remediation in Tonga, this paper provides a preliminary assessment of domestic horticultural supply chains constraints, in support of diversification and expansion of local fruit production. Current impediments and constraints to enhanced local fruit production are presented and possible strategies to increased domestic fruit supply discussed. We present a case for a more consumer-centric approach to industry development, with an emphasis on production systems that are compatible with existing social structures, customary land ownership constraints, and local nutritional needs.

Keywords: Pacific, Tonga, horticulture, fruit, non-communicable disease, economic empowerment, food security, mutton flaps

1 Introduction

Tonga has one of the highest rates of obesity in the world with non-communicable diseases (NCD) being the leading cause of mortality (Evans *et al.*, 2003; Hughes & Lawrence, 2005; Snowdon *et al.*, 2011; Carter *et al.*, 2012). Central to this problem is the low dietary intake of fresh fruits and vegetables (Evans *et al.*, 2001, 2003; Konishi *et al.*, 2011; FAO, 2015) (Table 1), increasing consumption of high-fat and high-sugar imported products (Walsh, 1970; Thaman, 1988; Evans *et al.*, 2003), and a more sedentary life style (Kolt *et al.*, 2006; Mavoa & McCabe, 2008). Type-two diabetes both diagnosed and in its early stages now affects almost 18 % of the total Tongan adult population (Matoto *et al.*, 2014). Similar trends have also been reported in adolescent youth (Phongsavan *et al.*, 2005; Smith *et al.*, 2007a; Cacavas *et al.*, 2011; McCabe *et al.*, 2011). This is alarming considering that diabetes was almost unknown in the Pacific 30 years ago (Smith *et al.*, 2007b). Although the incidence of NCD in Tonga reflects global trends, the combination of Polynesian etiology and associated adiposity, social-economic constraints, and a rapid transition toward western-dietary behaviour, have created an almost endemic obesogenic environment.

Promoting dietary habits based on increased consumption of fresh fruits and vegetables is widely considered to be a critical first step in tackling NCD (Verlangieri *et al.*, 1985; van't Veer *et al.*, 2000; Dauchet *et al.*, 2005; Carter *et al.*, 2010). Tonga was the first

* Corresponding author
Email: sunderhi@usc.edu.au

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Table 1: *Comparative household expenditure of selected food items in Tonga in 2001 and 2009.*

Food product	*Percent of overall food expenditure*	
	in 2001 †	*in 2009* ‡
Meat	31.6	28.7
Fish	10.4	10.1
Bread and cereals	10.5	13.3
Fresh fruit (excl. coconuts)	4.1	4.6
Banana (only)	–	1.7
Watermelon (only)	–	0.5
Fresh vegetables (incl. root crops) §	9.1	23.0
Taro (only)	–	5.2
Sugar, jam, chocolates and confectionary	6.7	4.0
Ice-cream		1.1
Oils and fats	1.1	2.9
Milk, cheese and eggs	6.4	2.5
Mineral water, soft drinks and fruit and vegetable juices	5.2	2.1

† Source: SDT (2001); ‡ Source: SDT (2010); § SDT (2010) classifies breadfruit and a vegetable product.

Pacific Island nation to launch a national NCD prevention strategy in 2004, based on dietary and lifestyle themes. In 2007, the Tongan Government established the Tonga Health Promotion Foundation to better streamline government and non-government organisation NDC remediation initiatives. The importance of increased fruits and vegetable consumption was subsequently re-enforced through the Tongan national strategy to prevent and control NCD (2010–2015). Current obesity-prevention and NCD policies and remedial interventions in Tonga, are based on the underlying assumption of a domestic fresh fruits and vegetables production capacity that could easily be expanded to support dietary transition. In reality, consumer accessibility to fruits and vegetables in Tonga can be highly capricious, particularly in regards to fruit crops. Tonga has an insignificant and declining domestic fruit industry (Table 2). For much of the year, commercial fruit supply-chains are restricted to a few retail outlets selling limited qualities of local or imported products. Looking forward, domestic fruit production is likely to deteriorate further, in regard to quantity and quality, as aging domestic amenity fruit trees are not replaced and those within semi-commercial plantings are poorly maintained. Paradoxically, few authors, with the notable exception of Evans *et al.* (2001, 2003), have highlighted the critical importance of ensuring consumer accessibility to fresh fruits and vegetables in the context of health strategies in Tonga. If the Kingdom of Tonga is to develop effective anti-obesity and NCD remedial policies, then supplementary efforts to enhance the supply of fresh fruits and vegetables will be essential as a foundational objective.

Livelihood and food security concerns have prompted the development of several internationally funded initiatives in Tonga (Allwood & Drew, 1997; Chay *et al.*, 2008; Morris *et al.*, 2014). Although Tonga's Human Development Index' rank is 100, placing Tonga in the high development group, there are concerns about Tonga's unequal wealth distribution (UNDP, 2014), and associated food security status (Matheson *et al.*, 2013). Following the global financial crisis, the total value of the annual national food import for Tonga doubled between 2010–2011, associated with a 110 % in local food prices and a 130 % in export prices during the same period. Tonga's emerging dependency on imported food is further cause for concern in this regard (Hughes & Lawrence, 2005; Sahal Estime *et al.*, 2014).

In seeking to expand fruit access, Snowdon *et al.* (2011) have argued for Government fundamental shifts towards tariffs and structural market reforms. While trade and fiscal policies to support NCD remediation outcomes are often promoted, there has been inconclusive evidence of their relative effectiveness (Thow *et al.*, 2010). The challenge here is that such trade reforms may place increased competitive price pressures on locally sourced product, with potentially adverse

Table 2: *Production area for fruits grown in Tonga (ha).*

Fruit (Common name)	*Total area* (ha)	
	2001 †	*2015* ‡,§
Plantain	343.7	199.1
Watermelon	263.5	168.3
Pineapple	196.0	183.7
Banana	168.4	164.3
Mango	27.5	0.8
Papaya	16.7	11.3
Breadfruit	16.3	2.4
Pacific lychee	9.8	0.4
Orange	6.8	0.4
Guava	6.3	2.8
Avocado	3.2	–
Custard apple	2.9	–
Jackfruit	1.2	–
Passionfruit	0.6	6.1
Lemon	0.5	–
Pomelo	0.4	–
Mandarin	0.4	–
Lime	0.2	–
Grapefruit	0.1	–
Granadilla	–	7.7
Total area (ha)	1065	740

† Source: Anon. (2002). ‡ Source: Anon. (2015).
§ Tropical cyclone Ian caused significant damage to horticultural production in Tonga in Jan 2014, and is likely to be a contributor to a reduction in perennial fruits observed in the 2015 agricultural census data.

local rural livelihood impacts, as observed in Australia (Gray & Lawrence, 2001). Amongst other Pacific island nations, policies have been directed towards restricting horticultural imports, driven primarily by concerns of eroding national food security. However, Tonga's membership in the World Trade Organisation (WTO) may limit its ability to apply such protectionist methods (Connell & Soutar, 2007). In isolation, Pacific trade policies can also inadvertently compound NCD risks factors. Thow *et al.* (2011) in their analysis of food trade policies in the Pacific, highlighted that poorly directed price controls on sugars and fats can actually reinforce price disparities in favour of NCD associated food products. While there is little debate that a multisectoral approach to formative trade policies could overcome many of these hurdles, as argued by Thow *et al.* (2010), we believe that any long-term solution to NCD's in Tonga must also include a diversification and expansion of local fruit production systems.

It would be easy to assume that Polynesian agricultural is bereft of horticultural successes; however, Tonga has had numerous important export-orientated horticultural industries. In the 1950's and 1960's there were significant exports of banana and plantain, and more recently, major squash and melon export industries (Hince, 2000; Fleming & Hardaker, 1995). A combination of shifts in international market demands underpinned by limited export market development, or pest and disease incursions, have unfortunately, consistently and almost cyclically resulted in rapid industry decline. The social and economic impacts associated with such industries failures have been severe (Storey & Murray, 2001; van der Velde *et al.*, 2007), and in the case of the collapse of the squash industry in the late 1990's, have re-enforced community and farmer perceptions of agricultural-productivity risks.

If there is one key lesson from such past commercial venture failures, it is the critical need for Tonga to adopt a multifarious horticultural productivity-base. Felemi (2001), pre-empting current Tongan Government policies, considered horticultural diversification to be an essential foundation for all future agricultural productivity. It is possible that the establishment of a viable fruit industry in Tonga should be more about establishing many small niche fruit industries, rather than seeking to increase productivity of existing key crops.

This paper seeks to support current efforts to develop a fruit industry in Tonga and wider NCD remediation by providing a preliminary assessment of potential domestic horticultural supply chain constraints. Given that much of the information pertaining to the Tongan horticultural industry exists in difficult to access technical reports or local Government policies, there has been an emphasis on documenting, analysing, and thereby making this information available to other researchers. Importantly, while previous researchers have sought to address resistors for fresh fruit and vegetable consumption in Tonga from either a social context or from an agronomic one, through this paper we have sought to do so from a multi-disciplinary perspective inclusive of the bio-physical and social and culture considerations. In this paper we examine key elements of the supply chain from the accessibility of land, the participation of farmers at the production end of the supply chain and then on consumer access to fruit: physically, socially and economically. Our attention to these elements intends to draw out the complexity inherent within the existing Tongan horticultural supply chain, in order to highlight ways forward or alternative methods of approach, which may support the shared objective to expand tree fruit production in Tonga.

2 Overview of current fruit production in Tonga

Agriculture is one of the major pillars of Tonga's economy (AusAID, 2008; Anon., 2015). In the recent National Agricultural Census (Anon., 2015), there were 13,944 households engaged in agricultural production, with 5 % of these considered commercially active enterprises.

Observations generated from previous horticultural project work in Tonga (Menz, 1988; Chay *et al.*, 2008) and from data gleaned from the recent Agricultural census (Anon., 2015) showed that smallholder commercial farms are commonly three to five hectares in size and grow a range of traditional root crops such as cassava, yam and taro, and various western vegetables such as tomato, capsicum, and head cabbage. Production systems tend to be labour-intensive, rain-fed and possess little supporting farm infrastructure. Where fruit production occurs, it is often limited to a few trees incorporated as boundary crops (i.e. mango, breadfruit and citrus) or temporary fruit species (i.e. banana, melon and pineapple) grown within a mixed cropping system. Much of Tonga's domestic fruit production is centred on just four crops; plantain, watermelon, pineapple and banana (Table 2).

A large portion of the tree fruits sold locally are sourced from wild harvesting, with production concentrated on islands of Tongatapu, and to a less extent on the outer islands of Eua, Vava'u and Ha'apai (Anon., 2010, 2015). Much of these existing fruit species are local varieties derived from self-seed material, historical plantings, or limited and disparate recent introductions. Given little documented evidence, it is difficult to put an accurate chronology to when specific fruits species and cultivars were introduced to Tonga. Based on recent archaeobotanical studies by Ussher (2015) many fruit species were present in Tonga pre-1900's, and in some cases pre-1800's. Commonly, there is little effort afforded to tree management giving rise to the common perception that - *Tongans don't grow tree fruit, they just pick them*. This fragmented and highly seasonal supply, coupled with a traditional reliance on household gardens and disparate amenity plantings explain, in part the current discontinuous commercial supply.

While non-commercial chains remain the principle means of sourcing fruit in Tonga (SDT, 2010; Anon., 2015), increasing rates of urbanisation and anecdotal

Table 3: *Fresh fruit imports into Tonga.*

Food product	*Amount of fruit imported into Tonga, annually* (kg)		
	2008 †	*2010* ‡	*2014* §
Apple	95,686	412,800	299,971
Orange	47,549	27,620	103,276
Pear	8,595	23,061	68,305
Raspberry	5,409	19	184
Peach	2,448	92	13,124
Mandarin	2,303	521	10,801
Grape	2,258	1,430	1,450
Lemon, Lime	1,587	352	6,955
Grapefruit	1,404	961	1,450
Kiwifruit	1,118	1,088	805
Guava, mango, mangosteen	430	68	336
Strawberry	106	67	75
Cherry	100	100	17
Plum	71	64	248
Apricot	70	3	15
Watermelon	45	39	12
Avocado	32	46	89
Pineapple	10	579	32
Banana, Plantain	5	49	0
Persimmon	0	0	98
Total fresh fruit (Tonnes)	169.2	469.0	512.9

Source: † SDT (2009); ‡ SDT (2011); § SDT (2014)

evidence of declining home-garden fruit tree plantings are rapidly re-shaping how consumer access fruit. Successive Tongan consumer household surveys (SDT, 2001, 2010) clearly indicate: an increasing consumer reliance on commercial supply chains, particularly in and around the capital Nukuʻalofa on the main island of Tongatapu. Chay *et al.* (2008) noted that local production for fresh fruit could not meet local demand. The nexus of declining domestic production and a greater dependence on commercial food chains, is clearly reflected in the volume of fruit imported into Tonga. Between 2008 and 2014, total fruit fresh imports increased from 170 tonnes to 513 tonnes (Table 3).

It has only been comparatively recently that there has been any effort to document, systematically, Tonga's fruit tree diversity. A declining distribution and limited and inconsistent knowledge of underlying varietal diversity are immediately apparent. Of the 93 edible-fruit species recorded in Tonga, 71 % are rare (Anon., 2010). While there are around 30 common horticultural fruit species (Yuncker, 1959; Daft, 1973; Whistler, 1991; Walter & Sam, 1999; Prescott *et al.*, 2004; Chay *et al.*, 2008; Anon., 2010) (Table 4), only pineapple, banana, plantain, watermelon and citrus species are grown commercially.

Table 4: *Major islands within the Tongan archipelago where fruit species have been reported.*

Common name (scientific name)	*Islands locations*			*Reference*
	Vavaʻu	*Haʻapai*	*Tongatapu*	
Avocado (*Persea americana*)	*	*	*	Anon. (2002); Chay *et al.* (2008)
Banana (*Musa* spp.)	*	*	*	Chay *et al.* (2008)
Banana plantain (*Musa* × *paradisiaca*)	*	*	*	SDT (2001)
Breadfruit (*Artocarpus altilis*)	*	*	*	Chay *et al.* (2008)
Carambola (*Averrhoa carambola*)		*		Chay *et al.* (2008)
Citrus †	*	*	*	Yuncker (1959); SDT (2001)
Alemow (*Citrus macrophylla*) ‡				Anon. (2010)
Grapefruit (*Citrus paradisi*)	*	*	*	Anon. (2010)
Key lime (*Citrus aurantifolia*) ‡	*	*	*	Anon. (2002); Anon. (2010)
Mandarin orange (*Citrus reticulata*)	*	*	*	Anon. (2002)
Pummelo (*Citrus maxima*)	*	*	*	SDT (2001); Anon. (2002)
Rough Lemon (*Citrus jambhiri*) ‡	*	*	*	Anon. (2002); Anon. (2010)
Tahiti lime (*Citrus latifolia*) ‡	*	*	*	Anon. (2002); Anon. (2010)
Custard apple (*Annona squamosa*)	*	*	*	SDT (2001); Anon. (2002); Prescott *et al.* (2004)
Granadilla (*Passiflora ligularis*)		*		Chay *et al.* (2008)
Guava (*Psidium guajava*)	*	*	*	SDT (2001); Chay *et al.* (2008)
Feijoa (*Acca sellowiana*)		*		Chay *et al.* (2008)
Fiji persimmon (*Diospyros major*)				Walter & Sam (1999)
Jackfruit (*Artocarpus heterophyllus*)				SDT (2001)
Lychee (*Litchi chinensis*)			*	Chay *et al.* (2008)
Mango (*Mangifera indica*)	*	*	*	Chay *et al.* (2008)
Noni (*Morinda citrifolia*)	*	*	*	Chay *et al.* (2008)
Ocean fig (*Ficus scabra*)				Whistler (1991)
Pacific lychee (*Pometia pinnata*)	*	*	*	Yuncker (1959); Anon. (2002); Chay *et al.* (2008)
Pacific chestnut (*Inocarpus fagifer*)	*		*	Prescott *et al.* (2004); Chay *et al.* (2008)
Papaya (*Carica papaya*)	*	*	*	SDT (2001); Anon. (2002)
Passion fruit (*Passiflora edulis*)	*	*	*	SDT 2001; Anon. (2002); Chay *et al.* (2008)
Pineapple (*Ananas comosus*)	*	*	*	SDT (2001); Anon. (2015)
Sapodilla (*Manilkara zapota*)	*			Chay *et al.* (2008)
Soursop (*Annona muricat*)			*	Chay *et al.* (2008)
Syzygium §	*	*	*	Prescott *et al.* (2004); Chay *et al.* (2008)
Vi (*Spondias cytherea*)	*	*	*	SDT (2001); Prescott *et al.* (2004)
Watermelon (*Citrullus lanatus*)	*		*	Daft (1973)

† Detailed information of species not provided by authors. ‡ Listed as critical and endangered (SDT, 2001). § Detailed information of species not provided by authors, most likely *Syzygium malaccense*

3 Compatibility of existing land-utilisation and smallholder participatory engagement

Reflecting on the production-end of the chain, accessibility to arable agriculture land is likely to be a major impediment to expanding fruit production in Tonga. Delforce (1988, 1990), Fakava *et al.* (2001), FAO (2004), and Anon. (2015), considered limited land availability in Tonga as one of the key constraints to smallholder participation in agriculture. Central to the problem is increasing urbanisation, significant land area being inaccessible due to landowners having migrated overseas, and restrictive land tenure arrangements. Of the Kingdom's 26,791 ha of total agriculture land, only 11,101 ha support annual and perennial crop production (Anon., 2015), with 51 % (13,645 ha) left fallow and not supporting any agronomic productivity.

In Tonga, land access is subject to highly complex social hierarchy and customary land ownership (Crawford, 2001; Fakava *et al.*, 2001; Storey & Murray, 2001; Jayavanth *et al.*, 2009). Women are not permitted to own land in Tonga (Matheson *et al.*, 2013). Conditions of tenure can be highly disparate, with long-term leases subject to ongoing uncertainty, emphasising the legacy and contemporary influence of the monarchy and noble class in Tonga's governmental system (Campbell, 2005). Traditional land management and ownership systems are primarily supportive of individual subsistence-based farming and social hierarchies, and often not conducive to expanded and more intense commercial productivity. Absent landholders, land holdings that often favour the social hierarchy, and disparate and often ineffective lease-agreements have the collective effect of locking away much of Tonga farming land. Given tree fruit production systems often necessitate greater initial investment and longer production cycles, even if land access can be secured, a lack of longer-term land security is sufficient disincentive for aspiring smallholder farmers to plant perennial crops.

There have been few sporadic attempts to expand tree fruit production in Tonga (Daft, 1973; Delforce, 1988; Ryan, 1988; Chay *et al.*, 2008), based on a diverse range of fruit species (i.e., mango, citrus, sapote and soursop) but all having comparatively little success. What is collectively evident from such work is the significant challenge in achieving smallholder farmer inclusion and critical impediments to gaining agronomic productivity. Even if such constraints, such as land tenure arrangements could be resolved, smallholder farmer's willingness to participate in an emerging tree fruit industry is likely to be tenuous. Perennial crops such as fruit trees tend to be viewed as high-risk commodities, due to their perceived vulnerability to high-intensity weather events (i.e. tropical storms), insecurity of long-term land tenure and competitive price pressures from amenity harvesting. In many cases, this perceived risk is well founded. In 2014, tropical cyclone Ian was reported to have destroyed 90 % of all horticultural crops and fruit trees in Tonga (Anon., 2015). While such constraints have been well documented (Hardaker *et al.*, 1987; Delforce, 1988, 1990), relatively little is known about underlying community, cultural and societal factors that ultimately shape associated smallholder farmer decision marking processes and behaviour (Fakava *et al.*, 2001).

International aid programs have sought to include smallholder farmers in commercial projects in order to secure sustainable livelihood benefits for participants (Morris *et al.*, 2014). A study by Mavrogenis & Kelman (2013) confirmed that the primary reason in which local Tongan people will engage in activities facilitated by international and local non-government organisations is to achieve secure livelihoods. There are some challenges, however, in engaging smallholder farmers who are not concerned with livelihood challenges, which may stem from embedded cultural paradigms. In contrast to western societies, societal status in Tonga is mostly derived from familial associations and historical lineages, thereby limiting the rise in social ranking through wealth generation, which Holtz (2010) suggests may account for the population's low entrepreneurial spirit. Brown *et al.* (2014) also observes that personal incentives for individual financial gains are also limited, as financial success is expected to be shared with family and friends. This may account for the high-level of remittances, which have at one point made up almost 70 % of Tonga's GDP (Lin, 2011).

It is likely that in the absence of significant and demonstrative livelihood benefits and associated support systems, smallholder farmer participation in a nascent tree fruit industry is likely to be speculative and highly transient. In essence, effort to establish commercial-scale tree fruit industry around poorly-resourced and risk-adverse smallholder farmers operating on limited landholdings is unlikely to be successful in the short-term.

An initial determination of risk commonly experienced in the early stages of industry development, with dilatory smallholder engagement strategies is not without its merits. There are strong socio-political structures in Tonga that have enabled the royal and noble class to exert significant control over the larger portion of Tonga's agricultural land (Crawford, 2001). By adopting a more centralistic approach to industry devel-

opment inclusive of elements of contract-based farming with possible Royal lands or Noble estates access, some of these initial constraints could be partially overcome. While contracted or semi-structured production systems can facilitate greater market engagement particularly in emerging industries (Birthal *et al.*, 2008), they can also have potential adverse social-exclusion impacts (Porter & Phillips-Howard, 1997; Coxon, 1999), particularly where there are asymmetric supply chain power structures. There has been ongoing debate in the literature concerning the relative merits of contract farming (Fleming, 2002); however, in the context of Tongan agriculture they warrant further consideration.

4 Consumer access and purchasing behaviour

Establishing a viable domestic tree fruit industry in Tonga can only be achieved if there is tangible connectivity between consumer access, purchasing behaviour and underlying retail supply chains. While health-related NCD researchers have long sought to understand better dietary choices and purchasing behaviour, consumer-demand has received cursory attention by horticulturists seeking to support an expanded fruit industry in Tonga.

4.1 Social and cultural influences on fruit and vegetable consumption

Understanding individual's food choices is in general highly complex. Nestle *et al.* (1998) challenge the traditional public health approach to dietary change, which has been based on the premise that consumers will abandon unhealthy diets in order to prevent future illness. Instead, they suggest that obstacles to dietary change, such as limited economics, accessibility, knowledge, skills and the awareness of opposing peer-pressure, advertising and cultural determinants need to be considered when promoting dietary change. The culture in which an individual is raised, and their social political interactions are believed to have a profound influence on food attitudes and eating behaviour (Devine *et al.*, 1998; Shepherd, 1999). In fact, Nestle *et al.* (1998) state that 'culture is the pervasive foundation that underlies all food choices'. Although there is limited information specific to Tonga about dietary change or food choices, demographics such as gender and age are reported to have a major influence on attitudes towards fruit and vegetables consumption in Tonga (Mavoa & McCabe, 2008; Cacavas *et al.*, 2011).

The other facet to assess food choices and consumer-purchasing behaviour is to determine the underlying consumer sensory preferences. Elsewhere, consumer organoleptic studies would provide the foundation from which cultivar selections and commercialisation strategies would be based (Crisosto *et al.*, 2005). In Tonga, there is little information on sensory-preferences or consumer attitudes towards unfamiliar fruits. In preliminary stakeholder studies (M. Taylor *pers comm.* 2013) suggests that there is a distinct conservatism towards such fruits crops (i.e. carambola, custard apple, and jackfruit) currently being grown in Tonga. Socio-economic considerations are likely to re-enforce such consumer conservatism.

4.2 Economic and physical accessibility

Changing consumer-purchasing behaviour in favour of imported fatty foods has been widely attributed to the fact that such products are often traded at substantially lower prices than alternative traditional food sources, including fresh fruits and vegetables (Evans *et al.*, 2001). However, the view that Tongans would prefer to purchase fresh fruits and vegetables if economically empowered to do so, would appear somewhat incongruous with long-term dietary trends in the Pacific (Lako, 2001).

There is little doubt that high-prices and associated perceived poor value for money, particularly within low socio-economic population cohorts, adversely influence consumer willing to purchase fresh fruits and vegetables in Tonga. Owen (1999) and Evans *et al.* (2002, 2003) proposed the additional, and possibly compounding, effects of limited capacity of consumers to easily and consistently access fresh fruits and vegetables. The concept of fruits and vegetables accessibility as a potential consumer-purchasing resistor in Tonga, has received little attention in the literature. In a country, traditionally shaped around subsistence-based farming, initially there would appear little support for this idea. However, fruit and vegetable supply chains in Tonga are often highly asymmetric. The commercial retail sector is constructed around comparatively few supermarkets. Instead, there is a high frequency of community-based small-enterprise shops trading almost exclusively in imported non-perishable processed products. Fruits and vegetables tend to be purchased directly from one of the three main central municipal markets (55.7 %) which are Talamahu Market and Fangaʻihesi Market (in Tongatapu) and ʻUtukalongalu Market (in Vavaʻu) or through transient road side trading (36.5 %) particularly on the main road access points to Nukuʻalofa (Tongatapu) (Ika, 2011). Interestingly, the number of roadside stalls have increased significantly following civil unrest in Tonga

in 2006, which destroyed 60–80 % of Nuku'alofa's business district (Wallis, 2010) - implying a trend away from centralised distribution chains. While extensive roadside trading provides diversity in supply options, fruit and vegetable markets and the road side stalls can be remote from where most general food retail transactions occur. This is significant as there is considerable evidence, based around the gravity and distance decay modelling of the importance of net retail accessibility in determining consumer fruit and vegetable purchasing behaviour. In the context of obesity studies, recent work in the United States by Robinson *et al.* (2013) reported a strong correlation between fruit and vegetable purchasing behaviour and retail proximity. Where fresh fruit and vegetable trading was remote from general food retail activity, net fruit and vegetable purchasing behaviour was reduced. In quantifying this relationship, Morland *et al.* (2002) demonstrated an almost 30 % increase in fruit and vegetable consumption for each additional retail outlet co-located within the supermarket precinct. Michimi & Wimberly (2010) also observed this relationship, particularly in urbanised areas. It is also apparent, that geographically, population logistics underpinned by socio-economic considerations have a major influence on purchasing behaviour (Morland *et al.*, 2002; Mavoa & McCabe, 2008; Pearce *et al.*, 2008).

Whether existing fruit and vegetable retail distribution networks in Tonga create a similar consumer purchasing disconnect based on inconvenience, resulting in a reduction in net consumer purchasing is unclear. The potential importance of current retail distribution networks on consumer purchasing behaviour in Tonga requires further attention. Cognisant of an underlying trend away from fruit and vegetable consumption coupled with highly price-sensitive consumer behaviour, the issue of consumer purchasing convenience clearly warrants further consideration.

The importance of economic and physical accessibility to fruit as a consumer-purchasing resistor is also likely to be transient in Tonga. When local fruit production is in season and purchasing accessibility constraints are removed due to high-volume trading, coupled with comparatively low prices, consumer demand decreases accordingly. In seeking to counter the potential combined effects of economic and temporal accessibility resistors, we suggest that the potential expansion of current commercial fruit production in Tonga needs to be constructed around competitive product pricing, counter seasonal or extended seasonality of supply and integrated into diverse domestic supply chain distribution networks.

Also underpinning the effectiveness and efficiency of horticultural supply chains in Tonga are the postharvest handling practices adopted. Unlike other Pacific Island countries, such as Fiji and Samoa, where such practices have been well documented (Underhill, 2013a,b,c; Underhill & Kumar, 2014, 2015), little is known about horticultural postharvest handling in Tonga with potential high postharvest losses a possible further challenge.

5 Conclusions

A diversified and expanded domestic tree fruit industry in Tonga is essential if wider NCD and anti-obesity health-based reforms are to be effective. In a country structured around opportunist and limited seasonal fruit supply, highly price-sensitive consumers, potential supply chain logistic resistors and significant physical impediments to smallholder farmer engagement, the objective to expand fruit production and local consumption is ambitious. Compounding this challenge is the need to explore tropical adaptive production systems compatible with heterogeneous speciation within the context of ongoing risk which includes high-intensity weather events, varietal evaluation strategies, systems to reduce biological risk (pest and diseases), overcoming limited critical supply chain inputs, and poorly resourced and often unpredictable Government interventions. However, what is probably of equal concern is the risk of further complicating this challenge. Government and donor-driven interventions commonly seek to focus on production-centric priorities with a strong emphasis on front-end smallholder-farm engagement. This can create the risk of a highly production-driven approach where there is an assumed intrinsic connectivity with consumer purchasing behaviour and efficient underlying distribution chains. In this paper, we have sought to highlight that consumer purchasing in Tonga is based on complex and transient social, gender, cultural and economic considerations, and is trending away from fruit and vegetable consumption. As such, achieving consumer purchasing connectivity will be far from automatic. The other consideration is that current strategies based around early smallholder farmer engagement are unlikely to succeed but may actually elevate farmers to exposure to commercial risk. Instead, a sustainable tree fruit industry in Tonga is more likely to be achieved through production systems that are compatible with current social and cultural land-use considerations. Given the considerable generic challenges outlined in this paper, we also believe that multidisciplinary food and trade policies, while only briefly commented on in this paper, are a further essential element.

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