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Original article

Food cooking methods contribute to the reduced vitamin C content of foods prepared in hospitals and care facilities: a systematic review

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Summary Recent cases of scurvy within health care have been reported internationally. One potential reason is vitamin C losses associated with food cooking methods. This review systematically synthesised the published literature to determine the extent that vitamin C in food is lost secondary to food cooking methods used in hospitals or care facilities. The review followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, and was prospectively registered in the Prospective Register for Systematic Reviews. Searches were run in three databases with no date restrictions, complemented by an internet search and reference checking. Search terms focused on the intervention and outcome. The final review included seven publications including longitudinal studies and comparison to reference standards. All studies identified vitamin C losses between preparation and service resulting from food cooking methods. Quality was rated as positive for four papers and neutral for the remainder of the included library.

Keywords Ascorbic acid, cook-chill, food service, scurvy, vitamin C.

Introduction

Scurvy has been defined as a disease that results from an inadequate intake of vitamin C, causing a deficiency (Rajakumar, 2001). First documented over 3500 years ago, the disease itself is most commonly associated with an ancient past, known for its prevalence among sea voyagers in the 15th century (Corruble & Ganascia, 1997; Rajakumar, 2001; Magiorkinis *et al*., 2011). Manifestations of the disease were initially described as bruising, gingival bleeding and fatigue (Hodges *et al*., 1971). It was not until L-ascorbic acid was successfully isolated, that vitamin C (commonly found in fruits and vegetables) was proven to be a specific and effective treatment for scurvy (Dunn, 1997; Hirschmann & Raugi, 1999).

Nowadays, scurvy could be termed a 'forgotten disease' and is relatively uncommon in developed countries (Akikusa *et al*., 2003; Giday, 2012). However, a number of recent cases identified at our health network and reported elsewhere in Australia and internationally, suggest that although a rarity in the modern day world, scurvy still has the potential to affect individuals not consuming a diet adequate in vitamin C (Hampl *et al*., 2004; Velandia *et al*., 2008; Charlton, 2016; Christie-David & Gunton, 2017). The retrospective study of Christie-David & Gunton (2017) identified significant vitamin C deficiencies in a sample of patients with diabetes. In this cohort, 63.6% of participants were vitamin C deficient with a high prevalence of ulcers, and low fruit and vegetable intake. Risk factors for vitamin C deficiency in this study included low income, age, alcoholism, smoking, cancer, mental illness and renal impairment (Christie-David & Gunton, 2017).

Despite the cause of scurvy being well known, a large proportion of individuals in developed countries do not meet their targets for fruit and vegetable intakes (Hampl *et al*., 2004; Moore & Thompson, 2015). Diets that contain inadequate amounts of fresh fruits and vegetables are common and the addition of discretionary items means that this essential nutrient may be left out of the diets of otherwise healthy individuals. Whilst such diets may lead to an increased risk of inadequate vitamin C intake, there are some population groups that are at higher risk of vitamin C deficiency and its manifestations. Such population groups include: patients with eating disorders or psychiatric conditions, the elderly, alcohol abusers and

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those with malabsorption conditions (Akhtar & Toor, 2016).

Malnutrition, commonly associated with inadequate nutrient intake is highly prevalent in the hospital setting, affecting up to 50% of patients (Barker *et al.*, 2011). It has been documented that up to 85% of individuals residing in nursing homes or care facilities could be classified as undernourished, depending on the assessment method used (Miranda *et al.*, 2016). Concerns have been raised that poor dietary intakes of hospital food or being institutionalised may be attributed to inadequate meal service, poor quality meals and inflexible food service systems (Dupertuis *et al.*, 2003).

Traditionally, food and meals served in hospitals or care facilities were prepared in in-house kitchens and held in heated units until being served to residents (Charlton *et al.*, 2004). However, the evolution of food service has seen the cook-chill model rise in popularity and involves foods being cooked, then chilled for up to 5 days prior to serving and reheated for provision to patients (Williams, 1996; Charlton *et al.*, 2004). Whilst the cook-serve method is the most popular system used in the United States, the cook-chill or cook-freeze system has become the predominant system used for food production within Australian hospitals (Edwards & Hartwell, 2006). In this system, the preparation of meals has been transferred off-site entirely to central production kitchens (Porter & Cant, 2009). Due to an increased incidence of listeriosis, some hospitals restricted 'high risk' foods from their menus, including items such as pre-prepared salads, pre-prepared fruit salads, raw vegetables and sandwiches contained these ingredients (Victorian Government, 2017). These restrictions could potentially exacerbate the risk of scurvy development as they are reducing valuable food sources of vitamin C offered to patients. Since the elderly and unwell are considered vulnerable groups for listeriosis, alternative high vitamin C sources are required.

Vitamin C is the most heat labile vitamin making it susceptible to degradation when exposed to heating, whilst up to 10% of vitamin C losses can also be anticipated during chilling processes (Charlton *et al.*, 2004; Konas *et al.*, 2011). Vitamin C losses in heating of food have been attributed to oxidative destruction, and to leaching of the vitamin into cooking water (Charlton *et al.*, 2004). Substantial losses may also occur from the reheating (in the case of cook chill systems); these losses are greater when a bulk volume is reheating, as compared with individually heated food (Williams, 1996). Vitamin C losses in chilled and frozen foods are also problematic. Previous studies have identified that the during processing, distribution and storage of frozen vegetables, ascorbic acid is oxidised to dehydroascorbic acid, which in turn is irreversibly hydrolysed to 2,3 diketogulonic acid, possessing no vitamin C activity (Giannakourou & Taoukis, 2003). Although vitamin C losses are limited where blanching and industrial quick freezing are close to harvest (Favell, 1998), the delay to purchase and storage in domestic freezers deviate from ideal conditions. Research exploring freezing models of different vegetables determined that differences between plant tissue itself can also affect the rate of vitamin C loss with frozen spinach most susceptible to loss of vitamin C, whilst moderate retention was recorded in peas and green beans. Vitamin C losses in okra were substantially lower (Giannakourou & Taoukis, 2003).

Numerous reports have documented that long-stay hospital patients or elderly institutionalised individuals have low concentrations of blood ascorbic acid (Jones *et al.*, 1988; Charlton *et al.*, 2004). Consequences of low blood vitamin C levels have been linked to negative health outcomes within this population group including progressive weakness, fatigue, delayed wound healing and depression (Charlton *et al.*, 2004). Low vitamin C levels could be attributed to reduced oral intake of the vitamin, reduced absorption from the gastro-intestinal tract and a low variety in foods served (Williams, 1996; Charlton *et al.*, 2004). More specifically, questions have been raised as to whether large scale food service systems deliver inadequate amounts of vitamin C in their foods, secondary to the degradation which may occur in the preparation and serving procedures. This review aimed to systematically synthesize the published literature to determine the extent to which vitamin C in food is lost secondary to a range of food cooking methods used in hospitals or care facilities.

Methods

Search strategy

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher *et al.*, 2009) and the protocol was prospectively registered with the Prospective Register for Systematic Reviews (PROSPERO; registration number CRD42017048950). Due to the identification of only one study reporting change in vitamin C status of patients/residents, a deviation from the published protocol occurred. The inclusion of the second planned outcome, i.e. vitamin C status of patients/residents in combination with foodservice models, was removed from the review process.

Searches were applied from the commencement of each database, in CINAHL (from 1937), Ovid Medline (from 1946) and Embase (from 1947) to April 2018. The search terms were determined through exploration of key words used in the relevant literature and refined after consultation with a healthcare librarian and

dietitian with food service expertise. The subject headings and phrases were searched to ensure maximum retrievals. The search strategy focused on the population and intervention of interest. Outcomes were not defined within the search strategy; instead these were a focus of the title and abstract, then full text, review. Search terms used were as follows: 'Cook Fresh', 'Cook Chill*', 'Cook Freeze', 'Food Service*', 'Meal Preparation', 'Food Production' and 'Cooking Method*'. These terms were combined with 'Scurvy', 'vitamin C', 'Ascorbic Acid', 'Ascorbate' and 'L-ascorbic acid'.

A supplementary internet search was undertaken in Google Scholar concurrently by two reviewers to identify any studies that may have been missed through database searching. The search terms used were 'food service', 'vitamin C' and 'hospital'. Reference lists of included studies were also reviewed to ensure the maximum number of studies were included.

Study selection

Criteria for study inclusion were developed using the Population-Intervention-Comparator-Outcomes format (Liberati *et al*., 2009). Adults (≥18 years of age) admitted to hospital or residing in care facilities were the population of interest. The intervention of interest was food service systems in either the hospital or aged care setting. The primary outcome measure was vitamin C content of food, including the percentage of vitamin C losses. Original research was eligible, whilst systematic reviews, commentaries and conference abstracts were excluded. Additionally, foods studied had to be prepared and rethermalised in the hospital kitchen, not in simulated kitchens. These inclusion criteria ensured that vitamin C data were representative of food that would subsequently be served to patients or residents. Studies written in languages other than English were excluded. Studies not conducted in a hospital or aged care setting, such as prisons and schools, were also excluded as they were not targeting the population of interest (patients who may be medically unwell, have increased nutrition requirements or may be old and frail putting them at greater risk of nutrient deficiencies).

A title and abstract review, followed by full text review of search retrievals, was conducted by two authors independently and in duplicate against inclusion criteria. Full texts were obtained for 44 papers and again reviewed independently and in duplicate by two authors against the inclusion criteria. Once each reviewer completed the assessment, any differences were discussed and resolved by consensus. At the completion of the full text review, the reference lists of included studies were reviewed to ensure that all eligible papers had been identified for the final library. The complementary internet search using Google Scholar was also conducted by two authors independently and in duplicate. The first 100 citations were checked for relevance against the inclusion criteria.

Data extraction and quality appraisal of individual studies

A template was developed to extract data relating to study setting, purpose, study design and intervention. Data were extracted by one author. Published data only were included in the data extraction process.

Two authors independently rated study quality using the Quality Criteria Checklist for Primary Research: Non-Human Subjects (American Dietetic Association, 2005). This tool includes criteria that are associated with decreased bias and improved validity in primary research and is specific for studies in the field of nutrition and dietetics. Ratings of negative (weak quality; does not adequately address inclusion/exclusion, bias, generalizability, data collection and analysis), neutral (neither exceptionally strong, nor exceptionally weak quality) or positive (strong quality; adequately addresses inclusion/exclusion, bias, generalizability, data collection and analysis) were assigned, with consensus obtained through discussion.

Eligible studies were grouped according to the outcome measures and results were described narratively, with a greater emphasis placed on findings from studies achieving high-quality ratings. Due to the heterogeneity of study designs, food service systems and diversity of foods studied, a meta-analysis was not undertaken.

Results

Three hundred and forty papers were identified through database and internet searching and reference checking. With the removal of duplicates and those which did not meet the inclusion criteria (i.e. were not conducted within a hospital, care facility or rehabilitation setting or not in an adult population), 44 studies were included for full-text review (Figure S1). No previous systematic reviews on the research question were located.

Seven studies were identified that fulfilled the inclusion criteria for this review (Table 1). The number of food samples tested in each study was not always specified. However, of the studies that did specify the number of food samples tested, the range of samples was from 3 to 40. The researchers used a variety of study designs including five longitudinal studies (Koehler & Hard, 1983; Löwik *et al*., 1993; McErlain *et al*., 2001; Charlton *et al*., 2004; Konas *et al*., 2011) and two studies which compared laboratory test data against reference standards (Jones *et al*., 1988; Feldman *et al*., 2006). Studies were undertaken in four different countries: USA, South Africa, UK and The Netherlands.

Table 1 Studies included in this systematic review to identify the effect of different food cooking methods on the vitamin C content of foods served to individuals residing in hospitals or care facilities

Author (year), location	Setting	Study purpose	Study design	Summary of study methods	Intervention
Charlton *et al.* (2004), South Africa	Psychiatric Hospital	Assess ascorbic acid losses in four vegetables in a cook-chill food service system	Longitudinal study	On two repeat occasions, three samples each of cauliflower, cabbage, broccoli and peas were sampled at each stage of production (i) deliver day, (ii) after preparation, (iii) after cooking, (iv) after blast chilling, (v) in the hold room and (vi) after regeneration. One sample from the left, centre and right side of the gastronome was taken. Each sample was immediately macerated and weighed in a measuring cylinder, with 8% acetic acid added to a volume of 100 mL to stabilize the ascorbic acid content	Cook-chill. Cooking (not specified), within 30 min blast chilling to a core temperature of 0–3 °C, hold room for up to 4 days, 25 min of reheating (trolley was at 180°) but samples only reached a maximum of 65° (except on one occasion where 75° was reached)
Konas *et al.* (2011), USA	Eldercare living facilities, including rehabilitation and long term care	Measure vitamin C concentration of vegetables exposed to different cooking processes	Longitudinal study	Forty samples (green beans and carrots) from five different facilities. Samples taken directly from steam table or service container, immediately vacuum sealed, transported on ice for testing	Initially frozen, steaming or boiling for 15–45 min. Hot holding (time not specified)
Jones *et al.* (1988), UK	Three hospitals	Compares the ascorbic acid content of a range of food provided by a standard hospital diet after being cooked and heated to standard food composition tables	Comparison to reference standard	Diets studied of thirty individuals during 1982–1984 at three hospitals 'A', 'B', C'. Representative samples of plated meals were randomly selected for 'on-plate analysis' by removal from the heated trolley in the ward at the point of serving to patients. Portions were weighed and aliquots taken for vitamin C analysis and processed immediately in a room alongside the ward. A 3-week menu cycle was operated with a one in four choice	Fresh, cook-serve, food in heated trolley (62°) for 60–90 min before reaching patient
Koehler & Hard (1983), USA	Hospital	Determine the amount of thiamine, riboflavin and ascorbic acid contents of pre-prepared foods that are served to hospital patients and nutrient changes during preparation	Longitudinal study	Samples of each food taken at beginning and end of serving period and a sampled from three different months. Foods were immediately weighed, sealed in zip fasteners and frozen on dry ice	Not specified
Löwik *et al.* (1993), USA	Nursing home	Examined vitamin C losses from preparation practices	Longitudinal study	Three samples (before and after preparation and at the time of consumption) were taken from 42 different foodstuffs. All samples were frozen immediately in liquid nitrogen.	Not specified – samples were taken during preparation and distribution of different food products served in the nursing home

Table 1 (*Continued*)

Author (year), location	Setting	Study purpose	Study design	Summary of study methods	Intervention
				Analysis was completed within 8 weeks of collection	
McErlain *et al.* (2001), UK	Hospital	Evaluate the ascorbic acid loss of vegetables prepared in a hospital cook-chill plated system	Longitudinal study	Boiled potatoes, mashed potatoes, carrots, peas selected for analysis of vitamin C level at several points in the cook-chill process	Cook (potatoes boiled for 30 min, mashed with salt-free butter and full-fat milk, carrots blanched and frozen prior to delivery, peas blanched and frozen prior to delivery), chill (3° within 90 min), store (3° for up to 5 days), plated, reheated (45 min to a minimum of 75°), served
Feldman *et al.* (2006), USA	Two hospitals	Quantify the amount of vitamin C in peas retained at various stages of processing	Comparison to reference standard	Samples of peas were immediately checked for temperature, vacuum sealed and then labelled using a blind notation system. Samples of frozen peas were taken directly from the storage freezer. Cooked, tray line and delivered peas were sampled at random times	Frozen peas, steam cookers (100–103°) (without water) for 15 min, left in cooker up to 5 min longer. Potential for peas to be returned to steam cooker if they had not reached 82° in temperature. Time from cooking to patient consumption ranged from 20 to 90 min. Hospital A tray line temperature was ~93°. Hospital B was ~85°

All studies made some reference to the amount of vitamin C lost in different phases of food preparation and serving to patients or residents. Food preparation and service procedures varied considerably and included: steaming, boiling, cooking (not specified), hot holding, blast chilling, hold room, reheating, cook-fresh, frozen samples, steam cookers (without water), mashing, blanching, left in oven for extended periods. It should be noted that the methods used for analysing vitamin C content varied between studies.

Outcomes

Table 2 shows the percentage loss of vitamin C that occurred in the studies secondary to different food service interventions employed. One of the seven studies showed a significant ($P < 0.05$) loss of vitamin C content from cooking. Charlton *et al.* (2004) reported the percentage loss of vitamin C from cooking the four vegetables studied as 33.2% in cauliflower, 57.2% in cabbage, 60% in peas and 80.8% in broccoli, all of which were significant. Löwik *et al.* (1993) and McErlain *et al.* (2001) also reported losses of vitamin C from cooking that ranged from 20.8% in potatoes (boiled for 30 min) to 84.1% in mashed carrots, but *P* values were not reported. Feldman *et al.* (2006) investigated losses of vitamin C in peas from steaming (100–103 °C without water for 15 min) and reported losses of 63% in Hospital A and 36% in Hospital B when compared to the levels of the frozen vegetable.

Two studies measured the impact of chilling on the vitamin C content of cooked foods. Charlton *et al.* (2004) reported significant losses of vitamin C in chilling processes (blast chilling to a core temperature of 0–3 °C) for cabbage and peas, 63% and 73%, respectively. However, Charlton *et al.* (2004) reported that the loss of vitamin C during chilling for cauliflower was not statistically significant ($P = 0.053$). The study conducted by McErlain *et al.* (2001) showed much smaller losses of vitamin C from chilling processes which involved chilling to 3 °C within 90 min of preparation. Only 0.1% of vitamin C was lost in chilled peas and up to 11.7% lost in diced carrots.

Five out of the seven studies measured the vitamin C loss that occurred throughout the reheating/regeneration or time on the tray line process of the samples studied. Konas *et al.* (2011) reported losses ranging from 36.4% in boiled carrots to 88.6% in steamed green beans that were hot held (time not specified). Results from Charlton *et al.* (2004) were similar with percentage losses ranging from 26.4% in cauliflower to 78.6% in peas after 25 min of reheating up to a maximum of 75 °C. Charlton *et al.* (2004) also reported a

Table 2 Percentage loss of vitamin C secondary to cooking, steaming, chilling, storage and regeneration or reheating procedures

Intervention	Study	Sample	Percentage (%) loss of vitamin C	*P* value
Cooking*	Charlton *et al.* (2004), South Africa	Broccoli	80.8%	<0.05
		Cauliflower	33.2%	<0.05
		Cabbage	57.2%	<0.05
		Peas	60%	<0.05
	Löwik *et al.* (1993), USA	Normal consistency		
		Beets	33.4%	NR
		Carrots	52.3%	NR
		Green peas	47.5%	NR
		Broad beans	45.9%	NR
		Mixture of vegetables	53.23%	NR
		Red cabbage	23.1%	NR
		French beans	67.54%	NR
		Potatoes (October)	20.8%	NR
		Potatoes (March)	30.6%	NR
		Mashed		
		Beets	33.4%	NR
		Carrots	84.1%	NR
		Green peas	53.3%	NR
		Broad beans	43.4%	NR
		Potatoes (October)	28.6%	NR
		Kale	41%	NR
	McErlain *et al.* (2001), UK	Diced Carrots	n/a	NR
		Peas	n/a	NR
		Boiled potatoes	54.2%	NR
		Mashed potatoes	58.33%	NR
Steaming	Feldman *et al.* (2006), USA	Peas (Hospital A)	62.9%	NR
		Peas (Hospital B)	36.6%	NR
Chilling	Charlton *et al.* (2004), South Africa	Broccoli	7.5%	NR
		Cauliflower	11.25%	0.053
		Cabbage	62.8%	<0.001
		Peas	72.92%	<0.001
	McErlain *et al.* (2001), UK	Diced carrots	11.7%	NR
		Peas	0.1%	NR
		Boiled potatoes	6.1%	NR
		Mashed potatoes	3.4%	NR
Storage	Charlton *et al.* (2004), South Africa	Broccoli	21.5%	NR
		Cauliflower	9.2%	NR
		Cabbage	10.4%	NR
		Peas	78.6%	NR
Regeneration/ reheating/tray-line	Charlton *et al.* (2004), South Africa	Broccoli	53.7%	NR
		Cauliflower	26.4%	NR
		Cabbage	53.1%	NR
		Peas	78.6%	NR
	Konas *et al.* (2011), USA	Green beans (steamed)	88.64%	NR
		Green beans (boiled)	64.4%	NR
		Carrots (steamed)	63.2%	NR
		Carrots (boiled)	36.4%	NR
	McErlain *et al.* (2001), UK	Diced carrots	56.6%	NR
		Peas	41.4%	NR
		Boiled potatoes	93.88%	NR
		Mashed potatoes	41.4%	NR
	Koehler & Hard (1983), USA	Potato dishes	13–15%	NR
		Mashed potato	3%	NR
	Löwik *et al.* (1993), USA	Normal consistency		
		Beets	50%	NR
		Carrots	81%	NR
		Green peas	87.5%	NR
		Broad beans	82.1%	NR

Table 2 (*Continued*)

Intervention	Study	Sample	Percentage (%) loss of vitamin C	*P* value
		Mixture of vegetables	17.2%	NR
		Red cabbage	47.3%	NR
		French beans	n/a	NR
		Potatoes (October)	48.2%	NR
		Potatoes (March)	48.2%	NR
		Mashed		
		Beets	>50%	NR
		Carrots	14.3%	NR
		Green peas	22.8%	NR
		Broad beans	73.3%	NR
		Potatoes (October)	35.8%	NR
		Kale	3.3%	NR

NR, not reported.
*Cooking – exact method not always specified.

significant ($P < 0.05$) interaction for all four vegetables where ascorbic acid content decreased more rapidly during reheating process than in the hold room.

The largest loss of vitamin C during the reheating process was seen in the study completed by McErlain *et al.* (2001) which showed a 94% loss of vitamin C for boiled potatoes that were reheated for 45 min to a minimum temperature of 75 °C. In comparison, Koehler & Hard (1983) showed almost the opposite, with mashed potatoes only losing 3% of their vitamin C content.

Feldman *et al.* (2006) was the only study to report significant ($P < 0.05\%$) losses for total percentage loss of vitamin C levels from frozen peas (pre-processing) compared to service to patient (post processing) in two different hospitals which were studied. Konas *et al.* (2011) reported a general loss of 50–75% of vitamin C in both green beans and carrots that were either boiled or steamed and then hot held for 20 min. Konas *et al.* (2011) also reported that losses seem to stabilize after this 20 min period. Charlton *et al.* (2004) reported that the most significant losses of vitamin C occurred between the preparation and cooking stage in all four samples with an average loss of 58%. Jones *et al.* (1988) study reported limited results, however, did state that the vitamin C losses of samples taken from three hospitals after traditional cook-serve methods and being held in trolleys for 60–90 min were comparable with a 'cooking loss factor' of 75% for green vegetables and 50% for other vegetables.

Study quality

Table S1 describes study quality whereby four studies (57%) were rated as positive, suggesting a low risk of bias (Koehler & Hard, 1983; McErlain *et al.*, 2001; Charlton *et al.*, 2004; Feldman *et al.*, 2006). Three studies (43%) were described as neutral quality (Jones *et al.*, 1988; Löwik *et al.*, 1993; Konas *et al.*, 2011). Given the age of the research, methodological details were not always reproducible. For example, several included papers involved food prepared in hospital kitchens but did not provide explicit details regarding rethermalisation processes. Given the time delay since publication of many included studies, we did not attempt to contact authors to seek additional clarification. A consensus decision was made by authors to include these studies in the library. Studies conducted by Jones *et al.* (1988) and Feldman *et al.* (2006) involved the comparison of vitamin C content of cooked samples to a published national reference standard. Given the variation of micronutrient content, comparison to a vitamin C sample obtained pre-cooking would have yielded more accurate results.

Discussion

This is the first systematic review to critically examine studies which have measured the loss of vitamin C in foods exposed to different preparation, cooking, storing and reheating techniques in hospitals or care facilities. All studies showed that vitamin C is degraded through a range of processing techniques which is consistent with other literature on this topic. The different interventions reported in the seven studies included cooking (not specified), steaming, boiling, chilling, storing and heating or reheating. Every intervention contributed to some loss of vitamin C in food samples studied. Studies did not report exact measures of vitamin C at each stage of processing or did not describe all interventions in detail. It was therefore difficult to compare similar interventions across different studies.

There are numerous studies throughout the literature which have investigated the effect that different cooking procedures have on the vitamin C content of foods but not all are reflective of meals served to patients. It is important that studies are completed in settings such as hospitals or care facilities, as the individuals receiving

these meals are already at greater nutrition risk (Mueller *et al*., 2011). All of the seven studies included in this review measured vitamin C content of those foods prepared in either hospitals or nursing homes. The lack of high-quality studies highlights the difficulty in comparing results and makes drawing consistent conclusions regarding the loss of vitamin C in foods prepared in institutions (not under domestic conditions) difficult. However, as previously discussed, all studies did demonstrate that vitamin C losses occurred in all food samples, as a result of multiple interventions when levels were compared pre- and post-intervention or against the reference standard. The consistency of this result with other studies that have measured losses of vitamin C in food preparation procedures, highlights the vulnerability of this water-soluble vitamin.

Guidelines for the daily intake of the adult population (males and females) are 40 mg in the UK (British Nutrition Foundation, 2016) and 45 mg in Australia (NHMRC, 2006), however, recommended intakes for the healthy population vary considerably with the needs of hospitalised groups. In combination, supplementary arginine, vitamin C and zinc are known to improve the rate of pressure ulcer healing prevalent both in hospitals and care facilities (Desneves *et al*., 2005). Intake of this essential vitamin is rarely reported in hospitalised patients or aged care residents given the challenges in accurately calculating availability from computerised databases. One Australian study reported that vitamin C in the usual hospital diet was 110.7 ± 37.0 mg, increasing to 573.9 ± 13.7 mg when supplemented by high vitamin C oral nutrition support products. (Desneves *et al*., 2005). However, as we have shown in this review, the model of food production used in different hospitals and facilities will significantly impact on vitamin C intake of patients and residents. Utilising a cook chill food service system, where patients/residents choose readily from fresh fruit and salads, vegetables cooked on site complemented by other menu items, should meet vitamin C needs of individuals. Where a cook-chill or cook freeze model exists (with food stored and then rethermalised), combined with restrictions on fruits and salads associated with listeria risk, vitamin C status may be significantly jeopardised.

The findings of the scurvy risk in published reports are concerning both in studies of the public (Mosdøl *et al*., 2008) and populations with specific disease states (Christie-David & Gunton, 2017). This review, and the context of the review whereby cook-chill techniques have replaced cook-fresh models, raise serious implications for clinical practice in hospitals and aged care facilities. It is important that health care staff across the continuum from clinical directors, dietitians and foodservice managers consider the findings in the context of their organizations. A systematic review conducted by Sullivan & Schoelles (2013) reported that the incidence of pressures ulcers has increased by as much as 80% between 1995 and 2008 in the United States. Vitamin C supplementation has been shown to promote healing of pressure ulcers (Posthauer *et al*., 2015). Therefore, it may be expected that an insufficient intake of the vitamin may contribute to delay wound healing and also may be implicated in their formation. The signs of scurvy: fatigue, bruising and gingival bleeding (Hodges *et al*., 1971), are all preventable through hospital menus and systems that provide adequate vitamin C levels. This review has shown that food cooking methods contribute to the decline of vitamin C provided to patients. Future reports of nutritional analyses should be conducted of food prepared for consumption, not the fresh or cooked ingredients. Pre-admission intake should also be considered, particularly in patients who have, or are anticipated to require, extended admissions. Importantly, cooking methods should be considered in the menu development for patients in hospitals and residents of care facilities to ensure that intake of this essential vitamin meets their nutritional requirements. Where possible chilling and heating times, and food portion sizes during rethermalising, should be kept to a minimum.

A particular strength of this review was that no time restrictions were placed on the search strategy. In addition, the open search strategy supported by reference checking and a complementary internet search enhanced confidence that the entire relevant library was captured. Limitations include that languages were restricted to English. In addition, the limited volume of literature, and the limited statistical analyses that have been reported were identified as further limitations across the body of included evidence.

Our health network, reliant on a cook-chill foodservice model overlaid with listeria guidelines for high risk groups has moved to mandatory daily vitamin C supplementation of all patients with a length of stay of 30 days or greater. This process is managed by the long stay committee, ward medical teams, and within the four nursing homes to avoid any instances of vitamin C deficiency. The relatively small cost for this intervention was considered from a risk management perspective as a worthwhile ongoing investment.

Conclusions

It is difficult to conceive that in the present time of strict clinical governance and evidence based healthcare that the signs of scurvy, first documented centuries ago, continue to exist in our patients. Surveillance of scurvy risk and predictors for scurvy will facilitate identification of at risk patients in the general community. Ongoing monitoring of the vitamin C profile of the menu with vitamin supplementation where necessary will ensure that the nutritional needs of patients are met.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Flow diagram of the literature search.

Table S1. Quality assessment of included studies.