Microbiological hazards and melons

Report prepared for: Codex Committee on Food Hygiene Working Group on the development of an Annex on melons for the *Code of Hygienic Practice for Fresh Fruits and Vegetables* (CAC/RCP 53-2003) (June 2011)

Executive summary

This report was prepared in response to a request to FAO/WHO from the Codex Committee on Food Hygiene (CCFH). In undertaking new work on an Annex to the Code of Hygienic Practices for Fresh Fruit and Vegetables (CAC, 2003) for melons, CCFH requested a Call for Data and an evaluation of the pathogen-specific hazards associated with various types of melons, the role of various agricultural and manufacturing practices in enhancing or mitigating these hazards, and influences of marketing and consumer handling. The report includes a literature review of microbial safety and the melon supply chain and data received from the FAO/WHO call.

Melons are widely consumed in the human diet. There are many varieties of melons known by common names, the most popular ones being watermelon, cantaloupe (rockmelon) and honeydew. Melon consumption, production and international trade in melons have increased over the last decade. In addition, foodborne illness attributed to melons has become a significant public health concern in some countries with significant negative consequences for trade in this commodity.

Epidemiological evidence of foodborne illness linked with melons is based on outbreaks. Between 1950 and May 2011, 85 outbreaks were identified, mainly in North America. The most common aetiological agent reported was *Salmonella enterica* (47.1%) followed by Norovirus (22.4%), *Escherichia coli* O157:H7 (5.9%), *Campylobacter jejuni* (3.5%), *Shigella sonnei* (2.4%), *Listeria monocytogenes*, *Cyclospora* sp. and a suspected combination of *Staphylococcus aureus* and *Bacillus cereus*. The cases numbers per outbreak varied from 2 to 600 with actual case numbers likely ≥100 fold higher. Two deaths were recorded in 3 salmonellosis and a listeriosis outbreak.

The epidemiological data emphasised several points:

- Investigation of illness associated with melons is complicated by the variety in their culinary use, their distribution and availability of traceback information
- The nature of melons and their popular use in food service, pre-cut and in mixes with other foods renders them vulnerable to contamination from the rind to edible flesh, via food handlers and the preparation environment
- *S*. *enterica* is the most common aetiological agent and the netted varieties of cantaloupe either alone or mixed with other melons and other food in meal/dishes is the most common melon type in recorded outbreaks
- Cross-contamination, poor washing, infected food handlers and poor hygiene together with poor control of holding temperature contribute to outbreaks in particular
- Norovirus outbreaks result from preparation of melons by infected food handlers with poor hygiene while other pathogens appear to more often arise from the intact melons, contamination of the flesh during preparation and poor temperature management to control growth

Melons have specific characteristics that are important in their interaction with foodborne pathogens and managing food safety risks, namely:

- Melon rind topography influences the attachment and protection of microorganisms. Netted rinds, such as on cantaloupe, provide a waxy and highly hydrophobic surface matrix where microorganisms attach and can be protected from removal by washing and the effects of sanitizers.
- Foodborne bacterial pathogens have the potential to grow and /or survive on melon rinds and melon flesh. Growth is arrested at refrigeration temperatures with the exception of *Listeria monocytogenes*. Growth can occur rapidly at 20-30^{0}C, the exception being *Campylobacter* spp., viruses and parasites that can survive

- Microorganisms have been shown experimentally to infiltrate the root system of melon vines or the fruit. The former is considered transient and of lesser importance in the field while the latter can occur through a negative temperature differential during immersion in contaminated water, via wounds caused by physical damage or pests, splits, the ground spot and the stem scars.

Melons can be contaminated throughout the food chain in a similar manner to other fresh produce. As fresh melons may be contaminated from their source and there is no further process that will eliminate the hazards, it is necessary to minimise contamination at primary production and reduce or at least not increase risk through to the consumer. Important points at primary production include:

- Favourable conditions for the growth of melons are also favourable for the presence of wildlife and other pests that may forage in growing areas for the high sugar content fruits therefore pest management requires special attention
- Melon vines are grown along the ground mostly where the melons are directly or indirectly (irrigation water, heavy rain splashes) exposed to soil; Use of drip irrigation and assessing risks at harvest time (e.g. after rain) is required.
- Melons can be exposed to human contamination in the field particularly if they are turned by hand to minimise the ground spot and sunburn and when placed on cups or mats; personal hygiene and hygienic use of cups etc and tools is necessary
- After harvest further contact with soil should be avoided.

Following harvest melons can be field packed or sent to packing houses where they may be washed, sanitized, treated to extend shelf life and cooled before distribution. Processes should be designed to control factors such as water quality and temperature, duration of immersion, sanitizer efficacy, personal and equipment hygiene. Sanitising in general maintains the quality of the wash water rather than sanitizing the melons. Melon growing can be seasonal and facilities and equipment left vacant and unused in the off season should be thoroughly cleaned and disinfected before re-use.

There is strong epidemiological evidence that during preparation of melons for consumption there is a potential for increasing the risk of foodborne illness. Contamination at this operation point can be introduced from the melon rind, from food handlers, the preparation environment (cutting boards, knives) and cross-contamination with other melons or foods. Poor temperature control between contamination during preparation and consumption can amplify the risk for several bacterial pathogens. The following are important in processing or value adding:

- While the evidence is variable, washing, scrubbing and sanitizing whole melons before preparation will result in some decrease although not ensure elimination of pathogens. Similar results are found with melon pieces and additional reduction strategies are the use of edible coatings or essential oils
- It has been demonstrated experimentally that pathogens were transferred from the melon rind to the edible flesh during cutting and cutting after rind removal resulted in less contamination than cutting before rind removal
- Storage temperature of cut melons and the duration between cutting and consumption is critical to control growth of bacterial hazards on melon tissue.

Melons have become popular as healthy, fresh, convenient and delicious foods that are hugely diverse in their use in dishes that appeal to all age groups in all cultures. However, consumers frequently do not appreciate there is any risk for fruits with an inedible skin. Melons are low acid fruits and their soft texture makes them appealing for the young, elderly and infirm who have been shown epidemiologically to be at increased risk when their food is prepared in an institutional setting. Education in safe handling of melons is required through

chain. Specific characteristics for emphasis include washing, scrubbing and sanitizing before use, contamination during cutting and serving and the need for temperature and time control. Industry, retailers and food service suppliers of fresh-cut products need to provide clear instructions for end users of their products on safe storage, shelf life and handling of their products.

The available evidence suggests that there will be a low risk melons can be contaminated in the field and that through the food chain this risk should be decreased or at the least not increased.

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1.0 Background

In 2006 the Codex Alimentarius Commission (CAC) through the 38th session of the Codex Committee on Food Hygiene (CCFH) sought scientific advice to support the development of commodity-specific annexes for the Codex Alimentarius "Code of Hygienic Practices for Fresh Fruit and Vegetables" (CAC, 2003). As a result a priority list of fresh fruits and vegetables was developed and an Annex for the first priority group of leafy vegetables and herbs was developed (CAC, 2010). At its 42nd Session, the CCFH proposed to undertake new work to address the specific problems associated with the control of microbiological hazards on melons that was included within the second priority group of concern.

The CCFH therefore requested the FAO/WHO to issue a Call for Data and to evaluate the pathogen-specific hazards associated with various types of melons and the role of various agricultural and manufacturing practices in enhancing or mitigating these hazards. How these products are marketed and handled by consumers and the impact of this on foodborne disease should also be taken into consideration.

1.1 Scope

Melons include fleshy fruits of a vartiety of members of the plant family including gourds or cucurbits. The plants grow as vines and the flowers following pollenation produce berries that develop into the mature melons.

Melons belong to the Family *Curcubitaceae* with two genera of melons widely consumed in the human diet, *Citrullus* in which *C. lanatus* includes commonly known watermelons, and *Cucumis* in which *C. melo* includes many melon varieties some commonly known as muskmelons or by other common or varietal names. The watermelon differs in producing berries with a harder rind when compared with the other melons. There are more than 1,200 varieties of watermelon grown in many regions of the world and these can vary in shape and colour. Among the *C. melo* varieties there are also notable differences in the melon rind with the smooth skinned honeydew, crenshaw and casaba melons, the netted skinned cultivars such as cantaloupe, Santa Claus or Christmas melon and some partly netted varieties such as the Persian melon, Chinese Hami melons and Charentais. Different cultivars of melons had been crossbred to improve suitability for commercial production (e..g robustness for transport, disease resistance) and consumer appeal (e.g. seedless and sweeter cultivars). Common usage has resulted in some confusion with common names, for example, muskmelon and cantaloupe or cantaloupe and rockmelon being used synonymously.

This report addresses melons, watermelons, muskmelons and their varieties for human consumption that are consumed fresh and sold either whole or sliced or combined with other ingredients as fresh-cut products. It does not include melon seeds, juice and skin (e.g. used pickled or stir fried) that are also consumed in the human diet. The melon food chain is considered from primary production to retail and includes information on marketing and consumer handling where this impacts on foodborne disease.

1.2 International production and trade

FAOSTAT world statistics on agricultural commodities includes a category for watermelons and uses the term "other melons" collectively to include cantaloupe and other varieties for human food consumption (FAOSTAT, 2011). World production of all melons in both 2008 and 2009 was approximately 126 million tonnes (Table 1). Of the total production, 78% of the melons were watermelons in both years.

Table 1 World production of melons 2008 and 2009 (FAOSTAT, 2011)

Year	Production (tonnes)		Total
	other melons	watermelons	
2008	27,637,248	98,439,589	126,076,837
2009	27,726,563	100,687,056	128,413,619

China was the top world producer of melons in 2008 accounting for 52% of world production and producing 4.7 times more watermelons than other melons. Other top producers were responsible for a far less proportion of world supply of 6.4% and less each and included Turkey, the Islamic Republic of Iran, Spain and the USA. For the decade to 2009, the production of total melons approximately doubled by 2005 after which it steadied. The increase in other melons has been double that of watermelons.

Country rankings for production and trade in melons differed in 2008. For example China's production would appear to have been predominantly for domestic consumption. The key exporters in 2008 for watermelons were Mexico (23%) and Spain (17%) followed by the U.S.A. and Panama and for other melons were Spain (17%) followed by Brazil (10%) and the U.S.A. (10%). The top importers of melons were Northern American and European Union countries with the U.S.A. importing almost 19% world imported watermelons and 30% of the other melons.

The association of foodborne illness with melons can have a significant impact on production and trade. An example is the melon industry in Mexico between1999 and 2005 where after reports of illness in North America linked to cantaloupes imported from Mexico, cantaloupe exports declined by 92% and production declined by 24% (Avendano et al, 2009). These trade gaps are then readily filled by other countries and the original position may or may not ever be recovered.

2.0 Foodborne illness associated with melons

Information on foodborne illness was collected from submissions forwarded to JEMRA in response to a call for data, literature searches, peer reviewed publications and websites. A Table listing outbreaks and related epidemiological data is provided in the Annex. It is noted that it was not possible to confirm in outbreaks if the role of melons and the causative agent were confirmed by laboratory detection or suspected based on statistically significant epidemiological evidence or both. Where data was suspected this information is included in the table; however, for many outbreaks it cannot be assured these were all confirmed.

Fresh melon can be eaten alone; however, melons are frequently included in salads (e.g. dishes combining cut fruits, vegetables and meats etc with optional condiments), and are used as garnishes on other foods. They have become popular in buffets, salad bars and catered meals where multiple foods can be consumed by a few or a very large numbers of people at a common source at the same or over periods of time. The salad can be prepared in a central facility for distribution to multiple retail or food service outlets. Melons can be purchased individually and in bulk and a single whole fruit may be only partially consumed at one sitting. These factors can lead to widespread distribution of outbreak cases and can make epidemiological investigation and attribution of food difficult. To meet the increased consumer popularity of melons and to provide year round supply, melons are traded internationally particularly from countries with warmer climates suitable for production. This has led to difficulty in tracing back to the primary source of melons and in collecting relevant epidemiological data on the individual fruit(s) along the supply chain.

Between 1950 and May 2011, 85 outbreaks were identified. The outbreaks were reported by the U.S.A., Australia, Brazil, Canada, New Zealand, Singapore, Sweden and the United Kingdom. In four outbreaks, cases occurred in more than one country e.g. U.S.A. and Canada and were distributed in multiple states in these countries. In the CCFH call for data from member countries, 8/13 responding countries reported they had no data on the occurrence of foodborne illness linked with melons. The U.S.A. reported the most significant number of outbreaks attributed to melons. The U.S.A. Food and Drug Administration reported that between 1996-2008 in the U.S.A., 82 microbial foodborne disease outbreaks were linked with fresh produce of which 13 (15.9%) were attributed to melons (USDA, 2009).

The aetiological agent was recorded for 72 of the 85 outbreaks. *Salmonella enterica* serovars were most commonly reported (47.1%) followed by Norovirus (22.4%) and *Escherichia coli* O157:H7 (5.9%; Annex 1). Much less frequent were *Campylobacter jejuni* (3.5%) and *Shigella sonnei* (2.4%) outbreaks.

Listeria monocytogenes, *Cyclospora* sp. and a combination of *Staphylococcus aureus* and *Bacillus cereus* were suspected each in a single outbreak. The number of cases per outbreaks varied from 2 to 600 with estimations the actual number of cases in one outbreak could have been as much as 100 fold higher. The number of cases did not appear related to the aetiological agent specifically. Two deaths were recorded for each of 3 outbreaks of salmonellosis caused by serovars Miami, Chester and Poona, and 2 deaths were reported in an outbreak of listeriosis.

Eighteen *S. enterica* serovars were reported in the 40 outbreaks of salmonellosis linked with melons. Some, notably Javiana, Litchfield, Newport and Poona, were linked with 5 outbreaks each and Oranienberg with 4 outbreaks.

Table 2 Serovars of *Salmonella enterica* recorded for 40 outbreaks of salmonellosis linked with melons and meals/dishes containing melon between 1950 – May 2011.

Serovar	Number of outbreaks	Serovar	Number of outbreaks
Anatum	1	Muenchen	1
Bareily	1	Newport	5
Berta	1	Oranienberg	4
Carrau	1	Panama	1
Chester	1	Poona	5
Enteritidis	2	Saintpaul	1
Heidelberg	1	Saphra	1
Javiana	5	Typhimurium	1
Litchfield	5	Weltevreden	1
Miami	1	no serotype	1

Some of these serovars were uncommon in human illness databases at the time of the outbreak. For example, serovar Poona causing several outbreaks in the U.S.A. was rare among humans at the time and known to be associated with contact with reptiles (MMWR. 2002; MMWR, 1999). This observation subsequently led to the hypothesis that contamination occurring during production could have been a result of wildlife activity.

Cantaloupe also referred to as muskmelon and rockmelon, honeydew melon and watermelon were the common melons specified as the food vehicle in outbreaks. In about 6% outbreaks, the type of melon was not specified. Cantaloupe either alone (24.7%) or included with other foods (including other melon types) in a meal/dish (29.4%) was most commonly implicated

(Table 3). Watermelon was the next most common melon (16.5%) although it was not so commonly reported in combination with other foods (4/14 outbreaks) other than when combined with other melons (10/14 outbreaks). In comparison, honeydew alone was linked to only 2 (2.4%) outbreaks. In 16 (18.8%) outbreaks meals/dishes contained honeydew although in 14 of these other melons were present also. In 5 (5.9%) outbreaks the type of melon was not specified and in 9 (10.6%) outbreaks combinations of melon types were included among the suspect food vehicles and were not identified specifically.

This information supports the experimental observations described in Section 4 that the netted varieties of melons such as cantaloupe present a greater risk of pathogen transmission.

Table 3 Food vehicles associated with 85 foodborne illness outbreaks occurring between 1950 – May, 2011, where melons were implicated

Food vehicles including melons	Number of outbreaks (%)
cantaloupe	21 (24.7)
honeydew	2 (2.4)
watermelon	14 (16.5)
melons (not specified)	5 (5.9)
meal/dish[a] including cantaloupe	25 (29.4)
meal/dish including honeydew	16 (18.8)
meal/dish including watermelon	14 (16.5)
meal/dish including melons (not specified)	9 (10.6)

[a] meal or dish can include other melons as well as other foods

In 10 outbreaks the melons were reported to have been imported of which 8 were linked with cantaloupe and one with watermelon. The data gathered on the outbreaks were in many cases brief and it was not possible to draw overall conclusion on associations with seasonal effects. However, Bowen et al (2006) in an extensive review of 23 cantaloupe associated outbreaks in the U.S.A. between 1984 and 2002 found outbreaks occurred in each calendar month although salmonellosis outbreaks occurred more frequently in December to June with a peak in May and Norovirus outbreaks occurred in June, September and December (Bowen et al, 2006).

The outbreak setting was recorded for 58 outbreaks. Food service type facilities such as restaurants, conference venues and a camp constituted 25 (43%) of these. Other community based settings included homes (26%), churches, temples, picnics, schools and a day care centre (17%) and hospital and care facilities (15.5%). The attributed food was widely distributed in 13 (22.4%) of outbreaks resulting in multiple outbreak settings being involved.

Food service and catering establishments were the most common places where melons were prepared for consumption, accounting for 60.4% and 15.1% respectively of the 53 outbreaks where this information was provided. Bowen et al (2006) had a similar finding for 28 cantaloupe-related outbreaks in the U.S.A. where 61% and 14% for these facilities were identified respectively. Grocery stores, supermarkets and a food stall (17% of 53) were also important while homes (3.8% of 53) and both a processor and a distributor were identified.

Pre-cutting of melons or inclusion of melons in a fruit or other type of salad or buffet type dish where they would have been sliced or chopped makes these foods particularly vulnerable to contamination during preparation. Pre-cutting or mixing was noted specifically in 12 (14.1%) outbreaks (Table 4). This process would have allowed the opportunity for transfer of contamination from the rind to the edible flesh or contamination by infected food handlers and the preparation environment. In 4 salmonellosis outbreaks it was noted the melons were

unwashed or poorly washed, including one attributed to watermelon and 3 to cantaloupe. In one outbreak of salmonellosis attributed to watermelon use of contaminated wash water was found (Ooi et al 1997).

Table 4 Contributing factors, where identified, among 85 outbreaks of foodborne illness associated with melons between 1950 - May 2011

Contributing factor	Number of outbreaks (%)
Pre-harvest/transport contamination	3 (3.5)
Unwashed melons	4 (4.7)
Pre-cut and/or mixed dish	12 (14.1)
Infected food handler	10 (11.8)
Poor hygiene, bare hands	8 (9.4)
Cross-contamination	2 (2.4)
Poor temperature control	13 (15.3)

Infected food handlers were listed as a contributing factor for 10 (11.8%) outbreaks (Table 4). Eight of these were caused by Norovirus. In one salmonellosis outbreak an infected food handlers was identified and for a 2 further outbreaks bare hand contact with food was noted. Gloved hands were also noted in 2 Norovirus outbreaks in food service settings that emphasises that even when gloves are used it must be in a hygienic manner. Two of the outbreaks caused by *E. coli* O157:H7 were likely caused by cross-contamination with red meat during preparation or storage. Poor hygiene during preparation was recorded in 6 outbreaks caused by several of the pathogens.

Poor temperature control (15.3% outbreaks) that would have provided the opportunity for bacterial growth, included both holding at ambient temperature (7 outbreaks) and poor cold storage (3). These were identified as contributory factors for the *S. aureus*/*B.cereus* (suspected), an *E. coli* O157:H7 and *S. enterica* outbreaks.

The epidemiological data emphasises several points:

- Investigation of illness associated with melons is complicated by the variety in their culinary use, distribution and traceback
- The nature of melons and their popular use in food service pre-cut and in mixes with other foods renders them vulnerable to contamination from the rind, food handlers and the preparation environment
- *S. enterica* is the most common aetiological agent and the netted varieties of cantaloupe either alone or mixed with other melon and other food in meal/dishes is the most common melon type in recorded outbreaks
- Cross contamination, poor washing, infected food handlers and poor hygiene together with poor control of holding temperature contribute to outbreaks in particular
- Norovirus outbreaks resulted from preparation of melons by infected food handlers with poor hygiene while other pathogens appear to more often arise from the intact melons, contamination of the flesh during preparation and poor temperature management to control growth.

3.0 Melon cultivation

Melons grow optimally in warm to hot, sunny locations with fertile, well drained soils. They grow on vines along the ground in a trailing and scrambling manner. If plants are trained over a trellis the fruits require support as they enlarge to avoid damage to the plant. Warm and, in non arid regions, humid conditions, favourable for melon growing can also be favourable for the survival and growth of human pathogens, and the presence of wildlife and pests. Melons

are susceptible to a wide range of insect pests and microbial diseases. Soil amendments and agricultural chemicals may be used in conventional primary production and the former in organic systems.

As melon vines grow horizontally when the fruit enlarges and increases in weight it rests on the ground. Melons will be exposed to soil contamination directly or via water splashing such as during heavy rain, spray irrigation or flooding. Plastic mulch if often used to cover the ground to provide various production advantages for growers by increasing the quality and quantity of fruit yields and decreasing the growing time compared with growth on bare ground. Where plastic mulch is used, this will also reduce direct soil exposure. The term "ground spot" is used to describe the particular area on the rind where the melon sits in contact with the ground or mulch. This area is thin and underdeveloped in melons and more susceptible to fungal and bacterial growth (Castillo et al, 2009). Muskmelons can be placed on plastic cups to raise them away from direct soil contact and melons can be turned during growth to limit the occurrence of the ground spot and sunburn as these cause discolorations of the rind.

Determining the maturity of melons varies among the varieties and may include any of visual or sensory indicators and sugar content. When cantaloupes are ripe the stem pulls away easily from the fruit with the formation of an abscission zone or "slips" from the vine leaving a dish-shaped scar. Industry uses terms to describe the stage of maturity and slip development e.g. "half slip" or "¾ slip". Melons such as honeydew do not slip from the vine and ripeness is indicated by softness at the flower end of the fruit. Watermelons have a small curled tendril on the end that becomes brown and dies when the fruit is ripe and in addition the ground spot changes colour and the skin changes hue. In deciding when to harvest the time between harvest and consumption is critical, for example, cantaloupes may be harvested between ¾ and full slip and watermelons destined for distant markets are harvested when mature but not fully ripe to counter against handling damage and loss of quality attributes (Boyhan et al, 2000).

Melons vary in storage life after harvest and can be only a few weeks for some cantaloupe varieties in uncontrolled storage conditions (Krarup et al, 2009). Soon after harvest it is necessary to remove the "field" heat and to control temperature and relative humidity until reaching markets or the quality begins to deteriorate and the shelf life is reduced. Melons can be susceptible to chilling injury for more than short periods at very low temperatures. Melons are cooled using cold water, cold air, or ice and cooling methods vary with the melon types and available facilities.

4.0 Melons and association with microbial foodborne pathogens

Melons can become contaminated with foodborne pathogens at any point along the food chain in a similar manner to other fresh fruit and vegetables (FAO/WHO MRA 14). In addition, there are specific characteristics of melons that influence the risk of pathogen contamination and the potential for growth and survival of pathogens that are important considerations in assessing and managing food safety risks.

4.1 Melon structure

The melon rind protects the internal flesh eaten as fresh product in human diets. Melons are marketed either whole with the rind intact, portioned with the rind intact or with the rind removed and flesh sliced or chopped into pieces. The structure of melon rind differs among the species and varieties and is loosely divided into 2 groups based on the rind topography. Watermelons and some other melons have a smooth surface while others have a rough,

corrugated surface referred to as “netted” (Gerchikov et al, 2008). The net is a network of suberized periderm tissue formed in response to natural cracking of the fruit surface during its enlargement. The degree of netting can vary among netted varieties.

In studies of the efficacy of washing melons it was observed that the rough netted skinned cantaloupe retained inoculated *S. enterica* serovars to a greater extent than smooth skinned honeydew (Castillo et al, 2009; Parnell et al, 2005). The netted melon surface is waxy and highly hydrophobic and has been associated with enhanced attachment and resistance to detachment of *Salmonella* (Ukuku and Fett, 2006). The strength of attachment of bacterial pathogens such as *Salmonella*, *E. coli* (O157:H7 and non-O157:H7), and *L. monocytogenes* on cantaloupe rinds involves a linear correlation between bacterial cell surface hydrophobicity, negative charge and positive charge (Ukuku and Fett, 2002). Further, the concentration of competing natural bacterial flora plays a role as an increase in attachment of *Salmonella* (Ukuku, 2006) and *L. monocytogenes* and a slower decline in *L. monocytogenes* was observed on inoculated cantaloupe rind following sanitization (Ukuku et al, 2004).

4.2 Melons and microbial growth and survival

4.2.1 Whole melons and rind

Pathogens are able to survive and grow on melon rind and flesh. Del Rosario and Beuchat (1995) inoculated *E. coli* O157:H7 on watermelon and cantaloupe rinds and found after storage at 5^0C significant population decreases occurred up to 4d then a slower decline until 8-14d (Del Rosario and Beuchat, 1995). When the inoculated rind was held at 25^0C growth was observed, more on cantaloupe than watermelon, increasing in the first 4d and then remaining constant for a further 14-21d. However, the authors noted that the nutrients in the suspending medium for the inocula together with high humidity may have influenced the result. They also note this may equate to a scenario with faecal contamination. Beuchat and Scouten, (2004) reported *S*. Poona inoculated onto intact cantaloupe rind, wounds and stem scars, survived unchanged when held between 2h and 24h at 4^0C and grew in wound scars within 24h when held at 21^0C and 37^0C.

Annous et al (2004) reported similar behaviour of *S*. Poona inoculated on cantaloupe rinds where at 4^0C, more than a 1log cfu/cm^2 decrease occurred by 72h. At 20^0C about 2log cfu/cm^2 increases occurred in the first 24h and the population stabilizing during a further 48h (Annous et al, 2005a). They suspended their inoculum in water and therefore considered added nutrients were not essential for growth. In the same inoculation experiments, a generic *E. coli* strain did not grow at 20^0C suggesting *E. coli* may not be a suitable surrogate for the presence of *Salmonella*. Behrsing et al (2003) found *S*. Salford and *E. coli* inoculated on whole cantaloupe (7^0C for 7d) and honeydew melons (12^0C for 1d then 8^0C for 7d) survived with no growth. In contrast, *L. innocua* increased about 2log cfu/mL after 7d at 8^0C (Behrsing et al, 2003) although growth was arrested by refrigeration below 4^0C.

In experimental studies washing melons when inocula of *S. enterica* were dried on the rinds for 1 h at ambient temperature (14^oC) a log greater reduction was observed on honeydew compared with cantaloupe rind (Parnell et al, 2005). Annous et al (2005b) demonstrated evidence of fibrillar material formed by *S*. Poona inoculated on cantaloupe rind after holding at 2h and biofilm formation by 24h at 20^0C and at 10^0C (Annous et al, 2005b). The meshwork of the netted rind observed by scanning electron microscopy revealed a large number of attachment sites, crevices and pits that could protect inoculated microorganisms (Annous et al, 2005b; Parnell et al, 2005).

4.2.2. Flesh and pulp

Bacterial pathogens are able to survive and grow in the low acid environment of melon flesh or pulp. Fredlund et al (1987) in the 1980's demonstrated the ability of *S. sonnei* to grow rapidly when injected into watermelon reaching 8.0 – 9.0 log cfu/g in 3d at 20 or 30^0C (cited by Castillo et al, 2009). Most studies have been based on *S. enterica* serovars inoculated on fresh-cut cantaloupe, honeydew and watermelon and in general the inocula survived at 4 or 5^0C, growth was retarded at 10^0C and from about 20^0C inocula could reach hazardous levels in 4-6h and up to 7days depending on the initial contamination level (Ukuku and Sapers, 2001; Golden et al, 1993; Escartin et al, 1989). *E. coli* O157:H7 behaved similarly when inoculated on cantaloupe and watermelon cubes (Del Rosario and Beuchat, 1995). High levels can be attained before spoilage is apparent.

Following inoculation of muskmelon (av. pH 5.87) and watermelon pulp (av. pH 5.50), *S*. Enteritidis populations increased at 10, 20 and 30^0C on muskmelons with generation times of 7.31, 1.69, 0.69h respectively and on watermelon with generations times of 7.47, 1.60, 0.51h respectively (Penteado and Leitão, 2004a). Suspensions of *S.* Typhi inoculated onto watermelon suspended in water and held at 22^0C were reported by Escartin et al (1989) to have a similar generation time of 1.3 (cited by (Penteado and Leitão, 2004a).

Differing from the Enterobacteriaceae is *C. jejuni* that has been shown to survive although not grow on watermelon stored at 25-29^0C for 6h (Castillo and Escartin, 1994). In contrast, psychrophilic *L. monocytogenes* inoculated on honeydew (pH 5.8) increased 4.6 logs at 10^0C after 7 days (Leverentz et al, 2003). Generation times of 7.12, 1.74 and 0.84h and lag times of 24, 6,and 4h have been reported when 2 log cfu/g *L. monocytogenes* was inoculated in melon (*C*. *melo* var Valenciano amarelo) pulp and held at 10, 20 and 30^0C respectively (Penteado and Leitão, 2004b). The same authors reported generation times in watermelon pulp were 13.03, 2.17 and 1.0h and lag times of 24, 28 and 4h at 10, 20 and 30^0C respectively. The average pH of the melon and watermelon pulps was 5.87 and 5.50.

Relative humidity has an additional impact on microbial survival at a particular temperature. When inoculated pieces of produce were held at 18-26^0C in a controlled environmental chamber with low (mean 45.1 – 48.4%) and high (mean 85.7 – 90.3%) relative humidity microbial survival was significantly greater on edible melon pieces than lettuce and bell peppers (Stine et al, 2005). Among the inoculated organisms, *E. coli* and feline calicivirus had the highest and HAV, coliphage and *Clostridium perfringens* had the lowest inactivation rates on edible melon flesh.

4.3 Infiltration of microorganisms into melons

The ability of microorganisms to infiltrate the integument of fresh fruits and vegetables has become of increasing interest as internalisation of the organisms has the potential to offer a medium for amplification or survival and protection from removal by washing and from exposure to sanitizers (Delaquis & Austin, 2007). Infiltration is referred here to lodgement of the microorganisms within the subsurface tissues or further internalisation into the flesh.

Suslow et al (2010) studied the feasibility of the uptake of inoculated *Salmonella* via the root system of cantaloupe and honeydew vines and contamination of the fruit under experimental conditions with extraordinary inocula concentrations (≥7log cfu) not expected in natural field conditions (Suslow et al 2010). Systemic dose dependent uptake by vines was demonstrated in the greenhouse; however, no transfer to fruit was observed, and the internalised *Salmonella* died off over 2 weeks. Uptake was variable with cultivar and growth conditions and the researchers could not rule out the possibility of cells entering a viable but non-culturable state. Under field conditions internalisation was not demonstrated in vines or fruit although under the extraordinary levels of experimental contamination of soil, contamination

of fruit occurred. Similar transient uptake following exposure to extraordinary numbers of *E. coli* O157 was observed (Suslow et al, 2008).

Direct entry points for fruit include wounds caused by physical damage or pests, splits and fissures and the stem scar. Infection of cantaloupe with phytopathogens on the rind surface and wound sites has been shown to enhance the survival and internal migration of *S*. Poona (Richards and Beuchat, 2005a). The phytopathogens effectively raised the pH of the tissues with the distance from the rind surface and *S.* Poona populations per sample increased up to 4logs during storage at 20^0C over 14d (Richards and Beuchat, 2005b). In a small survey of market cantaloupe, those with soft rot (87% of 8 samples) were found to be *Salmonella* positive more often compared with healthy cantaloupes (47% of 17; Wells and Butterfield, 1997).

Infiltration of pathogens into whole fruit can be enhanced as a result of a negative temperature differential for example where the temperature of the fruit is higher than the temperature of the pathogen contaminated water in which it is immersed. Infiltration of dye into cantaloupes during hydrocooling and of *S.* Typhimurium into cantaloupes during post-harvest processing has been demonstrated (Castillo et al, 2009). Infiltration of *S.* Typhimurium up to 5mm under the rind has been demonstrated primarily through the ground spot where the netting is underdeveloped, and, secondarily, through the stem scar (Suslow, 2004 cited by Castillo et al, 2009). However, Richards and Beuchat, (2004) found conflicting results with temperature dependent infiltration with experimentally inoculated cantaloupes with varying density of netting and concluded the effect of temperature alone was obscured by the complexity of the netting and bacterial interactions (Richards and Beuchat, 2004).

While studying approaches to disinfection of melon pieces, Perni et al (2008) found *E. coli* were able to migrate through melon tissue with an estimated velocity of around 300µm /min.

5.0 Melon production chain and risks of contamination with foodborne pathogens

The main operational units in the melon supply chain are as follows:

1. Production and harvest operations
2. Post-harvest operations
3. Fresh-cut/value added processing
4. Distribution/ transport
5. Consumer/retail/food service

These units are discussed with regard to microbial food safety risks and their control specific to melons. The Risk Assessment Series Report, MRA14, (FAO/WHO, 2008) on microbial hazards in fresh leafy vegetables and herbs should also be consulted as it contains both specific information on that commodity as well as information generally applicable to all fresh produce on each of these topics.

5. 1 Production and harvest operations

Several authors have reviewed the potential sources of pathogen contamination and preventive approaches to their control pre-harvest for fresh produce in general (Doyle and Erickson, 2011; FAO/WHO, 2008) and specifically for melons (Castillo et al, 2009, Bowen et al, 2006). The most important inputs in the production environment for fresh produce include wildlife, livestock, human activity and wastes, water, soil and soil amendments, seeds, plant stocks and equipment (FAO/WHO, 2008). Application of Good Agricultural Practices (GAPs) is appropriate for control in this sector and should be considered together with specific

guidance for melons. The draft Annex for melons in principle follows closely the Annex for Leafy Vegetables and Herbs (CAC, 2010) for which the FAO/WHO (2008) MRA series 14 provides the scientific evidence. Specific risk factors, available evidence and mitigations for melons are provided.

5.1 Growing site

- Environmental conditions favourable for melon cultivation are favourable for a variety of wildlife and insect pests and favourable also for the survival and possible growth of microbial pathogens. Melons and associated field waste are attractants to wildlife as a ready source of food (Castillo et al, 2009).
- In an investigation of melon growing sites wildlife has been found to carry *S. enterica* and nearby river water has been shown to have positive bacterial faecal indicators and to be contaminated with *S. enterica* serovars (Aguillar et al, 2005; Gagliardi, et al, 2003). An assessment of the risks associated with the growing site location should be undertaken with particular attention given to flooding (particularly in high rainfall areas) and run off from high risk sites, to evidence of wildlife and insect pest presence, and to the proximity to wildlife and pest reservoirs. Re-location or measures to eliminate or reduce the risk may be required (FAO/WHO, 2008).
- Growing areas should be protected and maintained to avoid attraction of wildlife and pests for example water puddles and waste accumulation. Pathogens could survive and grow in waste from prior or current harvests or vine maintenance. In melon growing environments *S. enterica* serovars have been detected in reptiles such as iguanas that were attracted to and fed on the melons and at the same time defecate in the vicinity (Aguillar et al, 2005). This pathogen has also been detected in water puddled in furrows (Gagliardi et al, 2003).
- Monitoring for the presence of wildlife, pests and domestic animal intrusion should be undertaken regularly and at harvest and reported by field staff. If detected, decisions are required on whether to harvest melons from affected areas (FAO/WHO, 2008).

5.2 Soil and soil amendments

- Pathogens such as *S. enterica* have been detected in soil in melon growing fields where the distribution can vary widely (Espinoza-Medina et al, 2006; Gallegos-Robles et al, 2009).
- The unique characteristic of melon rind and the netted surface of some varieties give them a special ability to attach microorganisms and subsequently protect them from removal as described in section 4.2. Pathogen infiltration is possible especially at the ground spot and wounds or abrasions to the rind, and fruit nearing and at maturity can support pathogen growth and/or survival (Section 4.3). Pathogen uptake via roots appears feasible although considered an unlikely and transient event (Suslow, 2010). However, if contaminated faecal material is deposited randomly with a high pathogen load this could lead to a sporadic contamination event.
- Foodborne pathogens can survive in soil e.g. *L. monocytogenes*, *S. enterica* and *E. coli* O157, and viruses for up to 8, 23 and 3 weeks respectively (Bowen et al, 2006). Pathogens can be introduced in soil amendments and their presence can be facilitated by insects and soil creatures such as nematodes.
- Melon vines are often grown on plastic mulch or the fruit on plastic pads or cups to reduce soil contact and ground spots. At the same time this reduces direct exposure to soil contaminants. These devices must be maintained in a sanitary manner if used.
- Use of an appropriate irrigation system such as furrow or drip can minimise soil contamination and irrigation water and melons is discussed further below (FAO/WHO, 2008).

- Suslow et al (2010) demonstrated in field studies with soils experimentally inoculated with exceptional large inocula via furrows that fruit could be surface contaminated after a significant rain event. Following heavy rain the risk should be assessed before deciding on harvest time, and on the operating condition required for washing in the presence of an increased soil load.

5.3 Water and irrigation

- Irrigation water can be a vehicle for exposure of vines, fruit or root systems to pathogens. Suslow et al, (2010) inoculated large numbers of *S*. *enterica* into soil via furrow and drip irrigation systems during cultivation of cantaloupes and found while the inocula could be detected for the duration of the growing season in soil the inoculated bacterium could not be detected in the vines or fruit at harvest. Rind surface of furrow irrigated fruit was contaminated during heavy rain only.
- Evidence is available that irrigation water for melons can be contaminated with faecal indicator bacteria and *S. enterica* at both the source and in holding ponds (Aguillar et al, 2005; Castillo et al, 2004; Gagliardi, et al, 2003). Surface waters, poorly maintained wells and irrigation canals were shown to be contaminated.
- Duffy et al (2005) detected *E. coli* in 39.4% of 179 irrigation water sources for cantaloupe, parsley and oranges with a mean count of 0.4 log cfu/ml. Well water was most frequently positive (10/10) followed by waters from reservoir (15/30), and riverine (9/30) sources. The well and reservoir waters had the highest *E. coli* counts of 0.7±0.3 and 1.0 ± 0.7 log cfu/ml. Cement irrigation canals were significantly less contaminated than dirt canals.
- Castillo et al (2004) similarly detected *S*. *enterica* and *E. coli,* 15% and 16% respectively, in irrigation water sources on 6 cantaloupe farms. A farm using water from an irrigation canal accounted for most of the positives compared with the others using well or pond water. Farms drawing water from the same primary riverine source were similarly contaminated. Filtering was effective in reducing the number of *E. coli* positives in water at some farms although the method was not described.
- Ground water (1/11), irrigation water (4/17), soil (2/24) and in-field cantaloupes (9/35) were positive for *S. enterica* using enrichment culture and the Polymerase Chain Reaction (PCR) in investigation of 5 commercial farms in Mexico in 2003-4 (Espinoza-Medina et al, 2006)
- In the study of Duffy et al (2005) *S*. *enterica* was detected in 16 irrigation water samples, the frequency of source being reservoir, dirt canals, furrow, cement canals and no positive well or riverine irrigation waters.
- Interestingly the *S. enterica* serovars detected in irrigation water and those on melons at the same farm can be different as can the serovars in washing water (Duffy et al, 2005; Castillo et al, 2004). This raises questions of the contamination source pre- and post-harvest and whether methodological insensitivities due to low prevalence and concentration may limit investigations.

5.4 Human activity

Where field workers turn melons attached on the vine as it matures to avoid ground spots developing and sunburn an opportunity arises for introduction of pathogens in conditions of poor hygiene.

- Field workers hands have been shown to be contaminated with *E. coli* (Castillo et al, 2004). In a survey of a small number of field staff working in a field with contaminated soil and cantaloupes no evidence of *Salmonella* was found in 24 hand samples (Espinoza-Medina, 2006).

- Gloves may be used; however, the use of wool or cotton gloves have been shown to be a source of contamination and a program for maintaining hygiene is required where they are used (Castillo et al, 2009).
- Care should be taken at harvest, whether manual or mechanical, to avoid environmental contamination or damage to melons that would introduce pathogens and increase the risk of microbial infiltration, survival or growth (See Section 4.2).

5.5 Harvest

- At melon harvest an stem scar or any unintentional damage to the rind during handling can allow invasion and proliferation of pathogens (See section 4.2). Melons such as watermelons at maturity can be heavy and cumbersome to manually handle. Careful handling is required to minimise contamination by handlers, water, soil and other environmental sources.

6.0 Post-harvest

Post-harvest practices vary between regions and countries and with the type of melon. Watermelons are generally packed and sent to market without pre-cooling although cool ambient storage temperatures are preferred. Others such as cantaloupe and honeydew varieties, depending on the stage of maturity, are cooled soon after harvest. Further storage conditions of temperature and relative humidity can depend on the maturity and ripening method and are optimised to maintain quality and prolong shelf life. Melons can be either packed in the field or transferred to a designated packing facility where cooling, rinsing, and washing and sanitizing can take place (Castillo et al, 2009).

6.1 Packing facilities

- Wildlife such as rodents, reptiles and birds frequent these facilities which may be of a temporary open-air design and intermittently used where production is seasonal. Damaged melons and waste are attractants for pests and can also be a reservoir where bacterial pathogens can grow (Duffy, 2005; Castillo et al, 2004). This emphasises the need for hygiene maintenance, pest control and a program with Standard Operating Procedures (SOPs) established. The fittings and environment of cantaloupe packing facilities have been found to be contaminated by *S. enterica*. These include walls and floors of cooling rooms (Castillo et al, 2004) and surfaces to which washed melons are exposed (Duffy et al, 2005) *E. coli* had been detected on surfaces such as boxing ramps, conveyor belts, plastic bags and bins used for harvesting, receiving hopper, transport trailer and an unloading ramp (Duffy et al, 2005).
- Fruit should be culled to remove those with damage or fungal rot and handled to prevent further damage due to the risk of microbial infiltration and growth (See section 4.2).
- Workers are a potential source of contamination. The hands of 3/60 field and packing plant workers surveyed on cantaloupe farms were contaminated with *E. coli* although salmonellas were not detected (Castillo et al, 2004). In another small study neither *E. coli* nor *S. enterica* as detected on hands or gloves of 10 workers (Duffy et al, 2005). Espinoza-Medina et al, (2006) detected *Salmonella* using the PCR on the hands of 4/24 packing house workers handling melons also found to be contaminated (7/34)
- Poorly controlled hydrocooler water was observed to have significant levels of faecal indicators and to contaminate cantaloupe rinds with up to 3.4 log cfu/g (Gagliardi et al, 2003). The process may result in infiltration of microorganisms (See section 4.3).

6.2 Washing and sanitising

As the rind of whole melon, in particular in netted varieties, is identified as a major source of the most common bacterial pathogens in outbreaks, considerable effort has been applied to reduce the risk at this point in the supply chain. Washing removes loose soil and can improve visible cleanliness; however, it can provide a mechanism for both the spread (Parnell et al, 2005) and introduction of pathogen contamination (Bowen et al, 2006). The need for washing varies with the farm location; for example, in more arid regions fruit is field packed while in humid areas washing and fungicide application that helps control plant pathogens is practiced (Gagliardi et al, 2003).

- In several studies it has been found pathogens (*S. enterica*) were introduced and the bacterial load of aerobic bacteria (Akins et al, 2008), *E. coli (*Duffy et al, 2005; Castillo et al, 2004), faecal coliforms and faecal enterococci (Gagliardi et al, 2003) on cantaloupe melons was increased between pre- and post- harvest. Whether processing released bacteria from the netted rinds and the extent of introduction of contamination or both were involved is not clear (Duffy et al, 2005).
- Water is used in abundance and can be a source of microorganisms if not treated to approximate potable quality. Contamination of source water has been mentioned above. Gagliardi et al (2003) found much of the contamination during cantaloupe processing could be traced to primary wash tanks and hydrocoolers.
- Cross-contamination between melons is a high risk when melons are co-mingled in dump tanks. Factors such as high biological load, turbulent flow, temperature and pH can impact on the concentration and efficacy of residual sanitizers and have to be monitored and controlled (Gagliardi, 2003). Washing melons in water in the absence of a sanitizer has been demonstrated experimentally to spread contamination in wash tanks (Parnell et al, 2005). This has resulted in some risk managers choosing to eliminate use of dump tanks in certification conditions (Alvarado-Casillas, 2010).
- Control of the temperature differential between wash water and melons is important to avoid risks of infiltration of pathogens into melons and has been discussed in the section 4.3.
- Experimentally sanitized and inoculated cantaloupe rind has been shown to retain higher populations of *Salmonella* (Ukuku, 2006) and *L. monocytogenes* (Ukuku et al, 2004) than untreated controls and the more netted melon varieties retain larger concentrations. Therefore once sanitization has reduced microbial populations, there is an increased risk of contamination of melon rinds emphasising the importance of maintaining the cleanliness and hygiene all contact surfaces post-sanitization.
- Soaking cantaloupe and honeydew inoculated with *S. enterica* in water for 60 sec resulted in 0.7 and 2.8 log decreases in the inocula respectively (Parnell et al, 2005). The greater amount of organic matter associated with netted rinds is believed to interfere with sanitizers (Parnel et al, 2005) and experiential use of a surfactant with sanitizers significantly increased washing efficiency (Bastos et al, 2005).
- There have been numerous studies of the use of sanitizers and alternate approaches to decontaminating melons. It is generally agreed that sanitizers control microbial populations in the wash water rather than on the melons (Castillo et al, 2009; FAO/WHO, 2008). Sanitizers have some effect and add to the through chain risk reduction although cannot be relied on to eliminate pathogens and are least effective for the netted varieties. High risk of re-contamination after washing and sanitizing has been mentioned.
- Mechanical removal of pathogens with scrubbing has been experimentally evaluated for both industrial and domestic use (Parnell et al, 1005). Scrubbing is more effective than soaking alone and scrubbing for 60 sec reduces the bacterial load. However, unless a sanitizer is added to wash water spread to other melons and sites on a melon will occur. Washing and scrubbing has been recommended for domestic households by authorities (Parnell et al, 2005). For industrial use water disinfection

and sanitary maintenance of brushes and equipment is also essential to prevent cross-contamination.

- Approaches to decontaminating whole fruit include using chemical agents in wash water, gaseous ozone, non-chemical (heat, irradiation, cold atmospheric plasma), bacteriocins, biocontrol using bacteriophages and lactic acid bacteria, and new approaches continue to evolve (Bowen et al, 2005; Castillo et al, 2009). In modified atmosphere cold storage of cantaloupes *S. enterica* growth was inhibited (Salgado et al, 2009); however, *L. monocytogenes* would need to be considered. The combination of agents can have an additive hurdle effect and increase efficacy; however, these have to be assessed considering economical and practical factors. The efficacy will depend on the bacterial load of the incoming melons, melon type and the facility and validation of any process will be necessary.
- The time between whole fruit decontamination and processing for fresh-cut products has been shown to be important. Sanitizing cantaloupe reduced transfer of *S. enterica* to cut pieces; however, if the melons were sanitized then stored for several days at 4 or 20^0C transfer of *S. enterica* was observed (Ukuku and Sapers, 2002). This has implication for process scheduling in the fresh-cut industry and requires further assessment (Castillo et al 2009).

6.3 Processing

There is strong epidemiological evidence that during preparation of melons for consumption there is a potential for increasing the risk of foodborne illness (Section 2.0). There are no further risk reduction steps as these products receive no further microbiocidal treatment before consumption. This supports the rationale for managing the risk through chain and preventing contamination at production to the greatest extent possible.

Contamination at this operation point can be introduced from the melon rind, from food handlers, the preparation environment (cutting boards, knives) and cross-contamination with other melons or foods. Poor temperature control between contamination during preparation and consumption can amplify the risk for several bacterial pathogens. Some important evidence follows.

- While the evidence is variable washing, scrubbing and sanitizing melons before preparation will result in some decrease although not ensure elimination of pathogens.
- It has been demonstrated experimentally that pathogens can be transferred from the rind to the internal edible flesh of the melon (Ukuku et al, 2005; Ukuku and Sapers, 2001). Where sanitizers had lowered rind contamination the transferred population was similarly reduced. Studies have relied on inoculated samples and how this relates quantitatively to naturally contaminated samples is less clear. As the netted cantaloupes have the highest potential for rind contamination and microbial concentration they present the greatest risk and this is supported epidemiologically.
- Castillo et al (2009) quote Vadlamundi (2004) who found experimentally that the sequence of skin removal and cutting was important as cutting after rind removal resulted in less contamination than cutting then removing the rind (Castillo et al, 2009)
- Decontamination of melon pieces for the fresh-cut market is a consideration with similar approaches taken as for whole fruit with the need for additional consideration of maintaining sensory quality. An approach suited to cut product is the use of edible coatings containing essential oils where some are considered to have potential and accepted sensory effects (Raybudi-Massilia et al, 2008).
- Storage temperature of cut melons and the duration between cutting and consumption is critical and growth and survival on melon tissue has been discussed (See section 4.2). Cantaloupe has been reported to support survival of *S. enterica* better than honeydew and watermelon. Holding contaminated fresh-cut product at

22^0C for 3h prior to refrigerated storage was concluded to increase risk of proliferation of salmonellas (Ukuku and Sapers, 2007) emphasising cut products of all melons should be chilled as soon as possible.

7.0 Consumers

Melons have become popular as healthy, fresh, convenient and delicious foods that are hugely diverse in their use in dishes that appeal to all age groups in all cultures. Given their utility, they are a popular choice in the home, food service and catering industries and are retailed whole, portioned or as ready-to eat salads or meals. The available evidence suggests that there will be a low risk melons can be contaminated in the field and that through the food chain this risk should be decreased or at the least not increased.

Melons are low acid fruits and their soft texture makes them appealing to the young, elderly and infirm. The epidemiological evidence provided indicates that these vulnerable groups are at increased risk when their food is prepared in an institutional setting (Section 2.0). Among the end users of this commodity, these vulnerable groups and those preparing their food are a priority in education on safe handling of melons.

As melons have a protective rind that is peeled and not eaten it is not surprising that consumers assume the edible flesh could not be contaminated. In a survey of 2,000 consumers in the U.S.A. 35% indicated they did not wash melons before preparation, 9% thought they were already clean and 16% thought it was not necessary as they did not eat the skin (Li-Cohen and Braun, 2000).

Authorities have taken initiatives often in response to foodborne illness outbreaks linked with melons to inform consumers and provide guidance to targeted food service industries on safety handling of melons through consumer information channels such as websites with guidelines and fact sheets. While most food safety programs will address the hazards and their management during preparation of melons, there are specific characteristics that need emphasis. In particular, these include washing, scrubbing and sanitizing before use, contamination during cutting and temperature control.

Industry, retailers and food service suppliers of fresh-cut products need to provide clear instructions for end users of their products on safe storage, shelf life and handling of their products (FAO/WHO, 2008).

8.0 Microbiological sampling

Under GAPs, Good Hygienic and Manufacturing practices, and food safety programs, the presence of pathogenic microorganisms in fields, water and melons appears of low incidence and concentration and with heterogeneous distribution. Whether the approach to sampling of foods can be applied in sampling soils and melons in fields in not clear.

Observations have been made on bacterial indicators for faecal contamination and in particular the presence of *Salmonella* in melons. Annous et al, (2005a) observed *S. enterica* survived better than *E. coli* at 4 and 20^0C and suggested *E. coli* was not a suitable surrogate. Stine et al, (2005) investigated the use of *C. perfringens* as an indicator of faecal contamination of fresh produce including melons, lettuce and bell peppers. They concluded that *C. perfringens* may be a more acceptable indicator of bacterial contamination and survival in various environments and different types of crops.

The methodology used for pathogen detection with melons varies widely in experimental studies and surveys. Sampling methods include sponging, incising, including skin and/or

pulp, blending, massaging and rinsing. Hammack et al (2004) compared sampling methods and recommended the rinse method used in regulatory control in the U.S.A. Melons are soaked in a non-selective broth at 35^0C for 24± 2hr before selective enrichment. Molecular methods such as the PCR have been developed and compared with conventional culture for pathogen detection on melons. PCR for *Salmonella* detection in selective enrichments can yield larger number of positive results although the viability of the target bacterium may be unknown (Gallegos-Robles et al, 2009; Espinoza-Medina et al, 2006).

Gallegos-Robles et al (2009) collected cantaloupes with soil still attached in quadrants of 4 fields, (25 per field) in Mexico in 2005. They detected *S. enterica* in 9 surface washings by conventional enrichment culture and 11 using a PCR of the enrichment. The distribution of positive melons varied between the quadrants of each field and between fields with 5, 5 and 2 positive samples from 3 fields by either method and none from the fourth. The application of GAPs in the latter field may have been the reason for the result although the study was not designed to assess this.

Surveys of pathogens in melons from the field often fail to detect their presence while low detection rates are reported after packing. In a study of cantaloupes on farms in the U.S.A. and Mexico, *S. enterica* was detected in 1/475 field samples and 2/325 samples from the cooler or after packing. *E. coli* at counts too low for analysis were detected in 12/475 and 42/325 of the same samples as tested for *S. enterica* respectively (Castillo et al, 2004). Similarly in another study, no salmonellas were detected in 100 field collected cantaloupes while 3/100 were positive in the packing shed; however, the mean log *E. coli* cfu/melon were similar, 2.2 ± 0.8 and 2.1± 0.7 (Duffy et al, 2005). Espinoza-Medina et al, (2006) detected *Salmonella* in in-field cantaloupes (9/35) and packed cantaloupe (7/34) using PCR although not using conventional culture suggesting the concentration was low.

Surveys have been conducted on domestic and imported produce including melons. Where the sample size is small the probability of detection of pathogens may be small under good hygienic practices. In a survey of imported foods in New Zealand, 50 samples were found of satisfactory quality as ready-tot-eat products (McIntyre and Cornelius, 2009). In a U.S.A. FDA survey of imported fresh produce in1999, 11 of 151 cantaloupes were contaminated with *Shigella* (3) and *Salmonella* (8; FDA, 2011). Ongoing surveillance in the U.S.A. of domestic and imported melons includes significantly larger sample sizes and between 2005 and 2010 less than 5 and in two exceptions 16 and 17 *Salmonella* positives were detected when testing from 1,000 to >2,000 samples per year (U.S.A. JEMRA response).

Conclusions

Melons are a popular fruit included in the human diet worldwide. Their taste, texture, versatility and healthy characteristics along with the convenience of fresh melon have resulted in increased consumption, production and trade. Melons have inherent characteristics that render them susceptible to contamination and potential vehicles for foodborne illness transmission. Fresh melons receive no processing along the food chain that will totally eliminate any contaminating foodborne hazards. Control has to begin at primary production and continue through to the consumer such that the low level of risk that may be present on farm is reduced or at the least is not increased before consumption.

9.0 References

Aguillar, G.A.F., Ramirez, M.G. Garcia, A.M., González, R.Y, Navarrete, Escutia, M.C.S. and Madrigal, J.C. 2005. Identification of *Salmonella* spp. in water, cantaloupe melons and iguana faeces in a melon orchard. Med. Int. Mex. 21:255-258

Akins, E.D., Harrison, M.A., Hurst, W. 2008. Washing practices on the microflora on Georgia-grown cantaloupes. J. Fd. Prot. 71:46-51

Alvarado-Casillas, S., Ibarra-Sanchez, L.S., Martínez-Gonzáles, N.E., Rodríguez-García, M.O., Castillo, A. 2010. Validation of a washing and sanitizing procedure for cantaloupes at a Mexican packing facility. J. Fd. Prot. 73:362-365

Annous, B.A., Sapers, G.M., Jones, D.M., Burke, A. 2005a. Improved recovery procedure for evaluation of sanitizer efficacy in disinfecting contaminated cantaloupes. J. Fd. Sci. 70: M242-M247.

Annous, B.A., Solomon, E.B., Cooke, P.H., Burke, A. 2005b. Biofilm formation by *Salmonella* spp. on cantaloupe melons. J. Fd. Safety. 25: 276-287.

Annous, B.A., Burke, A., Sites, J.E. 2004. Surface pasteurization of whole fresh cantaloupe inoculated with *Salmonella* Poona or *Escherichia coli*. J. Fd. Prot. 76:1976-1885.

Avendano, B., Narrod, C., Tiongco, M. 2009. Food Safety Requirements for Cantaloupe Exports from Mexico and their Impact on Small Farmers' Access to Export Markets. Internat. Fd. Pol. Res. Instit. IFPRI Discussion Paper, May 2009.

Bastos, M.D.S.R., de Fátima Ferreira Soares, N., José de Andrade, N., Cristina Arruda, A., Elesbão Alves, R. 2005. The effect of the association of sanitizers and surfactant in the microbiota of the Cantaloupe (*Cucumis melo* L.) melon surface. Fd. Contr. 16:369-373.

Behrsing, J., Jaeger, J., Horlock, F., Kita, N., Franz, P., Premier, R. 2003. Survival of *Listeria innocua*, *Salmonella* Salford and *Escherichia coli* on the surface of fruit with inedible skins. Postharvest Biol. Technol, 29: 249-256.

Beuchat, L.R., Scouten, A.J. 2004. Factors affecting survival, growth, and retrieval of *Salmonella* Poona on intact and wounded cantaloupe rind and in stem scar tissue. Fd. Microbiol. 21:683-694.

Bowen, A., Fry, A., Richards, G. and Beuchat, L. 2006. Infections associated with cantaloupe consumption: a public health concern. Epid. Infect. 134: 675-685.

Boyhan, G.E., Granberry, D.M., Kelley, W.T**.** 2000. Commercial watermelon production, Cooperative Extension Service, The University of Georgia College of Agricultural and Environmental Sciences. http://www.agmrc.org/media/cms/B996_B3D54FD90A36C.pdf).

Castillo, A., Escartin, E.F. 1994. Survival of *Campylobacter jejuni* on sliced watermelon and papaya. J.Fd.Prot. 57:166-168.

Castillo, A., Martinez-Téllez, M.A., and Rodríguez-García, M.O. 2009. Melons. Chapter 9. *In* Sapers, G.M., Solomon, E.B. and Matthews, K.R. (eds) The Produce Contamination Problem: Causes and solutions. Elsevier, Burlington, USA.

Castillo, A., Mercado, I., Lucia, L.M., Martínez-Ruiz, Y., Ponce De León, J., Murano, E.A., Acuff, G.R. 2004. *Salmonella* contamination during production of cantaloupe: A binational study. J. Fd. Prot. 67:713-720.

CAC..2010. Alinorm 10/33/13 Appendix II. Proposed draft annex on fresh leafy vegetables (Annex to the Code of Hygienic Practice for Fresh Fruits and Vegetables). p37.

Delaquis, P. and Austin, J.W.2007. The effect of heat treatments on the fate of foodborne pathogens in horticultural produce. Stewart Post Harvest Review. Review 3, art. no. 3.

Del Rosario, B.A., Beuchat, L.R. 1995. Survival and growth of enterohemorrhagic *Escherichia coli* O157:H7. J. Fd. Prot. 58:105-107.

Doyle, M. P., Erickson, M. 2011. Opportunities for mitigating pathogen contamination on-farm. Internat. J. Fd. Microbiol. doi:10.1016/j.ijfoodmicro.2011.02.037.

Duffy, E.A., Lucia, L.M., Kells, J.M., Castillo, A., Pillai, S.D., Acuff, G.R.. 2005. Concentrations of *Escherichia coli* and genetic diversity and antibiotic resistance

profiling of *Salmonella* isolated from irrigation water, packing shed equipment, and fresh produce in Texas. J. Fd. Prot. 68:70-79.
Escartin. E.F., Ayala, A.C., Lozano, J.S. 1989. Survival and growth of *Salmonella* and *Shigella* on sliced fruit. J. Fd. Prot. 52:471-472 (Cited by Penteado and Leitão, 2004a).
FAOSTAT 2011. FAO statistical databases data sets. Available at http://faostat.fao.org/.
FAO/WHO. 2008. Microbiological hazards in fresh leafy vegetables and herbs: Meeting report. Microbiological Risk Assessment Series 14. FAO/WHO, Rome.
FDA 2001. Survey of Imported Fresh Produce FY 1999 Field Assignment. January 30, 2001. (Cited 24/05/11 at http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/FruitsVegetablesJuices/GuidanceComplianceRegulatoryInformation/ucm118891.htm
Fredlund, H., Back, E., Sjoberg, L., and Tornquist, E. 1987. Watermelon as a vehicle of transmission of shigellosis. Scand. J. Infect. Dis. 19:219-221.
Gagliardi, J.V., Millner, P.D., Lester, G., Ingram, D. 2003. On-farm and post harvest processing sources of bacterial contamination to melon rinds. J. Fd. Prot. 66: 82-87.
Gallegos-Robles, M.A, Moraes, A., Alvarez-Oieda, G., Osuna-Garcia, J.A., Martinez, I.O., Morales-Ramos, L.H., Fratamico, P. 2009. PCR detection and microbiological isolation of *Salmonella* spp. from fresh beef and cantaloupes. J. Fd. Sci. 74:M37-40.
Gerchikov, N., Keren-Keiserman, A., Perl-Treves, R., Ginzberg, I.2008. Wounding of melon fruits as a model system to study rind netting. Scientia Horticulturae. 117: 115-122.
Golden, D.A., Rhodehamel, E.J., Kautter, D.A.1993. Growth of *Salmonella* spp. in cantaloupe, watermelon, and honeydew melons. J. Fd. Prot. 56:194-196.
Hammack, T.S.Valentin-Bon, I.E., Jacobson, A.P., Andrews, W.H. 2004. Relative effectiveness of the *bacteriological analytical manual* method for the recovery of *salmonella* from whole cantaloupes and cantaloupe rinses with selected preenrichment media and rapid methods. J.Fd. Prot. 67:870-877.
Krarup, C., Tohá, J. and González, R. 2009. Symptoms and sensitivity to chilling of cantaloupe melons during postharvest. Chilean. J. Agric. Res. 69:125-133.
Leverentz, B., Conway, W.S., Camp, M.J., Janisiewicz, W.J., Abuladze, T., Yang, M., Saftner, R., Sulakvelidze, A. 2003. Biocontrol of *Listeria monocytogenes* on fresh-cut produce by treatment with lytic bacteriophages and a bacteriocin. Appl. Environ. Microbiol. 69:4519-4526.
Leverentz, B., Conway, W.S., Alavidze, Z. Janisiewicz, W.J., Fuchs, Y., Camp, M.J., Chighladze, E., Sulakvelidze, A. 2001. Examination of bacteriophage as a biocontrol method for *Salmonella* on fresh-cut fruit: A model study. J. Fd. Prot. 64: 1116-1121
Li-Cohen, A.E., Bruhn,C.M. 2002. Safety of consumer handling of fresh produce from the time of purchase to the plate: A comprehensive consumer survey. J. Fd. Prot. 65:1287-1296.
Little, C.L., Mitchell, R.T. Microbiological quality of pre-cut fruit, sprouted seeds, and unpasteurised fruit and vegetable juices from retail and production premises in the UK, and the application of HAACP. (2004) Communicable disease and public health / PHLS, 7 (3), pp. 184-190.
McIntyre, L. Cornelius, A. 2009. Microbiological survey of retail fresh produce of imported, domestic, conventional and domestic organic origin. ESR Client report FW 09064. Cited 24/05/11 at http://www.foodsafety.govt.nz/elibrary/industry/microbiological-survey-retail-research-.
projects/FW09064Produce_Survey_Final_Report_30_Sept_09.pdf
MMWR. 2002. U.S. Multistate outbreaks of *Salmonella* Poona infections associated with the eating cantaloupe from Mexico, United States and Canada, period 2000-2002. Morbid. Mort. Wk. Rep. 51:1044-1047.
MMWR. 1999. Reptile-Associated Salmonellosis -- Selected States, 1996-1998. 48: 1009-1013.
Ooi P.L. Goh K.T., Neo K.S. and Ngan C.C. 1997. A shipyard outbreak of salmonellosis traced to contaminated fruits and vegetables. Ann. Acad. Med. Sing. 26: 539-443.

Parnell, T.L., Harris, L.J., Suslow, T.V. 2005. Reducing *Salmonella* on cantaloupes and honeydew melons using wash practices applicable to postharvest handling, foodservice, and consumer preparation. Internat. J. Fd. Microbiol. 99: 59-70.

Penteado, A.L., Leitão, M.F.F. 2004a. Growth of *Salmonella* Enteritidis in melon, watermelon and papaya pulp stored at different times and temperatures. Fd. Control. 15: 369-373.

Penteado, A.L., Leitão, M.F.F. 2004b. Growth of *Listeria monocytogenes* in melon, watermelon and papaya pulps. Internat. J. Fd. Microbiol. 92:89-94.

Perni, S., Shama, G., Kong, M.G. 2008. Cold atmospheric plasma disinfection of cut fruit surfaces contaminated with migrating microorganisms. J. Fd. Prot. 71:1619-1625.

Raybaudi-Massilia, R.M., Mosqueda-Melgar, J., Martín-Belloso, O. 2008. Edible alginate-based coating as carrier of antimicrobials to improve shelf-life and safety of fresh-cut melon. Internat. J. Fd. Microbiol. 121:313-327

Richards, G.M., Beuchat, L.R. 2005a. Infection of cantaloupe rind with *Cladosporium cladosporioides* and *Penicillium expansum*, and associated migration of *Salmonella* Poona into edible tissues. Internat. J. Fd. Microbiol. 103:1-10.

Richards, G.M., Beuchat, L.R. 2005b. Metabiotic associations of molds and *Salmonella* Poona on intact and wounded cantaloupe rind. Internat. J. Fd. Microbiol. 97:327-339.

Richards, G.M. and Beuchat, L.R. 2004. Attachment of *Salmonella* Poona to cantaloupe rind and stem scar tissues as affected by temperature of fruit and inoculum. J. Fd. Prot. 67: 1359-1364

Salgado, P.L., Hernández Anguiano, A.M., García, J.C., Aguilera, G.M., Quiroz, C.C. 2009. Survival of *Salmonella* typhimurium on 'Cantaloupe' melon during cold storage under controlled atmospheres [Sobrevivencia de Salmonella typhimurium en melón 'Cantaloupe' durante el almacenamiento refrigerado en atmósferas controladas]. Revista Fitotecnia Mex., 32:209-215.

Stine, S.W., Song, I., Choi, C.Y., Gerba, C.P. 2005. Effect of relative humidity on preharvest survival of bacterial and viral pathogens on the surface of cantaloupe, lettuce, and bell peppers. J. Fd. Prot. 68: 1352-1358.

Suslow, T. Sbodio, A., Lopez, G., Wei, P., Tan, K.H. 2010. Melon food safety: 2010 Final Report. California Melon Research Board (cited 09 May, 2011 at http://www.cmrb.org/documents/files/20110110085901.pdf).

Suslow, T. D'lima, C.,Tan, K.H. 2008. Assessment of pre-harvest attachment and internalization of bacteria into melons from irrigation water. Project Report 2008. California Melon Research Board (cited at 09 May, 20011 http://www.cmrb.org/documents/files/20081222152813.pdf).

Ukuku, D.O. 2006. Effect of sanitizing treatments on removal of bacteria from cantaloupe surface, and re-contamination with *Salmonella*. Fd. Microbiol. 23:289-293.

Ukuku, D.O., Bari, M.L., Kawamoto, S., Isshiki, K. 2005. Use of hydrogen peroxide in combination with nisin, sodium lactate and citric acid for reducing transfer of bacterial pathogens from whole melon surfaces to fresh-cut pieces. Internat. J. Fd. Microbiol. 104:225-233.

Ukuku, D.O., Fett, W.F. 2006. Effects of cell surface charge and hydrophobicity on attachment of 16 *Salmonella* serovars to cantaloupe rind and decontamination with sanitizers. J. Fd. Prot. 69:1835-1843.

Ukuku, D.O., Fett, W.F. 2002. Relationship of cell surface charge and hydrophobicity to strength of attachment of bacteria to cantaloupe rind. J. Fd. Prot. 65:1093-1099.

Ukuku, D.O., Fett, W.F., Sapers, G.M. 2004. Inhibition of *Listeria monocytogenes* by native microflora of whole cantaloupe. J. Fd. Safety. 24: 129-146.

Ukuku, D.O., Sapers, G.M. 2007. Effect of time before storage and storage temperature on survival of *Salmonella* inoculated on fresh-cut melons. Fd. Microbiol. 24:288-295.

Ukuku, D.O., Sapers, G.M. 2001. Effect of sanitizer treatments on *Salmonella* Stanley attached to the surface of cantaloupe and cell transfer to fresh-cut tissues during cutting practices. J. Fd. Prot., 64:1286-1291.

USDA. 2009. Guidance for industry: Guide to minimize microbial food safety hazards of melons; Draft Guidance. (Cited 16/05/2011 at http://www.food-label-compliance.com/Sites/5/Downloads/USFDA-Draft-Guidance-MELONS-issued-073109-complete-text.pdf)

Wells, J.M., Buterfield, J.E. 1997. *Salmonella* contamination associated with bacterial soft rot of fresh fruit and vegetables in the marketplace. Plant Dis. 81:867-872.

Annex 1 Foodborne illness outbreaks associated with melons

Year	Country of outbreak	Type of melon +other foods	Aetiology	No. ill (deaths)	Origin[a]	Possible contributing factors	place prepared (if stted0	Outbreak setting/	Source of Data
1950	U.S.A.	watermelon	*S.* Bareily	6	D	Held AT^0C^b		Roadside stall	Gaylor et al, 1955. Cited by Castillo et al, 2009
1954	U.S.A.	watermelon	*S*. Miami	17 (1)	D	Sliced, wrapped	Supermarket	Home	Gaylor et al, 1955. Cited by Castillo et al, 2009
1979	U.S.A.	watermelon	*S*. Oranienberg		D	Pre-cut damaged fruit; plastic film cover; Held AT^0C possible			MMWR, 1979
1984	U.S.A.	cantaloupe	unknown	12					Bowen et al, 2006
1985	U.S.A.	cantaloupe	unknown	77					MMWR, 1986 (cited by Bowen et al 2006)
1985	U.S.A.	cantaloupe	*C. jejuni*	16					Bowen et al, 2006
1987	Sweden	watermelon	*S. sonnei*		I	Purchased whole; suspect food fraud, inoculation with water		Home	Fredlund et al, 1987
1987	United Kingdom	melon[c]	Norovirus	206		Infected food handler			ACMSF, 2005
1989	U.S.A.	cantaloupe + honeydew and pineapple	unknown	101					Bowen et al, 2006
1989	U.S.A.	cantaloupe	*S*. Chester	245 (2) [estim. > 25000]	I or D	Cut, unwashed, served in salad bars	Caterer		Reis et al, 1990
1991	U.S.A.	cantaloupe	unknown	21					Bowen et al, 2006
1991	U.S.A.	watermelon	*S*. Javiana	39		Contamination during transport?; sliced unwashed;		Indoor picnic, in-school party	Blostein, 1993

						stored AT^{0}C; leftovers held 24h			
1991	U.S.A. Canada	cantaloupe	*S*. Poona	>400 US; 72 Can	D	Pre-cut, fruit salad		Multiple locations	MMWR, 1991
1993	U.S.A.	cantaloupe + honeydew	unknown	140					Bowen et al, 2006
1993	U.S.A.	melon + strawberries	*C. jejuni*	48			Food service	Restaurant	CSPI; CDC[d] 2003
1993	U.S.A.	cantaloupe	*E. coli* O157:H7	27		Cross-contamination raw beef possible	Food service	Restaurant	CSPI
1993	U.S.A.	watermelon	*S*. Javiana	27				Private home; church	CSPI; Del Rosario et al, 1995
1995	U.S.A.	cantaloupe + icecream	unknown	24					Bowen et al, 2006
1995	U.S.A.	cantaloupe + watermelon	unknown	27					Bowen et al, 2006
1996	Singapor e	watermelon + papaya + pineapple	*S*. Weltevreden	27		Contaminated wash water	Food stall	Workplace	Ooi et al, 1997
1997	U.S.A.	melon + lemon bars	*E. coli* O157:H7	9				Home	CDC 2003
1997	U.S.A.	cantaloupe	*S*. Saphra	5	I	Contamination pre-harvest, most unwashed, poor refrigeration in distribution		Multiple sites	Mohle-Boetani et al, 1999
1998	Canada	cantaloupe	*S*. Oranienberg	22	I	Sliced, held AT^{0}C several hrs		.	Deeks et al, 1998
1998	U.S.A.	honeydew + strawberries	?	41		Infected food handler, bare hands	Food service	Restaurant	CDC
1999	U.S.A.	cantaloupe, honeydew, watermelon	Norovirus	61		infected food handler, served at salad bar	Food service	Restaurant	CDC; CDC 2003
1999	U.S.A.	watermelon +pineapple	Norovirus	23		Poor hygiene	Food service	Restaurant	CSPI
1999	U.S.A.	cantaloupe	Norovirus	5		Infected food handler	Food service	Restaurant	CDC

			(sus.)				Caterer		
1999	U.S.A.	honeydew, watermelon	*S*. Enteritidis	82		Held at AT^{0}C		School	CDC; CDC, 2003a
1999	U.S.A.	Melon	*S*. Javiana	11		Pre-cut		Multiple locations or unknown	CSPI
2000	U.S.A.	cantaloupe + turkey sandwich	Norovirus	33		Infected food handler	Caterer		CDC
2000	U.S.A.	cantaloupe + turkey	Norovirus	20					Bowen et al, 2006
2000	U.S.A.	Melon	*S. aureus* (sus.), *B. cereus* (sus.)	55		Poor hygiene, poor cold storage	Caterer	Church, caterer	CDC, CSPI
2000	U.S.A.	Melon	S. Heidelberg	4		Buffet salad, poor hygiene, bare hand contact, cross-contamination	Food service	Restaurant	CDC
2000	U.S.A.	cantaloupe	S. Poona	46	I	Possible grower primary source, held AT^{0}C	Food service Grocery store Caterer	Restaurant, , nursing home, home	CDC
2000	U.S.A.	watermelon	*E. coli* O157:H7	23		Poor hygiene, poor cold storage	Food service	Restaurant	CDC
2001	U.S.A.	melon	not reported	33		Poor cold storage	Caterer		CDC
2001	U.S.A.	cantaloupe	*S*. Anatum						USDA JEMRA response
2001	U.S.A.	cantaloupe, honeydew +pineapple+ grapes	Norovirus	36			Food service	Restaurant buffet	CSPI; CDC
2001	U.S.A.	cantaloupe +pineapple	Norovirus	100					CDC
2001	U.S.A.	melon+ strawberry, fruit	?	42			Food service	Restaurant	CDC
2001	U.S.A.	cantaloupe	S. Poona	50 (2)	I	Poor hygiene	Food service grocery store	Multiple locations,	CDC; CDC 2002
2001	U.S.A.	honeydew, musk melon, watermelon	S. Poona	23		Salad handling	Food service grocery store	Restaurant, , home	CSPI

2001	U.S.A.	cantaloupe	*S. enterica,* no serotype	2			Food service	Restaurant, nursing home	CDC
2002	U.S.A.	cantaloupe +pineapple	Norovirus	15			Food service	Restaurant	CDC
2002	U.S.A.	watermelon, cantaloupe +grapes	S. Berta	29			Caterer	Church/	CSPI
2002	U.S.A.	cantaloupe	S. Poona	26	I	Food stored in advance	Food service grocery store	Nursing home, private home,	CDC
2003	U.S.A.	cantaloupe, honeydew	S. Muenchen	58			Food service grocery store	Daycare centre, private home	CDC
2003	U.S.A.	honeydew	S. Newport	68 (2)		Poor holding temperature	Food service caterer grocery store	Restaurant, hospital	CDC
2003	U.S.A.	honeydew	*S. sonnei*	56				Restaurant or deli	CSPI
2003	U.S.A.	cantaloupe + banana + pineapple	Norovirus	16		Infected food handler	Food service	nursing home	CDC
2004	U.S.A.	cantaloupe (suspect)	*S*. Oranienberg						USDA JEMRA response
2004	U.S.A.	cantaloupe, honeydew, watermelon	Norovirus	100		Salad	Food service	Banquet facility	CDC
2004	U.S.A.	watermelon, honeydew	Norovirus	34		Infected food handler		Church, temple	CDC
2004	U.S.A.	Melon +strawberries+ grapes + salad	Norovirus	62			Food service	Nursing home	CSPI
2004	U.S.A.	watermelon, honeydew, cantaloupe + fruit	Norovirus (sus.)	30		Gloved hands	Food service	Conference facility/	CDC
2004	U.S.A.	cantaloupe	*E. coli* O157 H7	6 [HUS]					ISID, 2004

2005	U.S.A.	watermelon	Norovirus	18		Gloved hands	Food service	Camp	CDC
2005	U.S.A.	cantaloupe + chicken (barbeque) + corned beef	S. Enteritidis	126			Home	Private home	CSPI
2005	U.S.A.	cantaloupe + beef (ground)	S. Newport	24				Unknown	CSPI
2006	U.S.A.	melon + fruit salad	*E. coli* O157:H7						USFDA JEMRA response
2006	U.S.A., Canada	honeydew & cantaloupe	*S*. Oranienberg	US39, Can 2			Processing plant	73% cases served at health care facility	MMWR (2007)
2006	U.S.A.	watermelon	*C. jejuni*	15				Picnic	CSPI
2006	U.S.A.	watermelon +fruit	Norovirus	14			Grocery store	Picnic/	CSPI
2006	U.S.A.	Melon, honeydew, plum, pizza, cheese	S. Newport	12				Multiple locations or unknown	CSPI
2006	U.S.A.	watermelon + fruit	S. Newport	20		Infected food handler, bare hands	Food service	Restaurant	CDC
2006	Australia	cantaloupe (rockmelon)	*S.* Saintpaul	115		Inadequate washing			Munnoch et al (2009)
2007	U.S.A.	honeydew +caramel rolls	Norovirus	19			Food service	Banquet facility	CSPI
2007	U.S.A.	honeydew	*S*. Litchfield	11			Food service	Restaurant, home	MMWR, 2008
2007	U.S.A.	cantaloupe + grapes + fruit salad, green salad (suspect)	*S*. Litchfield	30			Food service	Restaurant	CSPI
2007	U.S.A.	melon + mixed fruit	Norovirus	44		Infected food handler	Food service, Distributor	Restaurant	CDC
2008	U.S.A.	cantaloupe	Norovirus	23		Infected food handler	Food service	Restaurant	CDC

2008	U.S.A.	watermelon	S. Javiana	594		Infected food handler, poor storage temperature	Central kitchen	Multiple sites	CDC
2008	U.S.A.	cantaloupe (suspect)	S. Javiana	10	D			Multiple locations or unknown	CSPI
2008	U.S.A. Canada	cantaloupe +fruit suspected	S. Litchfield	US 53 Can 9	I		Food service	Restaurant; Private home; Hospital	CSPI; CDC
2008	U.S.A.	melon + fruit	S. Litchfield	5					CDC
2008	U.S.A.	melon + fruit	S. Litchfield	5			Food service	Restaurant/ grocery store/ home	CDC
2008	U.S.A.	cantaloupe, watermelon	S. Newport	3		Salad mix	Home	Private home	CSPI
2009	U.S.A. Canada	cantaloupe, honeydew, watermelon (suspect)	S. Carrau	US32 , Can 35	?			Community	PHAC, 2009
2009	New Zealand	Watermelon (unwashed)	*S*. Typhimurium PT1	19					ESR JEMRA response; McCullum et al (2009)
2010	Australia	cantaloupe or honeydew	*L. monocytogenes*	9 (2)			Food service	Hospital (possible), immuno-compromised patients	OzFoodNet Working Group (2010)
2010	Australia	cantaloupe, mint and lettuce (suspect)	*Cyclospora* sp.	314					OzFoodNet Working Group (2010)
2011	U.S.A.	cantaloupe	S. Panama	13	I				CDC, 2011
2007 - 2022	Brazil	watermelon	3 outbreaks no data						Brazil response to JEMRA

[a] D=domestic; I=imported; [b] Ambient temperature; [c] "Melon" indicates type unspecified; [d] CDC data provided in U.S.A. response to JEMRA

References used in Table

ACMSF (Advisory Committee on the Microbiological Safety of Food). 2005. Information Paper. Microbiological status of ready to eat fruit and vegetables. ACM/745. (Cited 11/05/11at http://www.food.gov.uk/multimedia/pdfs/acm745amended.pdf).

Blotstein, J 1993. An outbreak of *Salmonella* Javiana associated with consumption of watermelon. J. Envir. Hlth. 56:29-31.

Bowen, A., Fry, A., Richards, G. and Beuchat, L. 2006. Infections associated with cantaloupe consumption: a public health concern. Epid. Infect. 134: 675-685.

CDC. 2011. Investigation Update: Multistate Outbreak of *Salmonella* Panama Infections Linked to Cantaloupe. Cited 26/04/11 at http://www.cdc.gov/salmonella/panama0311/032911/index.html.

CDC. 2008. Investigation of outbreak of infections caused by *Salmonella* Litchfield. Cited May 2011 at http://www.cdc.gov/salmonella/litchfield/.

Deeks, S, Ellis, a Cieben, B et al. 1998. *Salmonella* Oranienberg, Ontario. Can. Commun. Dis. Rep. 24:177-179.

Del Rosario, B. A. and Beuchat, L. R. 1995. Survival and growth of enterohaemorrhagic *Escherichia coli* O157:H7 in cantaloupe and watermelon. J. Fd. Prot. 58:105-107.

Gayler, G. E. MacCready, R.A., Reardon, J.P. and McKernan, B.F. 1955. An outbreak of Salmonellosis traced to watermelon . Pub. Hlth. Rep. 70(3):311 (Cited by Castillo et al, 2009).

McCallum L., Torok M., Dufour, M.T., Hall A, and Cramp G. 2009. An outbreak of *Salmonella* Typhimurium phage type 1 associated with watermelon in Gisborne. N. Z. Med. J. 10;123:39-45.

Mohle-Boetani, J.C., Reporter, R., Werner, S.B., et al. An outbreak of *Salmonella* serogroup Saphra due to cantaloupes from Mexico. J. Infect. Dis. 1999;180:1361-1364.

MMWR, 2008. *Salmonella* Litchfield outbreaks associated with a hotel restaurant – Atlantic City, New Jersey, 2007. Morbidity and mortality weekly report. 57:775-779.

MMWR. 2007. *Salmonella* Oranienburg infections associated with fruit salad served in health-care facilities--northeastern United States and Canada, 2006. Morbidity and mortality weekly report. 56:1025-8.

MMWR. 2003. U.S. Outbreak of *Salmonella* serotype Javiana infections, Orlando Florida, June 2002. Morbidity and mortality weekly report. 51:683-684.

MMWR. 2002. U.S. Multistate outbreaks of *Salmonella* Poona infections associated with the eating cantaloupe from Mexico, United States and Canada, period 2000-2002, November, 2002. Morbidity and mortality weekly report. 51: 1044-1047.

MMWR. 1991. Epidemiologic notes and reports: multistate outbreak of *Salmonella* Poona infections. United States and Canada. Morbidity and mortality weekly report. 40:549-552.

MMWR. 1986. Aldicarb food poisoning from contaminated melons – California. Morbidity and mortality weekly report. 35:254-258.

MMWR, 1979. *Salmonella* Orangeburg gastroenteritis associated with consumption of pre-cut watermelons. Morbidity and mortality weekly report. 28:522-23.

Munnoch, S.A., Ward, K., Sherida, N. S., Fitzsimmons, G.J., Shadbolt, C.T., Pilspanen, J.P., Wang, Q., Worgan, T.L.M., Oxenford, C., Musto, J.A., McAnulity, Durrheim, D.N. 2009. A multi-state outbreak of *Salmonella* Saintpaul in Australia associated with cantaloupe consumption. Epid. Inf. 137:367-375.

OzFoodNet Working Group. 2010 OzFoodNet Quarterly Report, 1 April to 30 June 2010. Communicable Diseases Intelligence 34:345-354 (Cited at http://www.health.gov.au/internet/main/publishing.nsf/Content/cda-cdi3403-pdf-cnt.htm/$FILE/cdi3403o.pdf.

PHAC (Public Health Agency of Canada). 2009. International outbreak of *Salmonella* Carrau Infections - Final Epidemiological Report, Center for Food-borne, Environmental and Zoonotic Infectious Diseases, PHAC.

Ries A.A., Zaza S., Langkop C., et al. 1990. A multistate outbreak of *Salmonella* Chester linked to imported cantaloupe [Abstract]. In: Programs and abstracts of the 30th Interscience Conference on Antimicrobial Agents and Chemotherapy. Washington, DC: American Society for Microbiology. (Cited in MMWR, 2002).

Annex 2 FAO/WHO Call for data: Summary

FAO/WHO extended a call for data on the identification and control of microbiological hazards associated with melons to support the development of an Annex to the Code of Hygienic Practices for Fresh Fruit and Vegetables. The data received at May 2011 is summarised in this annex.

Thirteen countries responded to the call including Colombia, Mexico, Brazil, Argentina, Guatemala, France, United States of America (U.S.A.), Canada, Australia, New Zealand, China, Lithuania and the Republic of Armenia.

Only a couple of countries provided detailed information and references. There was insufficient data from enough countries to make comments on generalisations or trends in most data listed in the call. Key points in managing food safety hazards were listed for all sectors along the melons supply chains indicating the need for a through chain approach.

Melons and the link to foodborne illness
Five of the responding countries reported evidence of illness associated with melons within their country based on outbreak investigations. Not all countries had surveillance systems where data could be found or were confident their surveillance system would detect an outbreak related to fresh produce. These outbreaks and associated details have been incorporated in the Annex 1 together with data from the literature research.

Countries where outbreaks occurred or, countries exporting melons that had been linked to outbreaks in the importing countries, had developed follow-up actions. These included:

- Review of domestic, import and export risk management
- Development of industry guidelines specifically for melon production or amendments to existing guidelines for fresh fruits and vegetables to strengthen attention to risk mitigation in melon production
- Attention to safety of foods for vulnerable populations
- Risk communication with education packages for industry and consumers
- Research and surveillance of hazards in melons to support risk managers

Production practices
The responding countries produce the common watermelon, cantaloupe and honeydew and a myriad varieties of each. They are mostly grown in open fields. China in addition reports production of hami melons. They also report greenhouse production is some regions and growing some varieties of melon for longer periods and to a much larger size and maturity. The supply chain flow varies between countries mainly in the presence or otherwise of field packing.

Melons are produced in both large scale operations, especially for distant and export markets, and in small holder operations that could be pooled for distant locations or marketed locally.
For those countries reporting production guidelines or codes of practice for melon production, these include GAP, GlobalGAP, national or regional guidelines for fruit production or those specific for melons or a melon type (e.g. watermelons, cantaloupe), customer driven requirements (e.g. import country specifications).