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Food safety perceptions and practices of selected UK fresh produce farms

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food safety; fresh produce; pre-harvest; United Kingdom.

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Abstract

Introduction Evidence to date suggests that the incidence of foodborne outbreaks from the UK fresh produce sector is very low. It is interesting to note how the fresh produce farms practice their pre-harvest activities to ensure that safe produce enter the food chain. *Objective* The study aims to determine the perceptions of fresh produce farmers towards farm food safety. The current farm food safety practices among voluntary participating farms are also identified and discussed. *Methods* A survey of current farm food safety perceptions ($n = 44$ fresh produce farms) and practices were conducted. Twelve fresh produce farms (out of the 44) participated in detailed discussions relating to their current farm food safety practices. *Results* The present study is one of the few research works that focused on farm food safety management practices. The findings in this study suggested that the vast majority of the participating fresh produce growers generally have good perceptions and practices in farm food safety. *Conclusion* This reiterates the fact that the studied farms practiced good agricultural practices which lead to continuous safety and quality assurance of the crops.

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Introduction

The United Kingdom salad market is growing steadily in response to consumer demands for quick and convenient healthy foods (Tyrrel *et al.*, 2006). Some of the main fresh crops grown in the UK include cabbages, carrots, cauliflowers, lettuces, mushrooms, peas and tomatoes [Department for Environment, Food and Rural Affairs (DEFRA, 2009)]. The driving force behind the rapid growth of the fresh produce is the desire of consumers to lead a healthy lifestyle. The Food and Agriculture Organization (FAO) and World Health Organization introduced the '5-a-day' campaign that encourage people to eat at least five servings of fruits and vegetables daily (FAO, 2006). In fact, 78% of the UK population is aware of the 5-a-day message and 58% claimed consumption of five or more portions of fruit and vegetables daily [Food Standards Agency (FSA, 2008)]. The National Diet and Nutrition Survey (NDNS) from 2008/2009 to 2009/2010 revealed that 30% of adults and 37% of older adults met the 5-a-day recommendation. Adults aged 19 to 64 years on average consumed 4.2 portions of fruit and vegetables per day and older adults 4.4 portions (NDNS, 2011). In addition, UK imports a substantial amount of fresh produce from the European Union (EU) and other countries. The total import of fresh vegetables in 2009 was 1823 thousand tonnes – led by Spain (684 thousand tonnes) and the Netherlands (573 thousand tonnes) from EU and Kenya (33.1 thousand tonnes) from Africa. Meanwhile, the total import of fresh fruits amounted to 3175 thousand tonnes – also led by Spain (444.4 thousand tonnes) and South Africa (349.6 thousand tonnes) (DEFRA, 2011). The UK market comprises of both local and imported fresh produce to cater to consumers' demands. In order to protect the safety of consumers, the food supply chain is driving each food business operators (from farmers to retailers) to practice due diligence and to ensure that the safety and quality of fresh produce production is not breached. Evidence to date suggests that the incidence of foodborne outbreaks from the UK fresh produce sector is very low. Adak *et al.* (2005) estimated that between 1996 and 2000, there were 1 723 315 cases of indigenous foodborne disease per year resulting in 21 997 hospitalizations and 687 deaths, but only 3% of cases were attributed to produce. In England and Wales, produce-associated outbreaks increased from 0.07% (487 of 653 190 cases) in the 1990s to 0.15% (1006 of 668 525 cases) between 2000 and 2008 (HPA, 2010a, 2010b). Although fresh produce contributes only a small proportion of the total cases of foodborne illness in the UK, this class of food was deemed of particular concern to regulatory authorities (Monaghan *et al.*, 2008). Some fruits and vegetables are likely to be consumed raw or after minimal processing as previously described, and without cooking, so any human pathogens present in the products are given a maximized chance to cause foodborne illness as fruits and vegetables are mostly produced in a natural environment and are vulnerable to contamination (Matthews, 2006; Monaghan *et al.*, 2008). Most hazards originating from the farms can be cross-contaminated to other foods due to inappropriate processing and mishandling. It is imperative to start reducing risk factors at farms, so this may reduce the contamination load into the processing and food preparation stage.

Public–private food standards and drivers for change

The Food Safety Act 1990 was significant because it introduced the concept of 'due diligence defence' which shifted the responsibility for food safety along the whole food supply chain (Hobbs *et al.*, 2002). The critical word in the definition of due diligence is 'reasonable'. Under this Act, any supplier of a branded product is responsible for the safety of that product. Hence, enforcement could be taken against a wholesaler or retailer even if the offence was caused by other parties in the food chain (Lee, 2006). However, this is often difficult to define clearly and may have led retailers to institute stringent quality assurance programmes with their suppliers (Fearne, 1998). The due diligence defence was arguably the first major impetus for the development of private standards (Henson, 2008). UK Food Safety Act 1990 and the ensuing General Food Law Regulation (EC) 178/2002 (EU, 2002) have facilitated private standards by holding food business operators accountable for any wrongdoing in the supply chain. The EU Food Hygiene Regulations, enforced since 1 January 2006, extended the food safety legislations to primary producers. Farmers and growers are still not required to implement a HACCP system, but must follow good hygiene practices and to control food safety hazards occurring on farms (FSA, 2010a). The EC Directive 93/43 on the Hygiene of Foodstuffs (EC Directive 93/43/EEC, 1993) states that food business operators shall identify and adequately control hazards at any step in their activities to ensure food safety. It also identifies farmers as food business operators, hence primary production must take the necessary steps to ensure food hazards are adequately controlled.

Primary producers who are members of recognized farm assurance schemes are considered to meet the requirements of the legislation, hence resulting in less frequent inspection by local UK authorities (FSA, 2010b). By limiting public standards to minimum food safety requirement, governments often leave private standards to extend beyond the minimum standards (Henson & Reardon, 2005). In the UK, a series of private QA schemes have been developed by stakeholder groups, for example, the Assured Food Standards (AFS) Fresh Produce Scheme (2011), European Retailers Good Agricultural Practice (EUREPGAP) [now GlobalGAP Scheme (2011)] and the British Retail Consortium (BRC) Global Standard for Food Safety (BRC, 2011).

The UK food industry is driven primarily by its domestic market, with the supermarket retailers enjoying considerable market power as 92% of the consumers reportedly bought most of their household food from supermarkets (FSA, 2006). This shows that the power in the food sector in developed and emerging economies has shifted from manufacturers and producers to retailers (Fulponi, 2005). The governments also determined that the food industry should accept greater responsibility for the quality and safety of food. Meanwhile, food industries also considered that they should have a greater input in the formulation of national regulatory policy (Boutrif, 2003). Retailers are the key actors in the use of private food standards and driving the food system even though they claim that they are consumer driven. Firms compete among themselves in national and international markets and attempt to differentiate their products to protect and gain market share (Henson & Reardon, 2005). Different companies and groups within the industry also developed their own standards and resulted in the proliferation of private collective and individual firms' standards in the food supply chain (Julien, 2010).

In the UK, the retailers, notably Marks and Spencer with the Field to Fork codes of practice, are driving the food safety agenda through the development of their own standards. The retailer technologists are the main motivators and educators of suppliers to apply risk management on fresh produce (Monaghan, 2006). Reputation building, maintaining food safety and quality were considered the most important attributes in adopting private food standards (Fulponi, 2006). This is in agreement with Gulati *et al.* (2007) who reported that much emphasis was stressed on product quality and food safety because the risk of selling 'bad' food is devastating to the retailers. Multiple retailers are driving quality assurance scheme compliance by making it a condition of market access for suppliers (Monaghan *et al.*, 2008). It is arguably private rather than public standards that are becoming the predominant drivers of food safety and quality in food systems (Henson & Hooker, 2001).

Conceptual framework

From May to July 2011, one of the largest reported outbreaks of haemolytic uraemic syndrome (HUS) and bloody diarrhoea caused by the Shiga toxin-producing *Escherichia coli* (STEC) O104:H4 occurred in Germany (Jansen & Kielstein, 2011) and France (Gault *et al.*, 2011). The investigation concluded that a certain lot of fenugreek seeds were the most likely link to the outbreaks in Germany and France [European Food Safety Authority (EFSA), 2011]. Although farmers and growers are currently not required to implement a HACCP system, they must conduct assessments and follow good hygiene practices in order to control food safety hazards occurring on farms (FSA, 2010a). Although most high-profile fresh produce outbreaks such as sprouted seeds in Germany, *Listeria monocytogenes* in whole cantaloupes in US [Centers for Disease Control and Prevention (CDC, 2011a) and *Salmonella* ser. Agona in paw paw in the United States (CDC, 2011b) have occurred outside the UK, the fact that they have occurred at all indicates that the controls in place within the industry globally may not have adequately controlled the hazards associated with farming and distribution of fresh produce (Monaghan *et al.*, 2008). It is interesting to note how UK's fresh produce farms practice their pre-harvest activities to ensure that safe produce enter the food chain. Hence this paper strives to explore both the farm food safety perceptions and current practices. The author would like to indicate that this paper serves as a preliminary study and hope to generate more interest among researchers in studying good agricultural and food safety practices in UK's fresh produce.

Methodology

Nationwide survey of farm food safety and quality perceptions

Fresh produce farms (170 farms) were approached with personalized invitation cover letter and questionnaire. The mailing list was collected from the memberships in fruit and vegetable grower associations for fresh produce under the Horticultural Development Company. The targeted fresh produce populations in this study are growers growing ready-to-eat crops such as leafy greens, other salad greens, herbs, onions, carrots, brassicas, cabbage, spinach, tomato, asparagus, watercress and beans. The purpose of the project was explained to the farmer and interested farms were invited to participate in the research. However, farms that do not intend to participate were also invited to answer and return the questionnaire. The author practised a number of measures (e.g. short questionnaire, personalized cover letters, follow-up contacts, etc.) to ensure a high response rate. In addition, Edwards *et al.* (2002) noted that response rates could be improved with the addition of monetary incentives, using recorded delivery and first-class stamped return envelopes.

Survey of current farm food safety practices

Twelve UK fresh produce farms were sampled from the initial 44 registered fresh produce farms. The farms participated in detailed discussions relating to their current farm food safety practices. Data were collected in the 'Farm Food Safety-Risk Assessment' questionnaire. Even though the samples were not representative of the whole industry, this sampling procedure was pragmatic as it ensured good coverage of regions within a country (Figure 1), and also ensured that farms were clear as to their commitment to the project (since they were motivated to participate in the research by signing up). However, this is not a statistically representative sample of farms in these regions and results cannot be extrapolated to all farms in a region or country. The author also acknowledges the possibility of selection bias as the farms were not chosen at random but were selected by a convenience approach (Ellis-Iversen *et al.*, 2007) dependent on volunteering and willingness by growers. No stratification of farm samples was carried out.

Development of farm food safety practices questionnaire

The questionnaire was developed to gather current farm food safety practices from the fresh produce farms.

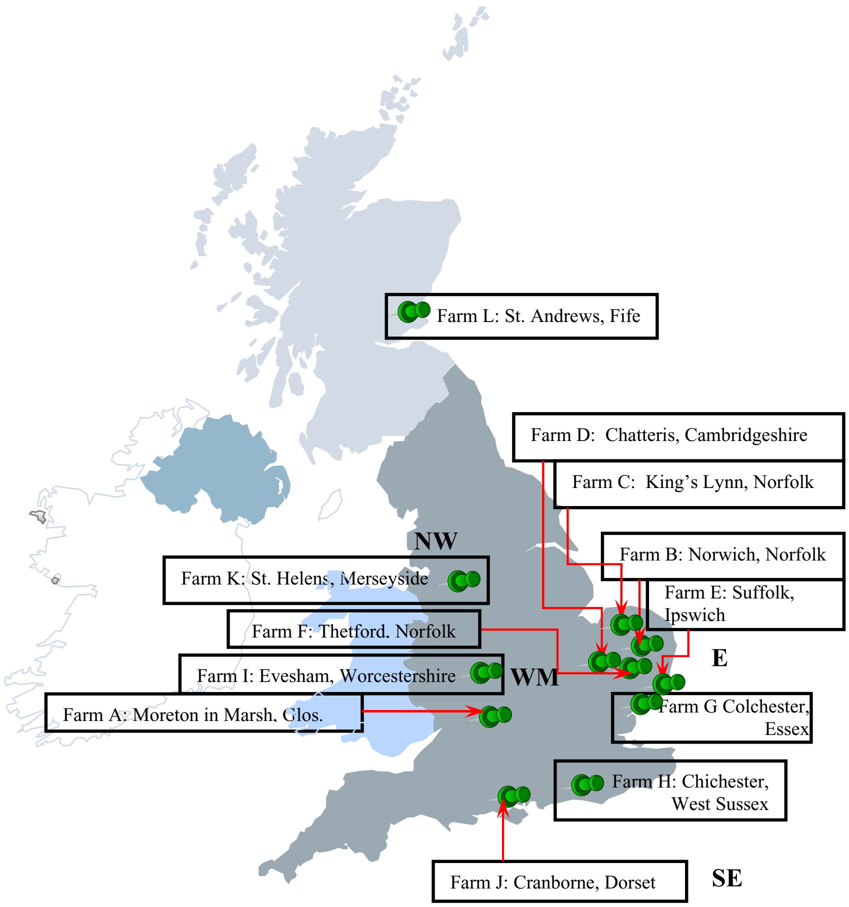

Figure 1 Geographical distribution of fresh produce farms in East (E), North West (NW), South East (SE) and West Midlands (WM) of England; and Scotland ($n = 12$ farms).

Development of the questionnaire was based on a literature review of risk factors for farm food safety (FDA, 2006; GlobalGAP, 2007; Jevšnik *et al.*, 2009; Ko, 2010). A total of 65 main questions were divided into 12 sections:

(1) Site history
(2) Water sources
(3) Manure management
(4) Animal management
(5) Fertilizers/Pesticides
(6) Harvest tools and equipment
(7) Packing/Processing facility
(8) Pest control
(9) Transportation
(10) Workers health and hygiene
(11) Sanitary facilities
(12) Traceability

Pre-testing of farm food safety practices questionnaire

To improve its clarity, the questionnaire was pre-tested on five farms. All questions were reviewed by the farm owners/technical representative and they were asked to comment if they did not fully understand any detail. Some questions were rephrased for clarity. The questionnaire is available upon request.

Results and discussion

Farmers' food safety perceptions

In all, 170 questionnaires were sent or e-mailed and a 25.88% response rate was achieved. A comparison against government-published horticultural crop statistics (DEFRA, 2009) confirmed that the survey data for fresh produce production accounted for 14.36% (17 950/125 000 ha) of the

Table 1 Demographic characteristic of the farms

	Demographics	Fresh produce n (%)
Gender (n = 43)	Male	35 (81)
	Female	8 (19)
Age group (n = 43)	<20 years	0
	21–30 years	4 (10)
	31–40 years	10 (23)
	41–50 years	13 (30)
	51–60 years	15 (35)
	>60 years	1 (2)
Years working on farm (n = 42)	<5 years	4 (9)
	5–10 years	3 (7)
	11–20 years	15 (36)
	>20 years	20 (48)
Education level (n = 42)	GCSE/O level	5 (12)
	A level	2 (5)
	Diploma/HND/degree or higher	31 (74)
	None of the above	4 (9)

GCSE, general certificate of secondary education; HND, higher national diploma.

total UK salad crop area. There are 7300 horticultural holdings (including fruits and ornamental plants) in the UK, with 4600 holdings in England and 1900 in Scotland (DEFRA, 2011). The demographic characteristics of the surveyed farms are shown in Table 1.

On-farm food safety and quality assurance programme

Managing food safety on the farm is necessary as agreed by 80% of the fresh produce growers. This figure may represent the general perception of the importance of farm food safety among the fresh produce farms. Fifty-nine percent of the crop growers felt that good agricultural practices are sufficient to ensure safe production of food at the farm level. At least 18% of the fresh produce does not agree with the idea of an on-farm HACCP.

The respondents strongly felt that some of the most significant criteria in ensuring on-farm food safety are the correct application of plant products (75%), good agricultural practices (64%), traceability (55%), food safety training (48%) and water safety (46%). The importance of food safety training is also reflected when only 7% and 14% of the farms do not train their employees in food safety and quality on a regular basis. Documentation and record keeping is perceived as less important in managing farm food safety (16%). One of the respondents also commented that the amount of documentation carried out is overwhelming and burdensome.

The correct application of plant protection products generated the most positive response (75%) and this is reflected by the research conducted by the Pesticides Residues Committee (PRC) in the UK which is responsible for monitoring residues in foods. The results from PRC's survey of pesticide residues in food and drink revealed that two third of the samples were pesticide free while almost 30% of the samples were below the maximum residue level (PRC, 2010). Growers also tend to have a strong perception towards traceability. This could be due to a series of high-profile food safety hazards occurring in the EU, and consumers lost trust in the public and private agents in the food industry (Monteiro & Caswell, 2009). In order to regain consumer confidence, the EU started a thorough revision of food laws leading to regulation 178/2002. Traceability became a mandatory requirement in 2005 for food and feed supplies (Regulation 178/2002), hence this may have contributed to the perception of farms towards the importance of an effective traceability system on farm (EU, 2002).

Fruits and vegetables can become contaminated during irrigation and post-harvest washing with contaminated water (Steele & Odumeru, 2004). A survey conducted in 2003 in the UK revealed that 71% of the salad farms used surface water and >99% of the salad crops are irrigated using sprinkler method. Such method may contribute to crop contamination if the water sources are of low microbiological quality (Tyrrel *et al*., 2006). Although there is no literature which indicates that irrigation water is responsible for foodborne disease outbreaks in the UK, the surveyed farms in this study do identify and acknowledge the importance of water quality. Documentation and record keeping are important to demonstrate the farm's compliance with established food safety regulations. It is beneficial especially during the application of farm assurance certification and traceability. Documentation acts as the only source of information an auditor can review with regard to the auditee's adherence to a food safety plan (Petersen, 2009).

Farm assurance schemes

Ninety-three percent of the fresh produce farms are involved in farm assurance schemes (e.g. Assured Produce, BRC, GlobalGAP, Marks & Spencer-Field to Fork, Tesco Nurture). At least 80% of the farms agreed that farm assurance schemes help to ensure fresh produce safety and quality. It is also interesting to note that 9% felt that the schemes were a waste of time and money. The characteristics that make a food safety/quality programme effective for the farmers were: increased product quality (86%); not too expensive (84%);

and based on scientific data (82%). More than half of the respondents felt that the programmes should not be government oriented but based on voluntary terms (61%). The fresh produce farms were also motivated to participate in food safety or quality programmes to maintain market access (96%), reduce foodborne diseases and recalls (91%), and to reduce the risk of violating food regulations (89%; $n = 43$). Premium price product (75%) scored the lowest among the various incentives. One of the respondents also commented that various farm accreditations do not guarantee premium prices for his produce.

Farm food safety practices

Twelve fresh produce farms (from the initial survey of 44 fresh produce companies) volunteered to participate in detailed discussion relating to their current farm food safety practices. These 12 farms represent 5.05% (6317.61/125 000 ha) of the total farming area in the UK (DEFRA, 2009), growing a variety of fresh produce such as asparagus, brussels sprouts, carrots, leek, lettuce, salad greens and salad herbs.

Site selection

All farms had been producing at their site for more than 5 years. One farm has expanded its site within the last 5 years (since December 2010). Site selection is an important process for new farms or during expansion, as previous land use will affect the safety and quality of crops. In this case, previous land use was insignificant as most farms had been established for a number of years (5 to 70 years). Three of the farms were exposed to flooding in 2007 and 2010 which covered grasslands and bare fields. Even though all farms revealed that the possibility of contamination with sewage or manure during heavy rainfall or flooding was low, the farms do carried out precautionary steps to reduce the likelihood of cross-contamination in their fields.

Irrigation water

Irrigation water is a potential point of pathogen entry into the food chain as many bacteria, viruses and protozoa of faecal origin can be found in waters which are used in the primary production of food crops (Falkenhorst *et al.*, 2005; Nygard *et al.*, 2008; Soderstrom *et al.*, 2008; Lofdahl *et al.*, 2009; Ethelberg *et al.*, 2010). The sources of water used for irrigation in UK include: rivers and streams (51%), deep boreholes (32%), ponds and lakes (7%), springs and wells (4%), mains supply (25), and other sources (3%) (Groves *et al.*, 2002). Seventy-five percent of the farms in this study used borehole and surface water for irrigation (Table 2). Only two farms (Farms C and G) had built large on-farm reservoirs. It was observed from Farm C that the on-farm reservoir is open to the environment and provided a useful habitat for many bird and fish species. Even though growers were encouraged to enhance the environmental benefits of reservoirs, the excreta from wild birds and other animals, which may contain pathogens, can contaminate reservoir waters. Approximately 50% of the farms were using the same source of water for irrigation and for mixing pesticides and fertilizers. For example, if the farm used borehole water as an irrigation source, hence borehole water was also used to

Table 2 Percentage of fresh produce growers using different water sources and water quality

Parameters	(%)
Water source	
Irrigation ($n = 12$)	Borehole (25)
	Rivers and streams (25)
	Rivers, streams and borehole (25)
	Borehole and rainwater (8)
	Rainwater (8)
	Mains (8)
Irrigation method ($n = 11$)	Overhead/sprinkler/rainguns (82)
	Overhead and sub-irrigation (9)
	Flood irrigation (9)
Does agricultural water come in contact with the edible portion of crop?	Yes (92)
	No (8)
Is irrigation water treated before use?	Yes (25)
	No (75)
Period between last irrigation and harvest	4 h to 7 days
Testing water quality	
Is water tested for bacterial contamination/indicators?	Yes (100)
Type of test	*Escherichia coli* spp., *Salmonella* spp., coliform (100)
	Listeria spp. (50)
	Streptococci (25)
	Pseudomonas (17)
	Heavy metal (8)
	Pesticide (8)
Testing frequency	Annually (42)
	Bi-annually (8)
	Quarterly (8)
	Monthly (33)
	Monthly and weekly for different crops (8)
Is ice used in the facility?	Yes (8)
Source of water for ice	Mains (made from leased/contracted ice-maker machine)

dilute/mix pesticides and liquid fertilizers. In general, the growers were unable to choose their water source as this was governed by the water available in the local environment.

The predominant irrigation method in the UK for salad crops is overhead irrigation (99%) (Tyrrel *et al*., 2006). Even though the samples in this study were small, the growers' irrigation method reflected Tyrrel *et al*.'s (2006) study. The majority of irrigation water was applied as spray from above the crop (92%) so that the aerial (and edible part for certain crops) are wetted. Sub-surface irrigation was less common (8%) and was only used for lettuce production (Table 2). This method avoided contact with the edible part of the crop and therefore may reduce the risk of pathogen transfer onto crops. Overhead irrigation is often highlighted as carrying a higher risk for ready-to-eat crops than sub-surface or drip systems as spray irrigation exposes the edible parts of crop directly to water. Crops with rough surfaces or leaves may also retain more water (Gerba & Choi, 2006).

The application of irrigation water was usually planned to ensure optimum crop quality and growth. The irrigation schedule varies, depending on crop types, crop water demand, soil, rainfall and weather parameters. In this study, the interval between the last application of water and harvest ranged from 4 h to 7 days. The harvest interval may affect the number of pathogens on crop surfaces as harvest interval will allow the effects of UV radiation, temperature and desiccation to reduce the pathogen load (Groves *et al*., 2002). Most farms (75%) do not treat the irrigation water as the water were tested on at least an annual basis and were deemed to be safe and do not require further treatment. On farm water treatment, to improve quality is also costly and rarely used (Groves *et al*., 2002). Two of the farms used chlorine (17%) while one farm used UV treatment (8%) to improve their irrigation water.

The frequency of testing, types of test and what to do with the results were some of the growers' concerns as surface water are subjected to temporal variability. River water quality can vary with time and a single test may not indicate the level of contamination. The time taken for water samples to be tested is another cause for concern. Growers using surface water may be forced to decide whether to irrigate or not based on the results which were tested possibly 2–3 days before (Groves *et al*., 2002). At present, all the farms tested their water for *E. coli* spp., *Salmonella* spp. and coliform, while 8% of the farms also conducted an annual heavy metal and pesticide residue analysis in their irrigation water. All the growers tested the water on at least an annual (42%), bi-annual (8%), quarterly (8%), monthly (33%) and weekly (8%) basis (Table 2).

Figure 2 (total coliform – CFU per 100 mL) and 3 (*E. coli* presumptive – CFU per 100 mL) show the microbial test results of water sources used for irrigation in the participat-

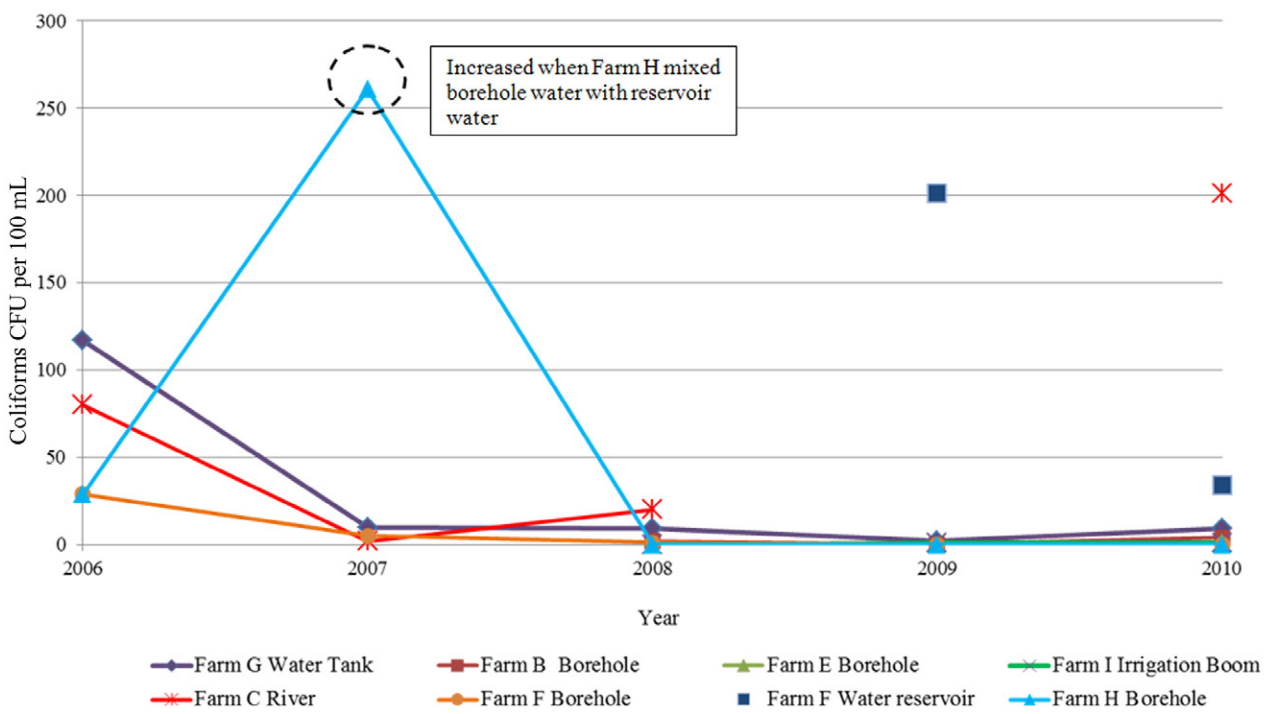

Figure 2 Total coliform (CFU per 100 mL) results from irrigation water sources of selected farms from 2006 to 2010 ($n = 8$).

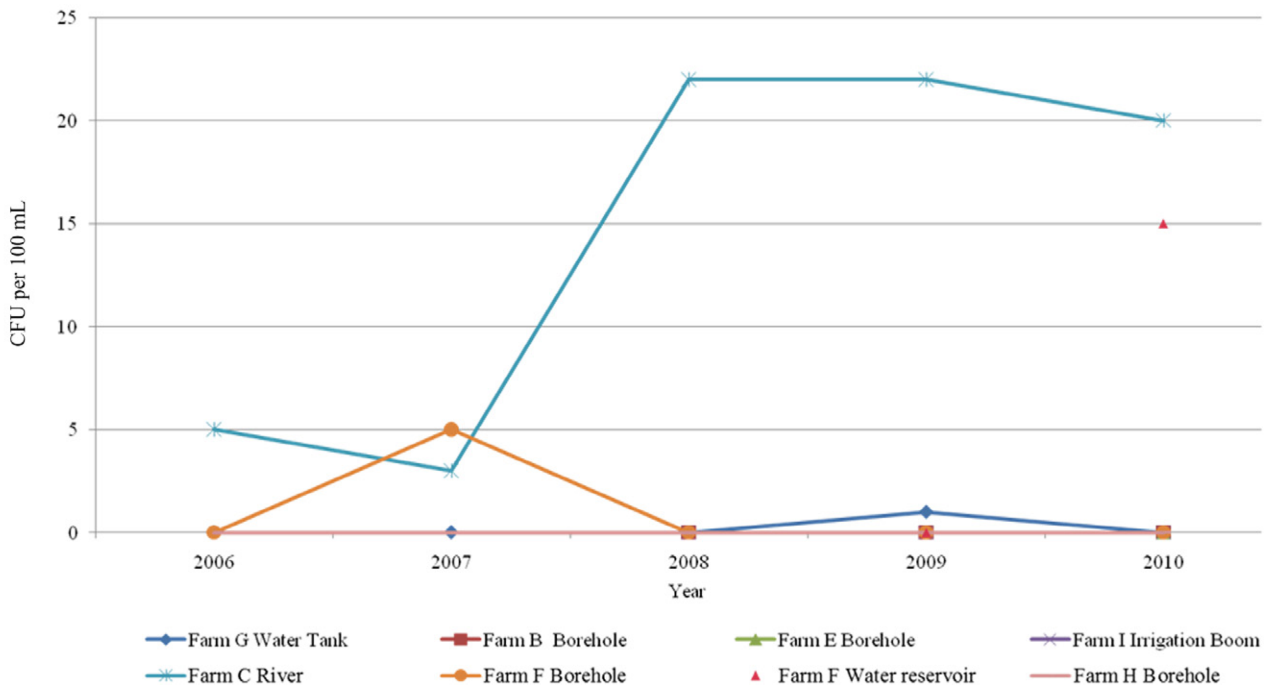

Figure 3 *Escherichia coli* (CFU per 100 mL) results from irrigation water sources of selected farms from 2006 to 2010 ($n = 8$).

ing farms. With the exception of Farm H's total coliform spike (261 CFU 100 mL^{-1}) in 2007, the water test results from the farms generally show very good microbial water quality (Figure 2). All the irrigation water test results shown were tested during the summer period. Farm H which uses borehole water faced an increase in total coliform in 2007 when they mixed their irrigation water with reservoir water. It was possible that during the time of usage, the water in the reservoir tank was at a reduced rate and this may have concentrated the number of microbes in the water. From Figure 3, Farm C which used river water for irrigation detected *E. coli* at >20 CFU mL^{-1} every summer from 2008 to 2010. However, there were no livestock farms situated within 1 mi radius of Farm C. But Farm C which utilized an on-farm reservoir (lake) may face possible contamination from wild animals attracted to the reservoir. This has reiterated the fact that surface water quality is unpredictable and subjected to temporal variability. Run-offs from livestock farms and wildlife are potential sources of contamination. Most farms used borehole water which was of very good microbial quality. None of the water tested positive for *Salmonella*. Water quality and the number of tests to be carried out to ensure water safety has always been a debate among growers. Results from this limited number of publicly available data or research suggest that the incidence of contamination of irrigation water with pathogenic bacteria is low.

Spearman's rho, $\rho = 0.59$, indicates that there was a slight correlation between type of water sources and frequency of testing. Irrigation water abstracted from rivers were tested more frequently (monthly basis) compared with boreholes (annual basis). Rangarajan *et al.* (2000) suggested underground water to be tested bi-annually while surface water (in northern climates) should be tested three times a year. But the farms in this study exceeded the recommended guidelines and worked closely with their customers and conducted tests as required by their clients. This reiterated the fact that farm food safety and quality issues are very much driven by retailers. Besides irrigation water, the use of contaminated water for washing, hydro-cooling and icing may also lead to produce contamination. According to Gagliardi *et al.* (2003), a hydro-cooler was found to be a source of faecal coliforms and faecal enterococci contamination in melon rinds. The use of ice for hydro-cooling after harvesting may be another source of contamination (Cannon *et al.*, 1991).

Manure management

Manure sourced from cattle (25%), poultry (25%), pigs (17%) and horse (8%) were used as fertilizers in five (42%) of the farms. But it was noted that these farms were a mixture of arable and horticultural crop producers, hence the manure were only spread on lower-risk crops such as cereal and sugar beet. Three of the farms stored the manure on the fields. Even though the manures were only used for lower-risk crops, however, there may be risk of run-offs and contamination to the fresh produce crops. The manure were usually spread and ploughed into soil between 6 and 11 months before the harvesting period. It is also interesting to note that all the farms were conscious of the weather and wind direction during spreading to reduce the likelihood of manure blowing downwind onto other fields. All manure (except for pigs' manure) were either composted by suppliers or 'aged' on the farm. Poultry (Farm B) and cattle manure (Farm F) were composted by suppliers. For example, the cattle manure were subjected to 70 °C for 3 days before being distributed to Farm F. Turnbull & Snoeyenbos (1973) also revealed that poultry manure stored for 2 months at 20 °C and applied to field 2 months before harvest has lower risk compared with cattle manure. The difference between poultry and cattle manure is mainly due to a more rapid die-off of pathogens in poultry manure because of the higher ammonia content.

When farmers were asked about the duration of 'ageing' (undisturbed pile) of manure, approximately 20% of the farms used manure that had been aged for 3 months and 40% for 6–12 months. The farm which used horse manure on fresh produce had 'aged' the manure for 4 years. Besides stacking, no other treatments were carried out. In this case, the growers may have a misconception about aging or composting. Aging or proper manure management is a heat pasteurization process at 60–65 °C (Kudva *et al.*, 1998). Manure composting refers to controlled aerobic and thermophilic (55–65 °C) decomposition of organic matter by microorganisms. Manure must be aerated and allowed to reach peak microbial composition in at least 3 months (Suslow *et al.*, 2003; Millner, 2009). However, self-heating of stacked manure without attention to the time and temperature needed to reduce pathogen load does not adequately meet the composting requirement (Millner, 2009). Even though the manure were only used for cereal crops, but the possibility of run-offs from the stacked manure to fresh produce fields may increase food safety risks.

Eighty percent of the farms that used manure tested the manure for *E. coli* spp. and *Salmonella* spp. In addition, 50% of the farms tested the manure for heavy metals. Sewage sludge had also been used in 17% of the farms for experimental purpose, while one of the farms used treated sewage sludge on sugar beet. At present, both these farms no longer use sewage sludge.

Animal management

A number of farms are also rearing deer (8%), cattle (8%), pigs (8%), sheep (8%) and horses (17%). All the farm animals (except for pig production) were fenced and kept away from water sources. Only 17% of the farms used farm animals such as horses or ponies in the fields, and 8% of the farms intentionally introduced animals into the crop production areas for weed control purposes or to eat residual produce after harvest. Twenty-five percent of the farms were also situated uphill (within 1 mi radius) of other livestock farms such as cattle and sheep. One farm was situated downhill (within 1 mi radius) of a 7000 cattle and fattening sheep farm. Even though the animals were fenced off, this farm faced drainage and run-offs from the livestock farm into their water source.

Various wild animals had been sighted on the farms. Birds were sighted on all the farms (100%), followed by rabbits and hares (75%), wild deer (67%), badgers (42%), foxes (42%) and bats (8%). Wild animals have been implicated as possible sources of contamination in fresh produce (Cody *et al.*, 1999; Jay *et al.*, 2007; Greene *et al.*, 2008). Although measures were taken to minimize the opportunity for produce in the field to come in contact with wild animals, in most instances it was impossible to keep wild animals out of farm land. The wild animals were discouraged and prevented from entering the fields through fencing (33%) and culling (42%). Fencing has the greatest potential to deter wild animals but requires a significant investment to build and maintain. The few farms that set up fencing were protecting vulnerable crops (e.g. young asparagus); hence fencing in this case served an economic purpose rather than for food safety. Birds posed the greatest challenge to all farms. Non-lethal methods such as using bird scarers (60%) were carried out while some farms also resorted to shooting (33%). Two nurseries switched off the vents before dusk to prevent birds from entering the glasshouses for roosting.

Seventy-five percent of the farms faced problems of faecal matter in the fields. This was mitigated by having a crop manager or supervisor who inspects the particular crop before harvesting. If faecal matter were found, the crop manager/supervisor (in 17% of the farms) will not harvest the produce that has come into direct contact with the faecal material. However, it is up to the crop manager's experience and judgment to gauge the safe distance for harvesting between the faecal matter and other fresh produce. California Leafy Greens Marketing Agreement recommended a minimum of 5-ft radius buffer distance [California Leafy Green Products Handler Marketing Agreement (LGMA, 2010)].

Table 3 Chemical treatments – fertilizer and pesticide application

Chemical treatments	(%)
Fertilizers ($n = 12$)	
Are chemical fertilizers used?	Yes (100)
Harvest interval	Between 3.5 months until the same day of harvest
Application method	Spreader (solid/granule fertilizer) – (67)
	Sprayer (liquid fertilizer) – (33)
Water source for mixing liquid fertilizers ($n = 5$)	Mains (60)
	Mains and borehole (20)
	Borehole and rainwater (20)
Pesticides ($n = 11$)	
Pesticide usage	Yes (92)
Water source for mixing pesticides ($n = 11$)	Mains (55)
	Borehole (18)
	Mains and borehole (9)
	Borehole and rainwater (9)
	Surface water (9)
What are the types of pesticides used most frequently?	Herbicide (Glyphosphate) and fungicide (boscalid + pyraclostrobin)
Application method	Self-propelled spray rig (67)
	Self-propelled spray rig and manual spray (18)
	Self-propelled spray rig with global positioning system (9)
Harvest interval	3 to 112 days
Are pesticide mixing tanks, mixing paddles and spray tanks cleaned?	Yes (100)
Are pesticides and equipment stored separately from fresh produce?	Yes (100)

Fertilizers and pesticides

All the participating farms used chemical fertilizers on their fresh produce crop. As a variety of synthetic fertilizers were used for various crops, the harvest interval (HI) varies between 3.5 months and within 24 h of harvesting. Pesticides were used in 92% of the farms and the harvest interval varies between 3 and 112 days (Table 3). Farm F also has an encouraging harvest interval policy of HI + 1 day. For example, if Farm F's harvest interval was 10 days for a particular pesticide, they will harvest the produce on the eleventh day after the application.

The Ministry of Agriculture, Fisheries and Food – MAFF Code of Practice for the Safe Use of Pesticides (currently the Pesticides Code of practice for using plant protection products 2006) – states that water used for pesticide sprays should not be taken directly from surface waters (MAFF, 1998). Approximately 55% and 36% of the farms used mains and borehole/rainwater for pesticide application while 9% used filtered surface water. Meanwhile, mains water (60%), borehole and rainwater (40%) were used to dilute liquid fertilizers. Using surface water and collected rainwater for application of pesticides and fertilizers should be carried out with precaution to reduce not only the blockages of spray nozzles but also to reduce the likelihood of contaminating the surface of fresh produce. Use of contaminated water in pesticide may contribute to produce contamination. Guan *et al*. (2005) found that *Salmonella* and *E. coli* O157:H7 were able to grow in various pesticide solutions and contaminate tomato plants when applied as spray.

Harvesting tools and method

Fifty-eight percent of the fresh produce growers harvested their crops using automated machine such as baby leaf harvester, while 67% of the farms harvest their crops by hand and automated machines. Only about 50% of the farms require their employees to wear gloves. Field worker hygiene is an important consideration in the harvesting and post-harvest operations due to the widespread use of human hands during the process. Hand contact during cutting, trimming, coring, bagging and packing is important to food safety due to the potential for cross-contamination from sick or infected farm workers to fresh produce.

Harvesting tools were washed in about 75% of the operations using mains water (67%) and borehole water (25%). But only 27% of the tools were both cleaned and sanitized. Reusable containers (harvesting bins) made from plastic (58%) and wood (42%) were used. Sixty-seven percent of these farms washed the containers using potable (64%), borehole (18%) and rainwater (9%). The containers were sent to crate washing lines (50%), pressure washed (33%) or brushed (8%). When not in use, the containers were kept inside sheds (45%), stored outside on pallets (36%), on concrete base (9%) or directly on the ground (9%) (Table 4). Some of the large equipment used to haul crops was also used for other tasks such as hauling garbage and waste. Even though a number of farms (33%) practised this, two farms stressed that they only use the equipment to transfer vegetable wastes back to the farm.

Packing/processing

Forty-two percent of the farms washed their crop before further packing, but only 25% monitored the incoming water quality. Mains, borehole and collected rainwater were used for washing. Seventeen percent of the farms recycled their washed water by reusing the washed water from the relatively cleaner to relatively dirty operations. Only 17% of the farms treated their processing water with chlorine. No

Table 4 Harvesting tools and methods

Harvesting tools and methods	(%)
Harvest method	Automated machine (58) Gloved hands (50) Bare hands (17)
Tools used for harvesting crop	Baby leaf harvester (58) Knives, scissors (50)
Are the tools cleaned each time after use?	Yes (75) No (25)
Water source used for cleaning harvest tools	Mains (67) Borehole (25) Sanitising wipes (8) None (knives are thrown away when blunt) (8)
How are the harvesting tools cleaned? (*n* = 11)	Pressure washed (45) Rinsed (18) Wiped (9) Cleaned and sanitized (27)
Are reusable harvest containers used?	Yes (100)
What materials are the harvest containers made from?	Plastic (58) Wood (42)
Are they cleaned after using?	Yes (67) No (33)
Water source used for cleaning harvest containers	Mains (64) Borehole (18) Rainwater (9)
How are they cleaned?	Pressure washed (33) Sent to crate washing line or crate supplier (50) Brushed (8) 'Washed' during primary rinsing of fresh produce (8)
How are the containers stored when not in use?	Shed (45) On pallets (36) On ground (9) On concrete base (9)
Is large harvest equipment leased or contracted out?	Yes (33) No (67)
Is equipment used to haul crops also used for other tasks such as hauling garbage, manure or waste?	Yes (33), but 17% only used it to transfer vegetable remains

Table 5 Packing/processing of fresh produce

Packing/processing	(%)
Water source for processing	Mains (17) Borehole and mains (8) Borehole (8) Rainwater and mains (8)
Are crops washed in the field?	Yes (25) No (75)
Monitoring of incoming water quality	Yes (25)
Recycling washed water	Yes (17)
Type of washing equipment	Continuous (25) Batch and continuous (8) Batch (8)
How often is washed water changed?	Daily (100)
Is disinfectant added into washing water?	Yes (17) No (83)
Is water treated with other antimicrobial agents/techniques before use (e.g. filtration/UV light)?	No (100)
Are any other wash water additives used (e.g. anti-browning, salt for slug, aphid removal agent, water softener, citric acid and carbon dioxide for pH control)?	No (100)
Is packing/processing equipment cleaned and sanitized?	Yes (100)
If yes, how often?	Daily after use (100)
Cooling	
How are the crops cooled?	Hydro vacuum (42) Cold storage (17) Hydro-cooler (8) Forced air cooler (8)
Water source used for cooling	Mains (33) Borehole (8)
How often is the cooler cleaned?	When necessary (100)
Temperature range of cooler	1–4 °C
Is ice used in the facility	Yes (8)
Source of water for ice	Mains (made from hired ice-maker machine)

other antimicrobial agents, techniques or wash water additive were used (Table 5). The most common cooling method used was vacuum cooling (42%). Only one farm sprayed its produce with chilled water. Hydro-cooling is an efficient method to remove heat, but at the same time, it may present risk of pathogen internalization as well as external contamination with pathogens. Mains water was used for this process but no disinfectant was added.

Transportation continues the job of preventing food-borne diseases by ensuring proper temperature and reducing damage potential to fresh produce. Trucks used by the farms were inspected prior to use (92%) as well as cleaned and sanitized (83%). Only 75% transported the produce in refrigerated trucks where temperature was usually monitored with an in-built temperature monitoring device (Table 6).

Workers' health and hygiene training

The number of full-time workers ranged from 2 to 120 staff, while seasonal workers were numbered at 2 to 185. The seasonal workers consist of Bulgarian, Latvian, Lithuanian, Polish, Portuguese and other Eastern Europeans. This is

Table 6 Transportation

Transportation	(%)
Is vehicle used to transport fresh produce also used to transport animals, manure or other sources?	Yes (8)
Is vehicle cleaned and sanitized prior to being used for fresh produce	Yes (83) Cleaned but not sanitized (8) No (8)
Inspected prior to use	Yes (92) No (8)
Is product temperature monitored while being transported?	Yes (75) No (17) Not require (8)
How is the temperature monitored?	Portable thermometer (25) In-built temperature monitoring device (67)

Table 7 Workers' health and hygiene

Workers	(%)
Full-time workers	
Is there health and hygiene training for full-time workers?	Yes (83) No (17)
How often is the training?	Once (during induction) (25) Annually (42) Every 3 years (17) None (17)
Seasonal workers	
Is there health and hygiene training for seasonal workers?	Yes (83) No (17)
If yes, how often is the training?	Once (during induction) (83) Not applicable (no seasonal workers) (17)
Senior staff	
Are senior or experienced staffs given periodic refresher sessions or follow-up trainings?	Yes (83) No (17)
Sanitary facilities	
What toilet facilities are provided for workers?	Indoor (33) Indoor and portable units (50) Portable units (17)
Where are the portable toilets located?	On headlands (86) On trailer (14)
Where are the portable toilets serviced?	At end of fields (for easy access and service) (100)
How often are the portable toilets serviced?	Once a week (71) Twice a week (14) Once a week during peak season, and once a fortnight in winter (14)

consistent with other studies (Cross *et al*., 2008, 2009) where farm worker populations were dominated by migrant foreign workers. The induction trainings were conducted for all new seasonal workers and the worker who was most proficient in English was encouraged to translate and train the rest of his/her colleagues. In addition, some farms have full-time East European staff or staff well versed in East European languages, hence these farms had an added advantage in training their new workers. It is highly commended that Horticultural Development Company (HDC), UK provides training DVD to farms to ensure the production of safe and quality produce. However, only 17% of the farms used the training DVDs provided by HDC. This training DVD is highly recommended as it provides health and hygiene training for farmers in eight languages: Bulgarian, Chinese, Czech, Latvian, Lithuanian, Polish, Romanian and Russian.

Seventeen percent of the farms did not carry out health and hygiene training for their full-time and seasonal workers. Forty-two percent of the farms required their full-time workers to undergo annual health and hygiene training, 25% were only trained once (during induction), and 17% were re-trained every 3 years. Meanwhile, seasonal workers were only given training once (during induction) in 83% of the farms. All farm workers (from the surveyed farms) were required to sign a health policy or food safety induction sheet on their first day of work to ensure that they fully comply with the health and safety requirements. The workers were advised to seek medical attention and to report to the management/supervisor if ill. Workers with infected wounds or cases of diarrhoea were prevented from coming to work (8%) or transferred to another department without direct contact with produce (92%). Senior and experienced staffs were given annual refreshers' training (67%), every 3 years (17%), or were only trained once (during induction) (8%) (Table 7).

The health and hygiene of all workers who handle fresh produce, whether it is on a farm or in the packinghouse, markets, grocery store or foodservice establishment, is of significant importance in preventing produce-associated outbreaks. Organisms such as Hepatitis A virus (Wheeler *et al*., 2005) and norovirus (Falkenhorst *et al*., 2005) had been implicated to spread to produce via the faecal-oral route of transmission from infected workers who work when they are ill. One of the best strategies for preventing contamination by workers is a well-designed and well-delivered education and training programme (Gravani, 2009).

It is interesting to note that the study conducted by Cross *et al*. (2008, 2009) regarding the health of workers in local horticulture farms in the UK was found to be lower than the UK population norm and was also significantly lower when compared with Kenyan and Ugandan export workers. Cross *et al*. (2009) suggested that this may be due to the accommodation and social conditions that were worse than average in the UK and below what they experienced in their home countries, hence contributing to their reduced health status. Official estimates suggest that there were 61 700 temporary workers employed in agriculture and horticulture in the UK in 2009 (DEFRA, 2009). A key question is if the health of migrant farm workers is lower, will this affect the safety and quality of crop production? This will require longitudinal studies on the health of migrant workers (and crop production in UK) prior to them entering the UK market, and for some time after they have been in this sector.

Traceability and internal audits

In January 2005, traceability became a mandatory requirement for food and feed supplies (Regulation 178/2002) (EU, 2002). All farms have an established traceability system in place. The farms have extensive documentation and were able to trace back fresh produce to the specific fields grown and operators who handled the produce within 2 to 4 h. All farms were able to trace back the details for all crops except for one farm which grew asparagus. In addition to the traceability audits required by their customers, internal audits and traceability exercises were carried out at least once a year. These farms supply to large retailers and were certified either by the retailers or industry standards (such as BRC or GlobalGAP). In this case, the traceability adoption at the farm level was high due to the compliance with the regulatory and suppliers' requirements.

Limitations of sampling strategy

There were substantial difficulties associated with obtaining a representative sample of farms. In an ideal experimental design, a total of 62 fresh produce farms (out of 170) were required in the survey sample. As the nature of sample recruitment reflected the desire of the farmer/farm manager to participate in the study, it was not possible to achieve the number of samples. There were several reasons to this limitation. First, there was no easily accessible database describing the characteristics and contact details of all registered ready-to-eat fresh producer growers. Second, farmers may be overwhelmed with documentation and paperwork and did not have time to accommodate more research on their farms or to answer the questionnaire. This is in agreement with Cross *et al*. (2009) who determined that the participation of farms was ultimately decided by the attitude of the farmer, and also the quality of the relationship they had established with the research institution.

Conclusion

The findings in this study suggested that the vast majority of the participating fresh produce growers generally have good perceptions and practices in farm food safety. This reiterates the fact that the studied farms practised good agricultural practices which lead to continuous safety and quality assurance of the crops. In addition, the support given by produce organization (e.g. HDC) and strict public and private food standards were imperative to the production of safe fresh produce. To our knowledge, this study was one of the first few to report on the farm food safety practices of participating farms across different geographical locations in the UK. However, because of the limited nature of this study, the findings should not be extrapolated to represent the whole region. This paper has benefited greatly from the insights and information from the farmers and serves as a preliminary snapshot of current farm food safety practices. Each production stage plays a major role in ensuring safe produce enters the food chain and the selected fresh produce farms have aptly demonstrated good agricultural practices. In light of what has been concluded so far, the author suggests that future farm food safety studies on HACCP-based and risk assessments in primary produce, microbial load in farm inputs (e.g. irrigation water, manure for organic crops, farm workers, fertilizers and pesticides), and fresh produce and behavioural sciences of farmers and workers will be beneficial to identify potential contamination point sources and to understand the motivational and environmental factors encouraging farm food safety practices.

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