Video Observation of Hand-Hygiene Compliance in a Manufacturer of Ready-To-Eat Pie and Pastry Products

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Food-handler hand-hygiene can be a contributory factor for foodborne illness. Cognitive data (knowledge/attitudes/self-reported practices), while informative, are not indicative of behavior, and are subject to biases. Consequently, observation of behavior is superior to survey data. However, researcher presence in direct-observation increases reactivity, whereas video-observation gives comprehensive analysis over a longer period, furthermore, familiarity reduces reactivity. Although video-observation, has been used to assess food safety at retail/foodservice, this valuable method is under-utilized in food-manufacturing environments. For the study, footage (24h) was reviewed to assess compliance in a food-manufacturing site with company protocol. Video-observation of food-handlers entering production (*n*=674) were assessed, upon 70 occasions no attempt to implement hand-hygiene was observed. Of attempted hand-hygiene practices (*n*=604), only 2% implemented compliant practices. Although 78% of attempts utilized soap, only 42% included sanitizer. Duration ranged from 1–69s (Median 17s). The study provides hand-hygiene data in an area that observational data is seldom captured.

Keywords:

Observation, behavior, food-handler, food industry, ready-to-eat, hand-hygiene,

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Main introduction.

The food-handler is often identified as one of the key causes of foodborne illness (Roberts 1990). Food-handlers can cause contamination of the food production environment through the transmission of pathogens from hands to surfaces and food products due to poor hand-hygiene practices (Lambrechts et al. 2014), consequently food-handler hand-hygiene has been frequently cited as a significant contributory factor for foodborne illness in restaurant-associated outbreaks (Gould et al. 2013). Indeed, adequate hand-hygiene is one of the most effective ways to prevent the spread of pathogens (Health Protection Agency 2013), and will assist efforts to reduce the risk of cross-contamination in the food-manufacturing environment.

Food premises are required by law to provide adequate and suitably located and designed facilities for hand-hygiene practices (European Parliament 2004). The British Retail Consortium (BRC) Global Standard for Food Safety sets out the requirements for food manufacturers to achieve certification against the standard. The framework for which, assists manufacturers to meet product quality obligations and to comply with legislative requirements for food safety to ensure product safety. The standard requires manufacturer's personal hygiene standards to be developed to minimize the risk of product contamination from personnel, and must be adopted by all personnel to the production facility (British Retail Consortium 2015). The manufacturer is required to provide suitable and sufficient hand-washing facilities for staff, at entry points, and at other appropriate points within production areas. Such hand-wash facilities should provide sufficient quantity of water at a suitable temperature, liquid soap, single use towels or suitably designed and located air driers, water taps with hand-free operation along with advisory signs to prompt the implementation of hand-washing (BRC Global Standard for Food Safety, Clause 4.8.6, Issue 7 (British Retail Consortium 2015)).

UK hand-hygiene guidelines for best practice recommend that a safe hand-hygiene procedure should include the wetting of hands using warm water (~40°C), before dispensing 3–5 ml liquid soap containing a biocide. Hands should be rubbed together vigorously for 15-30 seconds, ensuring that all parts of the hands on both sides, up to the wrists, around thumbs, fingers and nails are all rubbed. Hand should be rinsed with clean water and dried thoroughly, followed by the application of a hand sanitizer (Taylor and Holah 2000; Taylor et al. 2000).

Food businesses are also required by law, to supervise, instruct and/or provide training for food-handlers in aspects of food hygiene, such as hand-hygiene, to enable them to ensure food safety in line with their job role (European Parliament 2004). As training can be reliant upon knowledge acquisition and not application of behavior (Lelieveld et al. 2016), the food safety knowledge of trained food-handlers does not always result in the implementation of safe food behaviors (Brannon et al. 2009). Food-handlers may demonstrate awareness of food safety but often fail to translate knowledge into safe practices (Rossi et al. 2016). It must be considered that delivery of training and provision of suitable facilities alone does not guarantee that staff will implement adequate hand-hygiene practices at all times. Consequently, there is a need to adopt methods to assess hand-hygiene compliance in food-manufacturing environments.

Smith (2009) suggested that only 55% of food-handlers report to follow a standardized hand-hygiene technique. As discussed in consumer food safety research (Evans and Redmond 2014), although insightful, assessing cognitive measures of food safety such as knowledge and self-reported practices have limitations and are subject to biases. Self-reported practices can be subject to social desirability bias, whereby behaviors perceived to be favorable are over reported and undesirable behaviors are underreported (Hebert et al. 1995; Barker et al. 2002; Dharod et al. 2007). Considerable discrepancies have been determined between self-reported practices and actual behaviors (Clayton et al. 2002; Clayton et al. 2003; Redmond and Griffith 2003). Collation of food-handler knowledge and attitudes regarding hand-

hygiene are informative, however such data are not indicative of actual behavior, therefore there is a need to observe the behavior of food-handlers to evaluate hand-hygiene compliance in the industry.

Its suggested that data relating to the hand-hygiene compliance rates in the food-manufacturing industry are particularly limited (Taylor et al. 2000). As discussed by Taylor and Holah, it is unclear what the compliance rates are in the food industry, as many published works that focus upon hand-hygiene relate to the health care sector (Taylor and Holah 2000). However in recent years, a number of research studies utilizing behavioral observation methods have focused upon hand-hygiene compliance of professional food-handlers in retail (Lubran et al. 2010) and foodservice settings (Worsfold and Griffith 2003; Clayton and Griffith 2004; Green et al. 2006; Chapman et al. 2013; Rajagopal and Strohbehn 2013; Arendt et al. 2015). In such establishments, hand-hygiene malpractices are reported to occur more frequently than malpractices for cleaning or utensil separation during food-handling (Clayton and Griffith 2004). Although observation of behavior has been utilized to determine the short term impact of signage upon the hand hygiene practices of employees in a raw poultry processing plant (Schroeder et al. 2016), there is a particular lack of data relating to the hand-hygiene compliance of food-handlers in the food-manufacturing industry. Consequently, the aim of this study was to address this lack of data, by utilizing a video-observation study to evaluate food-handler hand-hygiene practices and compliance to company protocol in a manufacturer of ready-to-eat (RTE) food products.

Material and methods.

Sample and instrument development.

A large UK based food-manufacturing business that produces chilled and frozen RTE pies, pasties, and savory baked products for retail and food service outlets, was contacted regarding involvement in the study. The company was selected due to the production process of its products, which included the preparation of pastry, mincing and dicing of meat, preparation

and cooking of fillings, and the assembly, baking, chilling and packing of the product. The researchers were aware that recording cameras were used throughout the production site, but were not utilized to observe hand-hygiene practices. A briefing visit was conducted prior to commencement of observation of hand-hygiene practices. The aims and objectives of the project were discussed with the managing director, technical manager, QA and training managers. The business gave consent for the researcher to access pre-recorded video footage of the hand-hygiene facilities by completing a consent form.

Development of a hand-hygiene observation checklist.

The company hand-hygiene procedure required staff to implement handwashing with soap and water, based upon the World Health Organization technique (World Health Organization n.d.). The required steps to be implemented by staff prior to proceeding into the production area, for a hand-hygiene attempt to be classed as 'compliant' included:

- Wet hands with water
- Apply enough soap to cover all surfaces of the hands
- Rub hands palm to palm, rub right palm over left dorsum with interlaced fingers and vice versa, rub palm to palm with fingers interlaced, rub backs of fingers to opposing palms with fingers interlocked, rotational rubbing of left thumb clasped in right palm and vice versa, and rotational rubbing, backwards and forwards with clasped fingers of right hand in left palm and vice versa
- Rinse hands with water
- Dry thoroughly with a single use paper towel
- Apply hand sanitizer

An observation checklist was developed based upon the hand-hygiene protocol of the business using a Qualtrics (Qualtrics 2017, Provo, Utah, USA), database to allow for electronic data entry using a cloud infrastructure. The electronic checklist was piloted using

footage from the business (*n*=100 observations) which resulted in amendments to the flow of the checklist and the addition of variables to capture the implementation of behavioral malpractices. The finalized checklist captured every occasion a staff member passed through the hygiene hall (located between the staff changing facilities and food production area). The checklist recorded if the staff were entering or exiting the food production area, if a hand-hygiene attempt was implemented, the start time and end time of the attempt (to calculate duration), information regarding adequacy of personal protective equipment (PPE), adequacy and compliance of hand-hygiene attempt and observed malpractices. Gender and the job-role of staff (food-handlers or hygiene/engineering) was identified through different uniform.

Observation of behavior.

As discussed by Egan et al., reliable data from the workplace is essential to develop, implement and evaluate the effectiveness of food hygiene training, however data obtained by direct observation has limitations, such as altered behaviors in the presence of the observer (reactivity bias) to present what is perceived to be a more desirable behavior, known as the Hawthorne effect (Egan et al. 2007). In food industry-based research, the presence of others, particularly managerial staff, is reported to improve the food safety practices of staff in food environments (Egan et al. 2007).

The use of cameras to record food safety practices can give a more comprehensive analysis over a longer period of time. Although those being observed may present behaviors that are perceived to be more desirable behaviors, however such reactivity is reduced over prolonged periods due to familiarity with camera equipment. Furthermore, such video observation can determine baseline practices and compare to post-intervention practices to give a true evaluation of effectiveness.

To minimize the Hawthorne Effect in the present study, food-handlers, hygiene and engineering staff were not informed of the project as the researcher reviewed previously recorded footage. The cameras in the hygiene hall of the business had been in location for

over 3 years; cameras were not unique to the hygiene hall and were located throughout the business. Although staff were informed during pre-employment induction that cameras may be used to monitor hygiene practices, they were more commonly used for security purposes.

Data collection, storage and analysis.

Observation of footage from the hygiene hall were undertaken over a period of 24 hours, this incorporated a specified day of the week that the business reported would have a high volume of production. Observation commenced from 00:00:00 through to 23:59:59, the footage viewing software allowed for periods of 'no activity' to be skipped. The footage could be viewed at a regular and a reduced speed. Each member of staff that proceeded into the hygiene hall either entering or exiting the food production area were observed and recorded using the electronic checklist. The time staff members commenced hand-hygiene actions were recorded, each element of the hand-hygiene protocol that was complied with was recorded. End time was recorded to calculated hand wash duration. Inclusion of each required element enabled determination of hand-hygiene attempts that were 'compliant' with the company protocol. The electronic checklist created a database of all observations. Following completion, the entire database of 1333 entries, was checked and assessed to ensure no missing values. A 10% sample of the entries were randomly checked by the researcher to ensure intra-operator reliability.

Ethical approval.

Ethical approval for the study was granted by the Research and Ethics Committee of the Cardiff School of Health Sciences at Cardiff Metropolitan University. Project reference number: 8152.

Results.

In total, 1333 entries in to the hygiene hall were observed over a period of 24 hours, this

included 674 occurrences when staff entered the production area and 659 occurrences when staff exited the production area.

Hand-hygiene practices when entering and exiting the production area.

The company hand-hygiene procedure required staff to implement handwashing with soap and water, with vigorous rubbing of hands and fingers based upon the World Health Organization technique (World Health Organization n.d.), dry thoroughly with paper towel (totaling 40 – 60 seconds) and applying hand sanitizer prior to entering the production area. At the point of entry, on 70 occasions (10.4% of those entering), staff were observed failing to attempt the implementation of a hand-hygiene attempt. A significant difference was determined at point of exit, where by the majority (71.3%) made no attempt to implement hand-hygiene practices when exiting than when entering (10.4%) the production area (X^2 (1, n = 1333) = 499.57, p <0.001, phi = 0.614). Of the 188 occasions that hand-hygiene attempts occurred, 99.5% were not compliant; only one attempt was determined to be compliant with protocol. Many of those leaving the production area determined the need for implementing hand-hygiene practices by means of a visual inspection of hands up on exiting. All further analysis focuses on hand-hygiene practices prior to entering the production area only.

Adequacy of hand-hygiene practices.

Of the 604 attempts to implement hand-hygiene practices prior to entering production, only 2.2% (13 attempts) were determined to be compliant with the company protocol. Although not compliant, 8.8% of attempts were ‘adequate’ (in-line with the recommended hand-hygiene procedure outlined in guidelines for best practice (Taylor et al. 2000)). Consequently, the majority (97.8%) of hand-hygiene attempts before entering production were not compliant with the company protocol.

Despite 77.9% of attempts used soap to wash hands, only 45.3% of attempts wetted hands with water prior to applying soap as described in the company protocol. Furthermore, analysis

of observed methods established that although employees were observed rubbing hands palm to palm in 73.7% of attempts, there was a lack of hand rubbing practices in compliance with the protocol. As indicated in Table 1, rubbing the backs of hands, between fingers and thumbs were often neglected during hand-hygiene practices, observed in only 1.5 – 9.8% of attempts.

[Table 1 near here]

Less than half (41.6%) of attempts included the use of sanitizer. On 13 occasions, staff were observed failing to implement component elements of hand-hygiene (handwashing and drying) and used hand sanitizer only, prior to entering production.

Duration of hand-hygiene practices.

The duration of hand-hygiene practices (from wetting hands through to drying of hands), were recorded. The company protocol calls for the duration of the entire procedure to take 40 – 60 seconds. Observed hand-hygiene duration ranged from 1 – 69 seconds. The average recorded duration of observed hand-hygiene practices was 20 seconds. In total, the duration of only 6.3% of attempts were compliant with company protocol (Table 2).

[Table 2 near here]

Comparison of hand-hygiene practices between staff.

No significant difference ($p>0.05$) in the duration of hand-hygiene practices was determined according to gender (males: Md = 18 seconds, n = 722 and females: Md = 18 seconds, n = 50). However, a significant difference ($p<0.05$) in the duration of hand-hygiene practices according to staff roles was determined. When entering production, food-handlers (identifiable in white overalls) were observed implementing statistically significant longer durations of hand-hygiene practices (Md = 19 seconds, n = 456) than engineering and hygiene staff (identifiable in blue overalls) (Md = 15 seconds, n = 135) (U = 25066.5, z = -3.281, p <0.001, r = 0.12). Furthermore, as indicated in Table 3, it was determined that engineering/hygiene staff were significantly less likely (p <0.05) to implement hand-hygiene

practices detailed on the company protocol including wetting hands first, using soap, rubbing hands palm to palm, and were more likely to fail to implement any hand-hygiene practices.

[Table 3 near here]

Use of personal protective equipment (PPE).

The company protocol required staff to put on hairnets and snoods prior to putting on overalls and proceeding to the hygiene hall prior to entering the production area. The company personal hygiene rules required *"hairnets to be worn correctly to provide maximum possible coverage of head hair, all hair must be contained in hairnets and snoods must be worn over the nose to completely cover facial hair, beards and moustaches"*. On 1.2% of occasions entering production, staff were observed failing to implement adequate use of PPE. Hairnets were worn inadequately on three occasions, snoods were also worn inadequately on three occasions and on two occasions snoods were not worn by those requiring snoods. Hygiene malpractices observed prior to entering production included readjusting hairnets/snoods and touching hair or face after implementing hand-hygiene practices (9.3%), and putting a snood on after hand-hygiene attempt (8.9%). Such practices may have occurred due to the practical positioning of the snood dispenser being located next to the door to enter production, as opposed to in the changing facilities. There is a need to ensure that PPE is put on in the correct order, this could be overcome by relocation of the snood dispenser. Although hair may not be a significant risk to the microbial safety of the food products, inadequately covered hair (resulting from failure to use or put on hairnets/snoods in-line with the correct changing procedure) can result in the physical contamination of food, thus resulting in food products of a substandard quality. Workforce flow through the hygiene hall in to the production area should encourage positive hygiene behaviors

Hygienic design of hand-hygiene facilities.

The hand-hygiene facilities were located in the hygiene hall, positioned between the staff

changing facilities and the food production area. The hand-hygiene facilities contained two long handwashing troughs located on two parallel walls, each with 10 knee-operated water outlets. Each trough was identically equipped with two soap dispensers, two hand sanitizer dispensers, and two paper towel dispensers that were located above each handwashing trough as illustrated in Figure 1, the snood dispenser was located next to the door that entered into the food production area.

[Figure 1 near here]

Some of the behavioral malpractices observed may be a result of the design of the hygiene hall. Given that only two soap dispensers are provided for ten water outlets, on a few occasions employees at the three water dispensers on the right hand side of the trough on the right, were observed gesturing to reach for soap, however failing to do so as a soap dispenser was not conveniently located. On one occasion, a food-handler was observed attempting to apply soap, however the towel dispenser and sanitizer were closest, the employee looked for soap dispenser, looked around, but just dried hands following rinsing under water. Location is critical to assist in the implementation of hand-hygiene practices, the majority of those seen using sanitizer were observed using the dispenser located closest to the door entering production. However, there is a need to explore if the presence of others influence the use of hand sanitizer following a hand-hygiene attempt. Indeed, healthcare research has determined that the presence of other workers is associated with higher hand-hygiene adherence rates (Monsalve et al. 2014).

During production, the four paper towel dispensers became empty, consequently staff were observed implementing hand-drying malpractices during the 58 minutes before the paper towel supply was replenished. Observed malpractices including; drying hands on PPE and entering production without drying hands. Lots of communication and frustration was observed staff in the hygiene hall regarding the lack of paper towels, however no employees were observed replenishing paper towel supply, which remained empty until a hygiene

operative checked the dispensers as part of their routine cleaning checks. The provision of suitable and sufficient hand-washing facilities and equipment is likely to impact upon hand-hygiene practices, the absence of such materials is a barrier to adequate practices compliant with the company protocol.

The design of the bin (side-entry bin) intended for disposal of used paper towel post hand-hygiene, may increase the likelihood of contact, hand contact with the bin was observed on five occasions following hand-hygiene practices, an open top, or foot-operated bin may reduce the likelihood of hand contact. Contact with the bin following hand-hygiene practices may result in the re-contamination of hands. Many employees were observed blowing noses in the paper towel used to dry hands after implementing handwashing, with no further hand-hygiene practice implemented following nose blowing prior to entering the food production area.

Cleaning of hand-hygiene facilities.

On various occasions during the 24-hour observation period, hygiene operatives cleaned the hygiene hall. The cleaning undertaken by each hygiene operative took a different approach. Observed cleaning practices observed in the hygiene hall were not compliant with the company 'instruction card for cleaning hand-hygiene facilities'. The numbered method was not followed in the order specified by the company, which starts with checking and replenishing supplies prior to washing and drying of all dispensers paying particular attention to the areas that personnel touch to operate. General observations included that contact time for use of sanitizer spray was not adhered to, and although all paper, soap and sanitizer dispenser units were wiped, the specific hand contact areas of such dispensers were not cleaned. Cloths were used to wipe the bin prior to wiping the handwashing trough and water outlets. Observations suggest that the cleaning of the hygiene hall is not maximizing the potential for hand-hygiene.

Discussion.

Although a vast body of research exists in relation to food-handler food safety, a lack of research conducted in food-manufacturing environments is evident, with the majority of work focus upon retail and foodservice settings. Additionally, the majority of research has incorporated the measures of food safety knowledge and self-reported practices; with a lack of observational data. A narrative review of twenty food-safety research studies of professional food-handlers, established the majority of studies (70%) were from foodservice and retail establishments; fewer studies were conducted in manufacturing and processing environments (10%). Survey methods of data collection were widely applied, including self-completed questionnaires (80%) and interviews (35%) indicating that observation of behavior was less frequently used (Evans and Evatt 2018). With such findings suggesting a lack of food industry focused observational data there is a need for an in-depth review of food-handler food safety studies to consolidate the data conducted in food production environments and to facilitate a comparison of differences between food-handlers in different food environments and between utilized data collection methods and measures.

Smigic et al. (2016) suggested that food safety knowledge is significantly better among food-handlers in food-manufacturing environments than those at retail outlets. However, despite evident knowledge and positive attitudes, the self-reported food safety practices of food-handlers in food-manufacturing environments, such as in meat processing plants, are reported to be not acceptable (Ansari-Lari et al. 2010). However, given that self-reported food safety practices, knowledge and attitudes do not concur with food-handling behaviors, there is a need for observed behavioral studies (Ansari-Lari et al. 2010).

Observed hand-hygiene practices.

More frequent hand-hygiene attempts were observed prior to entering production, compared to exiting production, suggests an awareness of the need for hand-hygiene practices and illustrates employees attempt to comply with company protocol. Although 89.6% of those entering production were observed attempting to implement a hand-hygiene practice prior to

entering production, the vast majority of attempts (97.8%) were not compliant with company protocol. Observation of foodservice employees has determined hand-hygiene compliance of 47 – 75% when employees were starting their shift or returning to the work area (York et al. 2009).

Previous research involving observation of food-handlers in foodservice establishments determined that 8-12% of hand-hygiene attempts failed to use soap (of 1,096 hand-hygiene attempts, 87 failures to use soap when soap was present, 44 occasions when no soap was present) (Clayton and Griffith 2004). Similarly, research conducted with grocery store food-handlers determined that 15% of attempts did not use soap (Robertson et al. 2013). Although industry based behavioral research has observed <92% of employees using soap (Schroeder et al. 2016), in this present study, 22.1% of attempts prior to entering production failed to use soap. Failure to use soap to implement hand-hygiene practices can have potential implications for food safety as handwashing with soap and water is more effective for the removal of bacteria from hands than with water alone (Burton et al. 2011).

The time taken to wash hands and the degree of friction generated during lathering are more important than water temperature for removing soil and microorganisms (Todd et al. 2010). Previous research has determined that 29% of handwashing attempts by grocery store food-handlers did not meet the recommended time (Robertson et al. 2013). Whereas only 44% of food service employees' have been observed vigorously scrubbing hands for at least 20 seconds (York et al. 2009), however, in this current study, 93.7% of attempts were not compliant with the duration specified on the company protocol (40-60 seconds) and attempts frequently failed to include rubbing the back of hands, between fingers and around thumbs. An assessment of hygiene practices of food-handlers in retail establishments established that food-handlers who washed their hands for less than ten seconds had higher counts of aerobic mesophiles and staphylococci than those who washed for >10 seconds (Fawzi et al. 2009).

Drying of hands is a vital part of hand-hygiene, as hands that remain damp are able to transfer microorganisms (which may remain following an inadequate hand-hygiene attempt) to food and food contact surfaces (Taylor et al. 2000). In previous research with food-handlers in food service establishments, the lack of proper hand drying with a paper towel contributed to 93% of observed incorrect hand-hygiene events (Chapman et al. 2010). Although 83.4% of attempts by employees in this study implemented drying using single use paper towel, hand-drying malpractices were observed, whereby, hands were not dried before entering production or were dried on PPE. Such malpractices can have implications for food safety.

When combined with handwashing, the use of sanitizer significantly enhances the hygiene process (Michaels et al. 2003). In this study 58.4% of attempts by employees failed to include the use of sanitizer, despite the company protocol requiring employees to apply hand sanitizer prior to proceeding into the production area. Currently, there is a lack of data detailing the awareness, attitudes, self-reported use or observed utilization of hand sanitizer among food-handlers in food-manufacturing research to allow comparison. It is widely accepted that there is a need to maximize hand-hygiene practices by utilizing hand sanitizer after handwashing and drying to ensure food safety, further research regarding food-handler cognition and behavior relating to sanitizer use is needed.

Differences between staff.

The significant differences between the observed hand-hygiene practices of food production staff and hygiene/engineering operatives are of concern. The UK Food Standards Agency define the term “food-handler” to include anyone who may touch food contact surfaces or other surfaces in rooms where open food is handled (Food Standards Agency 2009). This is because they can also contaminate food by spreading bacteria to surfaces that food will come into contact with, and should therefore include cleaners and maintenance staff (Food Standards Agency 2009). Although the company in this study provided the same food safety training to all staff members, findings suggest a need for targeted hand-hygiene

education/training as food safety subcultures may exist within the company. Manning (2017) propose that four food safety subcultures exist within food-manufacturing environments, which include; executive, operations, engineering, and technical/quality. However, to develop bespoke training (created for a specific user or purpose), for different teams of employees based on job responsibility and priorities, there is a need to explore any cultural and attitudinal differences that may exist between food production staff and hygiene/engineering staff. Understanding the interaction of these subcultures is critical to prevent a potential food safety incident (Manning 2017). No significant difference ($p>0.05$) in the hand-hygiene practices of staff were determined according to gender in this study.

Hand-hygiene facilities.

The BRC standard requires cleaning systems to be in place to ensure appropriate standards of hygiene are maintained at all times to reduce the risk of product contamination (British Retail Consortium 2015). The cleaning undertaken in the hygiene hall by hygiene operatives in this study was not compliant with company protocol. There is a need to ensure adequate cleaning of hand-hygiene facilities, particularly as handwashing sinks can be sources of pathogenic bacteria (Fawzi et al. 2009), indeed, greater sink usage is associated with higher levels of bacterial contamination of the sink (Cloutman-Green et al. 2014). Contamination of hand contact surfaces, such as hand-hygiene equipment, can be a reservoir for contamination, which could result in the contamination of hands during or after hand-hygiene practices (Griffith et al. 2003).

The hygienic design of food processing facilities is central to the manufacture of safe products (Holah and Lelieveld 2011). There is much activity in relation to the hygienic design of food production environments and the impact on food safety among international special interest groups such as the European Hygienic Engineering & Design Group (EHEDG), 3A Sanitary Standards Inc. and the National Sanitation Foundation (NSF) International (Schmidt 2012). Although much of this interest relates to engineering and design of equipment

manufacture and contact materials, there is a need to consider the potential impact of the physical workplace environment, such as the hand-hygiene facilities, can have an impact upon employee behavior (Lelieveld et al. 2016). Failure to provide appropriate facilities may result in employees perceiving barriers towards the implementation of adequate hand-hygiene practices (Lelieveld et al. 2016). Findings from this study suggest that the layout of the hygiene hall may have been a contributory factor to the observed hand-hygiene malpractices. Observed behaviors potentially influenced by layout of hygiene hall included putting on a snood after hand-hygiene practice due to the location of the snood dispenser and failure to use soap as proximity of the soap dispenser was not within arm's reach of the water outlet. Healthcare research indicates the important role of sink location in hand-hygiene compliance (Cloutman-Green et al. 2014; Zellmer et al. 2015), thus there is a need to explore the impact upon hygiene facility layout upon hand-hygiene practices in a food-manufacturing environment and the potential implications for food safety.

There is a need to explore potential methods to improve hand-hygiene compliance within the business, such as investment in technology that prevent food-handlers accessing production without using hand-hygiene equipment. However, staff may continue attempting to 'cut-corners'. Investing in effective training interventions and efforts to improve the food safety culture of the business, and enable suitable assessment methods to continuously evaluate and monitor hand-hygiene compliance, may be of greater benefit than investing in technology alone. Investment in advanced hand-hygiene equipment alone may not ensure that employees will wash hands adequately. Food safety practices will only be implemented given adequate resources and an appropriate food safety culture (Clayton et al., 2002). The involvement and engagement of stakeholders in the development of a Theory of Change for handwashing is said to be critical for understanding promotional programmes to enable behavior change (De Buck et al. 2018).

Bespoke training needs to ensure different teams within the business have a clear understanding of the potential risk of their implementation of inadequate hand-hygiene practices and to realize their individual responsibilities for ensuring food safety. There is a need to conduct subcultural research to identify any potential differences in the perceptions of risk, control and responsibility and hygiene consciousness between food-handlers and engineering/hygiene employees.

Limitations.

Potential limitations of the study include that data presented may not be indicative of the entire food production industry, however this study gives a novel snapshot of one company at a specific point in time that identifies and highlights the need for training. Although the study gives insight to the hand-hygiene practices of food-handlers, hygiene and engineering staff in a food-manufacturing environment prior to entering production, data relating specifically to hand-hygiene practices during production are not captured. Monitoring operatives washing hands after they have become potentially contaminated during production is less easy (Taylor et al. 2000), consequently there is a need for research detailing the occasions at which hand-hygiene practices are implemented during production and exploring the motivations and barriers to do so.

Conclusions.

Cumulatively, this study has facilitated an in-depth observational assessment of hand-hygiene practices at a UK manufacturer of RTE cooked meat products. Although the manufacturer had cameras recording activity at hand-hygiene facilities, the manufacturer did not have the resource/time to conducted frequent, structured observation of footage to assess hand-hygiene practices. Utilizing the prerecorded footage from the company may have reduced potential reactivity bias in this type of research.

The study provides data of current hand-hygiene practices and identification of site-specific issues to inform the development of an intervention to improve hand-hygiene practices. Duration of observed hand-hygiene practices did not meet the duration specified in the company protocol, vigorous rubbing of hands and fingers was seldom observed and failure to utilize sanitizer was widespread. Consequently, only 2% of observed hand-hygiene attempts prior to entering production were compliant with protocol.

Completion of this study has identified the need for further research to explore potential barriers that exist for staff to adequately implement hand-hygiene practices, including:

- Determination of production staff (food-handlers, hygiene and engineers) cognition in relation to hand-hygiene, including knowledge, attitudes, self-reported practices, perceptions of risk, control, responsibility and hygiene consciousness, and future training/educational preferences.
- Further exploration into organizational sub-cultures regarding the potential disconnect between the responsibility for food safety among engineering and hygiene staff.
- Compare cognitive and behavioral data to determine discrepancies in awareness and actual behavior.
- Explore the potential cognitive differences in the perceived need for hand-hygiene practices at point of exit compared to entry.
- Although the purpose of the study was to observed the hand washing practices of staff as they enter the production environment, which is a requirement for all staff. Further observational research to identify the factors during production that influence hand-hygiene practices is required.

Additionally, there is a need to consolidate data relating to food-manufacturing and processing environments. A greater volume of research has been conducted in food retail and hospitality settings. Given the volume of products produced and the national distribution

chain, the potential impact of hand-hygiene malpractices in food-manufacturing and processing environments on consumer food safety may be more far-reaching than in a restaurants. Consequently, there is an identified need for an in-depth comprehensive review of food-handler food safety research studies conducted in food-manufacturing and processing environments to establish the most commonly used data collection methods and measures and review the food safety training interventions utilized in food-manufacturing and processing environments. Such findings may be used to inform the development of bespoke, targeted hand-hygiene education/training programs in food production environments. The company have expressed an interest in the development of an intervention to improve hand-hygiene practices in the company. Baseline data collected in this study can be utilized to evaluate the effectiveness of training/education programs delivered to food-handling staff in an experimental study.

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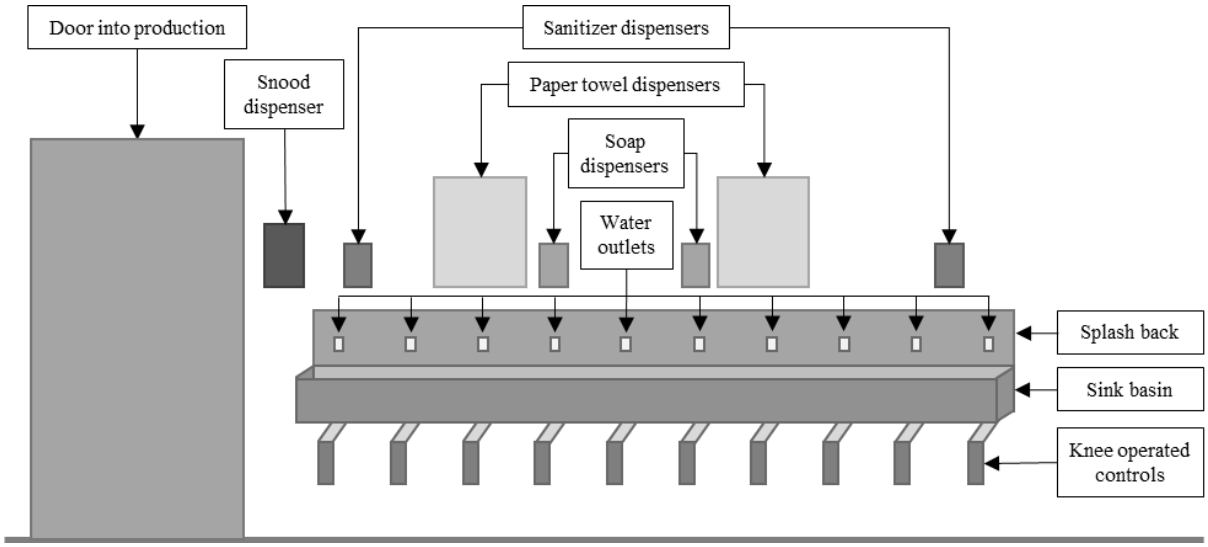
Figures

Figure 1. Layout of hand-hygiene facilities in the hygiene hall



Tables

Table 1 Observed hand-hygiene practices of employees prior to entering production (*n*=604)

Observed practices	***n***	**%**
Hand-hygiene practices		
Wet hands with water first	305	50.5
Apply soap	525	86.9
Rubbing hands palm to palm	445	73.7
Palm over dorsum and interlaced fingers	20	3.3
Palm to palm with interlaced fingers	59	9.8
Backs of fingers to opposing palms with fingers interlocked	9	1.5
Rotational rubbing of thumb clasped in palm	25	4.1
Rotational rubbing of palm with clasped fingers	12	2.0
Vigorous and various rubbing actions when lathering likely to be adequate due to restricted view	45	7.5
Rinse hand with water	573	94.9
Dry thoroughly with a single use towel	504	83.4
Duration of the entire procedure took 40 – 60 seconds	37	6.1
Use of hand sanitizer	251	41.6
Malpractices		
Touched face/hair	56	9.3
Touched bin	4	0.7
Put snood on after hand wash attempt	54	8.9
Hands dried on PPE	22	3.6
Hands not dried	8	1.3
No attempts to wash used sanitizer only	13	2.2
Compliance		
Attempts compliant with procedure	13	2.2
Adequate attempts	53	8.8

Table 2 Grouped duration of observed hand-hygiene practices (from wetting hands through to drying of hands) of employees before entering production (*n*=591)

Grouped duration	***n***	**%**
≤5 seconds	13	2.2
6 - 10 seconds	84	14.2
11 - 20 seconds	262	44.3
21 - 30 seconds	137	23.2
31 - 40 seconds	63	10.7
41 - 50 seconds	24	4.1
51 - 60 seconds	3	0.5
>60 seconds	4	0.7

Table 3 Significant differences in observed hand-hygiene practices of food-handling staff (*n*=503) and hygiene/engineering staff (*n*=171)

Hand-hygiene practices	**Food-handlers (%)**	**Hygiene / engineering (%)**	**Statistical analysis**
No attempt to implement hand-hygiene protocol	9.1	19.3	X^2 (1, n = 674) = 11.75, p <0.001, phi = 0.137
Wet hands with water first	50.5	29.8	X^2 (1, n = 674) = 21.19, p <0.001, phi = -0.181
Apply soap	80.5	70.2	X^2 (1, n = 674) = 7.34, p <0.05, phi = -0.108
Rubbing hands palm to palm	68.4	59.1	X^2 (1, n = 674) = 4.54, p <0.05, phi = -0.086
Palm over dorsum and interlaced fingers	3.6	1.2	p >0.05
Palm to palm with interlaced fingers	8.9	8.2	p >0.05
Backs of fingers to opposing palms with fingers interlocked	1.8	0.0	p >0.05
Rotational rubbing of thumb clasped in palm	4.6	1.2	p >0.05
Rotational rubbing of palm with clasped fingers	2.4	0.0	p >0.05
Restricted view - vigorous and various lathering actions likely to be adequate	8.0	2.9	X^2 (1, n = 674) = 4.40, p <0.05, phi = -0.088
Rinse hand with water	87.5	77.8	X^2 (1, n = 674) = 8.67, p <0.005, phi = -0.118
Dry thoroughly with a single use towel	75.5	72.5	p >0.05
Duration of the entire procedure took 40 – 60 seconds	6.4	2.9	p >0.05
Use of hand sanitizer	36.8	38.6	p >0.05
Adequate attempts	9.3	3.5	X^2 (3, n = 674) = 17.92, p <0.001, Cramer's V = 0.163
Attempts compliant with protocol	2.6	0.7	p >0.05

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