Hand Sanitisers - their use and efficacy

be safe be healthy be well

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Foreword and acknowledgments

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Executive summary

Introduction

Hand washing is the most important practice to prevent the spread of pathogens (the cause of diseases), especially for people who handle food (CDC 2009). Washing with water and soap is the "gold standard" way to remove bacteria and food from hands. Soaps do not kill bacteria and viruses. However, they are considered to be effective in removing dirt, soil and bacterial load from the outer layers of hand skin. The "bacterial load" is the level or numbers of bacteria that may have built up.

Over recent years there has been increasing availability and usage of hand sanitising products. The main advantage of these products seems to be that they are quicker and easier to use. They may also provide another way to clean the hands when water and soap are not available. Using hand sanitisers is usually considered to be an effective hand hygiene regime for hospital and health-care settings. However, their use in food settings has historically been refused because they do not remove food debris.

This study aimed to provide scientific information on the efficacy of hand sanitisers, compared to hand washing with soap and water, in removing foodborne pathogens from hands. In the second part of the study an online survey was undertaken to assess how often hand sanitisers are used. The study also assessed the perceived efficacy of these products – how well the participants believe they work – over water and soap in preventing foodborne illness among consumers on the island of Ireland.

Results and discussion

The scientific literature analysed for this study showed limitations on the information available. These limitations include the absence of a standardised protocol (a particular set of rules or method) to evaluate the efficacy of hand sanitisers compared to hand washing with water and soap. They also include the presence of different experimental conditions that were applied in different studies.

Most of the selected studies consisted of two types of test, in vitro susceptibility testing and in vivo experiments. "In vitro susceptibility testing" is a laboratory test to see how pathogens react to different chemicals, such as hand sanitiser. "In vivo" experiments are carried out on living organisms.

Most of the studies artificially contaminated hands or finger pads with pure laboratory-grown cultures of bacteria and viruses.

Also, there is limited information about the effectiveness of hand sanitisers on visibly dirty hands, and great variability in the experimental conditions adopted. These include differences in the quantity of products used, the length of treatment, and the methods used to estimate inactivation rates of the products being tested. The "inactivation rate" shows how fast the pathogens are killed or made harmless.

Despite the existence of conflicting results, scientific evidence seems to support historical scepticism about the use of waterless hand sanitisers in food settings. Water and soap appear to remove more food debris and bacterial load from hands than waterless products, such as sanitisers. Water and soap also appear to be more effective in the removal of bacteria and viruses from fingernails, when used with a nailbrush. However, a residual level of bacteria is reported in most of the studies. A two-step process of thorough hand washing followed by sanitiser use can be more effective at reducing contamination from the hands than hand washing alone. However, in a domestic setting a thorough hand wash for 20 seconds, with scrubbing, is effective.

According to scientific literature, alcohol-based hand sanitising products achieve fast and effective inactivation of various bacteria, when tested in vitro in broth cultures. (The broth is a clear liquid made from vegetables, meat or bones boiled in water. Pathogens are grown, or cultured, in this liquid.) However, the effectiveness of alcohol-based sanitisers is limited against viruses. Also, when hand sanitisers were tested on hands soiled with food debris their efficacy seemed to be significantly affected: results showed limited levels of bacterial inactivation ($\leq$1-2 $\log_{10}$ reductions).[1]

The efficacy of antimicrobial soaps, which kill bacteria or inhibit their progress, over and above plain soaps is unclear. It is generally accepted in the scientific literature analysed in this study that

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[1] "Log reduction" is a mathematical term used to show the relative number of live microbes eliminated from a surface by disinfecting or cleaning. For example, a "5-log reduction" means lowering the number of microorganisms by 100,000-fold. So, if a surface has 100,000 pathogenic microbes on it, a 5-log reduction would reduce the number of microorganisms to one.

antimicrobial soaps do not perform better than plain soaps when used on either naturally or artificially contaminated hands. The possibility of increased resistance to antibiotics due to extensive use of these types of antimicrobial compounds for hand washing has also been debated.

The scientific literature analysed in this study has shown that, contrary to popular belief, the use of warm water has no effect on reducing the level of bacteria on hands. The use of warm water rather than cold water simply makes hand washing more comfortable. The combined activity of the soap, friction and rinsing maximises the effectiveness of hand washing in removing harmful bacteria.

Results from the online survey of 192 participants showed that conventional hand washing with water and soap is perceived by people as the most effective hand hygiene practice. Instant hand sanitisers are well known among both male and female respondents, but their usage does not seem particularly widespread on the island of Ireland. The data generated from the survey shows that people consider instant hand sanitisers an easier and quicker alternative to conventional hand washing with water and soap. However, when water and soap are available sanitisers are not the hand hygiene regime of choice.

Despite the positive attitude toward the use of water and soap over hand sanitisers, poor hand washing skills were generally recorded among those who responded to the survey. Less than 15 per cent of participants applied proper hand washing methods such as those recommended by the Food Code (FDA 2013)[2]. The majority of participants reported washing their hands for less than 20 seconds. Around one-third of participants reported frequent use of water alone when washing their hands. Lack of soap and also adequate washing facilities were reported as the two barriers to effective hand washing most frequently faced by consumers. This suggests that more information on the importance of proper hand washing should be provided by food safety–promoting organisations to consumers. This will help to minimise the risk of foodborne illness from contaminated hands. Further efforts should be also made to ensure that soap and adequate washbasins are available in public areas.

[2] The Food Code is a set of recommendations presented by the Food and Drug Administration (FDA) as being the best current knowledge regarding proper handling of food, including proper hand washing procedures at the retail level.

Key project recommendations

Recommendation 1: Conventional hand washing with water and soap seems to be the most effective way to remove harmful bacteria and debris from hands, whether using an antimicrobial soap or plain soap. However, often some remaining microorganisms can still be detected on washed hands. So if a family member is unwell, using a hand sanitiser after washing hands could provide an extra defence against cross-infection to other people.

Recommendation 2: The scientific literature analysed in this study has shown that the use of warm water has no effect on reducing the level of bacteria on hands. The use of warm water rather than cold simply makes hand washing more comfortable. The combined activity of the soap, friction and rinsing are crucial to maximising the effectiveness of hand washing in removing harmful bacteria from hands. Therefore, where warm water is not available it is still best practice to wash hands thoroughly with soap and cold water.

Recommendation 3: The results generated by the online survey showed that consumers perceive hand washing with water and soap as the best hand hygiene practice. Despite the high level of awareness about the efficacy of water and soap compared to hand sanitisers, poor hand washing skills were reported by participants. Less than 15 per cent of participants washed their hands for at least 20 seconds, as advised by Food Code 2013. A third of participants reported frequently washing their hands with water only. These findings suggest that there is a need to raise consumer awareness of the importance of proper hand washing as a way to minimise the risk of spreading infections.

Recommendations 4: Despite advances in hygiene and food safety knowledge achieved over the last few years, lack of soap and adequate facilities still seem to be the main barriers that prevent people from washing their hands. There is a need to promote the availability of soap and adequate washbasins in public areas in order to reduce risk of spreading infections.

1 The efficacy of hand sanitisers in the removal of foodborne pathogens compared to hand washing with soap and water

Introduction

Foodborne disease – disease that is contracted through the consumption of contaminated food and drinks – is one of the most common causes of illness (NIAID 2014). Among 31 known pathogens (the cause of a disease), five foodborne pathogens, known as the "Top five", have caused most outbreaks of foodborne illness. They are:

1. Norovirus, sometimes called the “winter vomiting bug”,
2. *Salmonella typhi*, which causes a typhoid-like fever,
3. Verocytotoxigenic *Escherichia coli* (VTEC), a harmful strain of *E. coli*,
4. *Shigella* spp., sometimes called “bacillary dysentery”, and
5. Hepatitis A virus (HAV), which causes liver disease (FDA 2013).

Listeria spp., *Campylobacter* spp. and *Toxoplasma gondii* also cause high numbers of cases that need hospitalisation or that are fatal (CDC 2011).

The possible origins of pathogenic microorganisms in food include the food itself, or its source – for example the growing, harvesting or processing environment. The origin may also be cross-contamination from, for example, food preparation equipment or cleaning equipment. Or it may be that infected food handlers are trasmitting bacteria and viruses.

Infected food handlers have been identified as a common cause of foodborne illness in industrialised countries. Estimates suggest that between four per cent and 33 per cent of outbreaks in the UK are caused by infected employees (Bonner et al. 2001; Guzewich and Ross 1999). A study of foodborne illness outbreaks in US restaurants identified food handling by infected workers as the main factor contributing to around two-thirds (65 per cent) of these outbreaks (Hedberg et al. 2006). Good personal hygiene and safe food-handling practices are essential to preventing foodborne illness.

Effective hand washing is the best way to prevent transmission of harmful bacteria from infected people. Hand washing with water and soap or detergent is well known to be an effective way to remove pathogenic microorganisms such as bacteria and viruses. In recent years there has been an increase in the availability and usage of hand sanitising products. This study aims to provide scientific information about the efficacy of hand sanitisers in removing foodborne pathogens, compared to hand washing with soap and water. The report will provide first a full description of different preparations that are used for hand hygiene. The report will then review selected scientific literature on the efficacy of hand sanitisers against specific foodborne pathogens.

Review of preparations and practices used for hand hygiene

Hand washing

Hand washing can be defined as the "act of washing hands with plain or antimicrobial soap for the purpose of physically or mechanically removing dirt, organic material and/or microorganisms" (WHO 2009). Conventional hand washing involves the use of water and a detergent. A "detergent" is a compound that contains no added antimicrobial agents and that has a cleaning action.

Detergents

Water is defined as a "universal solvent" because it dissolves more substances than any other liquid. However, hand washing with water alone cannot remove hydrophobic substances. When mixed with water, "hydrophobic" substances collect into clumps or slicks and repel the water. They include oils, fats and proteins. These are usually present on soiled hands but are not readily dissolved in water alone. Soap or detergent is also needed.

Soaps and detergent-based products contain "surfactants" such as esterified fatty acid and potassium or sodium hydroxide. The surfactant increases the solubility of the oils, fats and proteins. This allows these substances to lift off instead of sticking to the skin of the hands (WHO 2009). Surfactants have both "hydrophilic" and "hydrophobic" groups – they are chemical compounds that are able to interact with both water and water-insoluble components forming multiple micelles. “Micelles” are molecular aggregates (clumps of molecules). The hydrophilic "head" regions are in contact with the surrounding solvent, and the hydrophobic single-tail regions are sequestered, or trapped, in the centre of the molecule. The result is an emulsion of the oils, fats and proteins in water (Micheals et al. 2002).

Temperature of water

The temperature of the water used for hand washing and its possible effect on the level of bacterial removal has also been questioned. There is a theory of increased effectiveness of hand washing with warm water. The reason supporting this is that warm water combined with a detergent should provide greater emulsification of dirt. Also, the higher temperature of activation should speed up the chemical reaction and enhance the rate of bacterial kill (Michaels et al. 2002). However, based on scientific evidence, warm or hot water alone has no bactericidal effect, meaning that it cannot kill any bacteria. The use of warm water rather than cold water makes hand washing more comfortable. It is also more effective than cold soapy water at removing natural oils from washed hands.

In addition, and also contrary to popular belief, the scientific evidence shows that the use of warm water has no effect on reducing the level of transient bacteria from hands. (“Transient” bacteria are picked up from contaminated sources, and may be removed from the outer skin, for example by thorough hand washing.) So, the combined activity of the soap, friction and rinsing are crucial to maximising the effectiveness of hand washing in reducing the bacterial load (Michaels et al. 2002; Laestadius and Dimberg 2005).

Antibacterial soap

Aside from the use of conventional detergents, use of antibacterial soap containing antiseptics, and disinfectants with antibacterial activity such as triclosan, chlorhexidine and para-chloro-meta-xylenol (PCMX), has been promoted over the last 20 years.

Triclosan (chemical name 2, 4, 4’-tichloro-2’-hydroxydiphenil ether) is a non-ionic, colourless substance with antimicrobial activity. It is usually incorporated into detergents and soaps (at 0.4% to 1% w/v) for hand hygiene and ‘de-germing’. Triclosan can enter bacterial cells and affects the synthesis of ribonucleic acid, or RNA, fatty acids and proteins (Jones et al. 2000).

Chlorhexidine gluconate (CHG) is usually included in some soap preparations because of its residual effects against various bacteria (Larson et al. 1995). However, it has been reported to be less effective against viruses (Mbithi et al. 1993).

Para-chloro-meta-xylenol, or PCMX, is generally considered to be effective against “Gram-positive” microorganisms – that is, those that take up the violet colour of the Gram Stain in their thick cell walls. PCMX is also considered to have fair activity against viruses and against tubercle bacilli, which is a major cause of tuberculosis (TB). It is considered less effective against Gram-negative microorganisms – those which take up less of the Gram Stain, appearing pink under the microscope (Larson et al. 1995).

Although they are marketed as being more effective than plain soaps, it is still unclear whether antimicrobial soaps really are more effective. There is literature supporting both types of product. Scientific evidence seems to indicate that plain soaps should enhance the physical removal of transient bacteria, whereas antimicrobial soap should theoretically achieve chemical inhibition of both transient and resident flora of hands. (“Resident” flora are the microorganisms that are normally present in the body and may be harmless; but they may also multiply to cause infections where they are, or in another part of the body).

The benefit of using antimicrobial soap over plain soap is still not proven. The possibility of increased resistance to antibiotics due to extensive use of these types of molecular compounds for hand washing has also been debated (Weber and Rutala 2006; Aiello et al. 2007).

Drying

As wet hands can both acquire and spread microorganisms, proper drying of hands is an essential part of the hand washing process. Paper towels, cloth towel from a roller, warm air and jet air dryers are commonly used to dry washed hands. Many studies have been carried out to compare the effectiveness of different methods in drying hands and removing bacteria (Matthews and Newsom 1987; Ngeow et al. 1989; Ansari et al. 1991; Gustavson et al. 2000; Swarz 2005; Redway and Fawdar 2008). Because different experimental conditions and protocols are used to evaluate hand washing and hand drying methods, results available in the scientific literature appear undecided. Further studies are needed to issue any recommendation in this respect.

Based on the scientific evidence available, jet air drying and individual paper towels seem to have similar efficiency in drying hands. The use of disposable hand towels appears to be the best choice for hand hygiene (Huang et al. 2012) – especially over cloth roller towel, which seems to enhance the risk of cross-infection (Ansari et al. 1991).

Hand sanitisers

Hand sanitisers are waterless products, often used as an alternative to conventional soap and water to kill germs during hand washing. Since the late 1990s, use of hand sanitisers and also hand antiseptic preparations have gained more and more popularity. Many preparations, including gel, foam and liquid solutions, are now available. Hand sanitisers currently on the market can be divided into two main families: alcohol-based and alcohol–free hand sanitisers (WHO 2009).

Alcohol-based hand sanitisers

Most alcohol-based hand sanitisers (also called "rubs") contain either an active ingredient such as ethanol, isopropyl alcohol, or a combination of these two molecules. They also contain a thickening agent or humectants (moisturisers) such as polyacrylic acid, glycerin, propylene glycol or essential oils. These decrease the drying effect of the alcohol. The quantity of alcohol in alcohol-based hand sanitisers usually varies between 60 per cent and 95 per cent.

The antimicrobial activity of alcohol-based hand sanitisers is due to the ability of alcohol to denature" protein: the alcohol can change the chemical structure and functions of protein). Preparations containing 70 per cent alcohol have been reported to be more effective than higher concentrations, possibly because denaturation of protein cannot be easily achieved in the absence of water (Larson and Morton 1991). 70 per cent alcohol has been shown to be the most effective concentration of ethanol when used to kill microbes. 70 per cent alcohol can penetrate the bacterial cell wall causing protein/enzyme denaturation. >85 per cent alcohol cause coagulation of the protein instantly on the outside of the cell wall and prevents any alcohol from entering the cell. Therefore, denaturation does not occur when water is not present A level of inactivation is documented for some viruses, including the human immunodeficiency virus, or HIV, herpes, rhinovirus, hepatitis, influenza and parainfluenza (Fendler and Groziak 2002). However, alcohol-based hand sanitisers are generally considered to be more effective against bacteria (Rotter 1999) and fungi (Fendler and Groziak 2002) than against viruses. Data available in the scientific literature suggests the alcohol inactivates lipophilic (fatloving) “enveloped” viruses such as those mentioned above, as they have a sensitive fat layer on their outer surface. But its efficacy against hydrophilic (water-loving) non-enveloped (“naked”) viruses, for example polio, is significantly lower (Rotter 1996; Fendler and Groziak 2002).

Alcohol–free hand sanitisers

Beside alcohol-based hand sanitisers, other products incorporating compounds with antibacterial activity, such as povidone-iodine, benzalkonium chloride, triclosan and quaternary ammonium compounds, are also available. Despite being historically recognised as less effective than alcohol, more recent formulations have been suggested to be a better choice for hand hygiene than alcohol-containing sanitisers. In particular, products prepared with benzalkonium chloride demonstrated cumulative and residual antimicrobial activity after use. They have less of a drying effect on hand skin, and they show little decrease in efficacy after repeated use such as is commonly reported for many alcohol-based products (Dyer et al. 1998).

Materials and methods

An extensive review of scientific literature was conducted in November 2014 using the electronic databases Web of Science, Scopus and Pub Med. The search was limited to articles published in English from 1990 to 2014. The research terms used were:

- (i) “efficacy of hand washing”,
- (ii) “efficacy of hand sanitisers”,
- (iii) “evaluation of hand sanitisers”, and
- (iv) “effect of hand hygiene products”.

The aim was to find the scientific evidence about the efficacy of hand sanitisers in the removal of foodborne pathogens from washed hands. Once the preliminary results matching the search terms were obtained, data extraction was carried out in four steps.

First, some preliminary criteria were adopted: only articles that described the level of inactivation of foodborne pathogens from washed hands were included in this study; and all book chapters, studies carried out on non-relevant foodborne pathogens, studies involving inactivation of foodborne pathogens from raw food or surfaces and studies carried out on developing countries were removed before analysis. Second, duplicate articles were identified and removed. Third, the remaining titles and abstracts (summaries of articles or publications) were screened for eligibility against the preliminary inclusion criteria. Fourth, full text articles were retrieved and assessed in terms of their study design and scientific approach.

Results[3]

Overview

Many studies testing hand washing products against various foodborne pathogens such as norovirus, hepatitis A virus, *E. coli*, *Staphylococcus aureus* and *Listeria* spp. were retrieved. Little information was finally found about the efficacy of hand hygiene products against *Salmonella* spp. No scientific information on the subject was finally retrieved for pathogenic bacteria such as *Campylobacter* spp. and toxigenic bacteria such as *Bacillus cereus*.

Beside the use of conventional water and soap, products more generally tested against pathogenic bacteria and viruses included the following: antibacterial liquid soaps containing triclosan or chlorhexidine; alcohol-based hand sanitisers; and non-alcohol–based sanitisers, including povidone–iodine, benzalkonium chloride and quaternary ammonium–based products.

The soap and saniters' efficacy relative to each other was generally tested in vitro and/or in vivo. "In vitro" studies involve experiments carried out on a standardised quantity of the target microorganisms, such as foodborne pathogens. These are treated with increasing concentrations of the product being tested, with the aim of estimating the inactivation rate for each product. "In vivo" studies involve experiments carried out using selected human volunteers. These experiments aim to estimate the efficacy of each product to remove or inactivate the target microorganism from artificially contaminated whole hands, finger pads or gloves.

The majority of in vivo studies were carried out on hands or finger pads artificially contaminated with pure cultures of bacteria or viruses without the presence of food components (debris). Very few studies evaluated the efficacy of hand washing products in a food preparation setting on naturally or artificially soiled hands. Experimental conditions applied to achieve "naturally" soiled hands involved contamination of food workers' hands with food, for example burgers or minced meat). This is to check the effectiveness of hand hygiene products against natural food flora – bacteria, fungi and

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[3] Details of the number of records matching the search terms and a list of papers included in this report are listed in Appendix 1.

other microorganisms. For artificially soiled hands the inoculum, or deliberate source of infection, used generally consisted of a mixture of previously sterilised food (chicken or beef broth, cooking oil, crab cooking water, minced meat, and so-on) and a known quantity of target microorganisms.

Human norovirus (HuNoV)

Human norovirus (HuNoV) is the leading cause of non-bacterial acute gastroenteritis, an inflammation of the stomach and intestines, in humans all around the world (Guzewich and Ross 1999; Lopman et al. 2002; Widdowson et al. 2005; Blanton et al. 2006). Contaminated hands play an important role in its transmission (Moe et al. 2001; Bidawid et al. 2004; Todd et al. 2010), and disinfection is an essential measure for interrupting the spread of infections.

Very high numbers of viruses are shed in the faeces of infected people (105 to 1011 viral replications, or "copies" of viral genomes) (Atmar et al. 2008). The estimated dose that can produce infection in 50 per cent of the human population is as low as ≥18 viral particles (Teunis et al. 2008). For this reason the ideal product to ensure removal of HuNoV from washed hands should have high level activity and achieve virus reduction of ≥4 $\log_{10}$ (Liu et al. 2010).

Many studies have been carried out and various hand washing products, including antibacterial liquid soaps and both alcohol- and non-alcohol–based hand sanitisers, have been tested (Lin et al. 2003; Gehrke et al. 2004; Kampf et al. 2005; Malik et al. 2006; Lages et al. 2008; Park et al. 2010; Liu et al. 2010, 2011; Edmonds et al. 2010, 2012a; Steinmann et al. 2012; Czerwinski and Cozean 2012; Tung et al. 2013). However, very little is yet known about the real effectiveness of hand hygiene products on HuNoV. Results available in the scientific literature remain unclear.

The main reasons for this lack of information include the absence of a standardised method to check the removal of viruses from washed hands, and the lack of a "gold standard" method for counting the surviving HuNoV. Human norovirus cannot be routinely cultured in vitro, but other methodologies can be used to estimate level of virus reduction. These include the use of cultivable "surrogates" (viruses that can be cultured and examined in place of norovirus); or the use of real-time reverse transcription–quantitative polymerase chain reaction (RT–qPCR).

The surrogates most commonly used to predict the efficacy of sanitisers and disinfectants against HuNoV are feline calicivirus (FCV) and murine calicivirus (MCV). These viruses are useful because the level of survival in inactivation studies can be measured by cell culture assays. “Assays” are investigations designed to quantify the number and activity level of cells. However, the appropriateness of FCV and MCV as surrogates for human HuNoV has been debated. More than one study shows that cultivable surrogates behave differently (Duizer et al. 2004; Gehrke et al. 2004; Cannon 2006) and do not always mimic HuNoV (Park et al. 2010; Tung et al. 2013).

RT-qPCR can quantify the number of viral RNA copies extracted and purified from tested samples as a theoretical measure for estimating the level of residual infectivity. However, the relationship between detection of residual viral RNA and virus infectivity is not clear (Baert et al. 2008; Lee et al. 2008). Evidence suggests that the viral capsid – the protein shell of a virus – plays an in important role in the viral infection process (Nuanualsuwan and Cliver 2003) and, therefore, the presence of RNA only cannot necessarily be taken as an indication of residual infectivity. The vast majority of hand sanitisers determine denaturation of the viral capsid proteins. They generally do not cause significant damage to the genome, the set of information which is needed to create and maintain an organism. So the level of RNA degradation, as measured through quantitative PCR, could be not relevant as an approach for estimating the effectiveness of sanitisers and disinfectants.

Despite the presence of conflicting reports, it is generally accepted that none of the hand washing products tested achieved the effectiveness desired. Antibacterial liquid soaps containing chlorhexidine and triclosan lack efficacy on HuNoV (Edmonds et al. 2012a; Tung et al. 2013). Efficacy of hand sanitisers such as alcohol-based (Kampf et al. 2005; Malik et al. 2006; Liu et al. 2010; Park et al. 2010; Edmonds et al. 2012a; Tung et al. 2013) or quaternary ammonia–based products (Lages et al. 2008) are generally reported not to exceed 2 $\log_{10}$ reduction, suggesting minimal impact on HuNoV. Only two studies reported a higher level of inactivation than 3 $\log_{10}$ reduction (Liu et al. 2011; Czerwinski and Cozean 2012).

Very little information seems to be available in the literature about the efficacy of conventional hand washing with water and plain soaps. All the studies found in the analysed literature consider the efficacy of hand sanitisers in comparison with antimicrobial liquid soaps and a simple water rinse. However, similar removal rates are generally reported between hand sanitisers and a water rinse (Liu et al. 2010; Steinmann et al. 2012). This suggests that physical removal plays a key role for all the products tested, whereas no evidence of a disinfection effect has ever been demonstrated.

No evidence about the efficacy of hand hygiene products on food-soiled hands is available in the literature.

> **Key points**
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> - Very high numbers of viruses (105–1011 viral copies) are shed in faeces of infected people; the estimated dose that can produce infection in 50% of human population is as low as ≥18 viral particles.
> - The ideal product to ensure removal of HuNoV from washed hands should have a high level activity and should achieve virus reduction of ≥4 $\log_{10}$.
> - Very little is still known about the real effectiveness of hand hygiene products on HuNoV, and results available in the literature remain unclear.
> - Results achieved from both natural and artificial nails clearly demonstrated a higher level of virus removal achieved by hand washing with soap and a nailbrush (2.5 - 3 $\log_{10}$ reduction from natural and artificial nail respectively).

Only one study estimated the efficacy of different hand washing techniques in removing HuNoV under the fingernails from hands artificially contaminated with a mixture of faeces and high numbers of FCV, used as a surrogate for HuNoV (Lin et al. 2003). The study involved: hand washing with tap water alone; hand washing with soap; hand washing with antibacterial soap; hand washing with soap and a nailbrush; use of hand sanitisers alone: and hand washing with soap followed by use of sanitisers. Results from both natural and artificial nails clearly demonstrated a higher level of virus removal achieved by hand washing with soap and a nailbrush (2.5–3 $\log_{10}$ reduction from natural and artificial nail respectively). None of the other hand washing methods exceeded a 1.5 $\log_{10}$ reduction. No significant difference between water, plain soap, antibacterial soap or hand sanitiser used alone was observed.

Hepatitis A virus

Hepatitis A virus (HAV) is a well-known human pathogen that causes outbreaks of disease in various settings including hospitals and daycare centres. Its role as a foodborne pathogen has been increasingly reported over the last 20 years (Lowry et al. 1989; Mishu et al. 1990; Guzewich and Ross 1999; FDA 2013; ACMSF 2015). HAV is relatively resistant to many disinfectants. It can survive on surfaces for many days and on human hands for several hours (Mbithi et al. 1992). In light of this, proper hand washing would be expected to minimise the risk of HAV being spread by hands and contaminated surfaces.

Little information is available in the scientific literature about the relative effectiveness of hand washing products against HAV. Only three studies describing the efficacy of hand washing products against HAV were retrieved (Mbthi et al. 1993; Fendler and Groziak 2002). Results published by Fendler et al. (2002) and Fendler and Groziak (2002) demonstrated limited efficacy in vitro against HAV of a commercially available alcohol-based hand sanitiser containing 62 per cent alcohol and emollients (skin-softening preparations). The level of inactivation achieved in 15- and 30-second exposure evaluation tests was 1.75 and 1.25 $\log_{10}$ reduction respectively. This corresponds to 94.37 per cent and 94.4 per cent of the original inoculum.

The study carried out by Mbthi et al. (1993) evaluates viral elimination rates of ten different products and the residual infectivity of viruses remaining on whole hands or finger pads artificially contaminated with a mixture of viruses and faeces. Products compared in the study included one non-medicated soap, five alcohol-based hand sanitisers and four antibacterial liquid soaps. It also included the use of tap water without soap. None of the tested products reached an inactivation level of 99.9 per cent, as generally desired. Inactivation rates achieved by different products were generally similar. They ranged between 79 per cent and 92 per cent for both whole hands and finger pads. Triclosan-based soap and non-medicated soap generally reached a level of virus reduction similar to that observed for alcohol–based sanitisers (around 88%), whereas the use of tap water without soap did not exceed 80 per cent.

A viral plaque is a visible structure formed within a cell culture. Viral plaque assays determine the concentration of live viruses in a sample. A plaque assay test used to evaluate residual infectivity of viruses remaining on washed hands showed better viricidal activity achieved by most alcohol-based products compared to the other products. Plaque forming bodies are also known as plaque forming units (PFU's). Residual infectivity measured as the number of PFUs ranged from 0 to 0.64 PFUs/ml for alcohol-based hand sanitisers. It measured 0.63 to 1.74 PFUs/ml for antimicrobial soap, 1.57±0.5 PFUs/ml for plain soap and 3.88±0.63 PFUs/ml for tap water. A viral plaque is a visible structure formed within a cell culture.

The results of the study suggest that over 20 per cent of the original virus input remains detectable and that nearly two per cent might be transferred to another surface. For this reason, proper hand washing might not be completely effective in stopping "horizontal dissemination" Horizontal dissemination means transferred horizontally by person to person or from surface to person or surface to surface. Use of alcohol-based hand sanitisers after hand washing seems to be the best way to minimise residual viruses remaining on washed hands. No information seems be to be available in the literature about the efficacy of hand washing and hand sanitisers against HAV on soiled hands. More studies are needed to determine the virus-eliminating efficiencies of hand hygiene products in food settings.

Key points

- HAV is relatively resistant to many disinfectants. It can survive on environmental surfaces for many days and on human hands for several hours.
- Proper hand washing would be expected to minimise the risk of HAV being spread by hands and contaminated surfaces.
- Limited information is available in the scientific literature about the efficacy of hand washing and hand sanitisers against HAV on soiled hands. More studies are needed to determine the virus-eliminating efficiencies of hand hygiene products in food settings.

Listeria monocytogenes

Listeria monocytogenes contamination is important in all areas of food processing, catering and retailing. *L. monocytogenes* contamination poses particular hazards and challenges in relation to ready–to–eat (RTE) foods and related products (FSAI 2005). The pathogen, which can cause a serious infection, listeriosis, is widely distributed in the environment and has been isolated from a variety of food and food-processing environments (Motes 1991; Dillon et al. 1994; Eklung et al. 1995).

L. monocytogenes can grow at refrigeration temperatures and multiply to significant levels. Contaminated food can potentially cause listeriosis even if stored for short periods of times (Guyer and Jemmy 1991; Farber et al. 2000). Hand hygiene using soap and/or hand sanitisers is recognised as a means of control. However, very little information is available in the literature about the efficacy of soaps and hand sanitisers against *L. monocytogenes*.

Only two papers describing in vitro efficacy of sanitising products against *L. monocytogenes* were found in the analysed literature. Fendler et al. (2002) reported completed inactivation of *L. monocytogenes* achieved by a commercially available hand sanitiser containing 62 per cent alcohol in a 15-second timed exposure kill test. McCarthy (1996) compared the efficacy of two chloride-based, one iodine-based, one peroxide-based and a quaternary ammonium–based sanitiser with an alcohol-based instant hand sanitiser on contaminated latex gloves. The impact of the organic compounds on inactivation rates of the tested products was estimated through immersion of the gloves in both sterile phosphate-buffered saline (PBS, a salty solution) and crab cooking water artificially contaminated with 5 $\log_{10}$ CFU/ml (Colony Forming Units) of *L. monocytogenes*.

Only the peroxide-based product achieved complete inactivation of attached *L. monocytogenes* in both soiled and non-soiled contaminated gloves. Iodine- and chloride-based and quaternary ammonium–based products achieved complete inactivation in gloves contaminated in sterile PBS (there is no food residue present). However, they demonstrated lower efficacy ($\leq$1–2 $\log_{10}$ reduction) in the presence of crab cooking water. Iodine-based sanitiser and alcohol-based instant hand sanitiser showed limited efficacy in both cases. No data about the efficacy of conventional hand washing in removing *L. monocytogenes* from gloves or hands was retrieved in the literature.

Key points

- *Listeria monocytogenes* contamination is important in all areas of food processing, catering and retailing. *L. monocytogenes* contamination poses particular hazards and challenges in relation to ready–to–eat (RTE) foods and related products.
- Hand hygiene using soap and/or hand sanitisers is recognised as a means of control. However, very little information is available in the literature about the efficacy of soaps and hand sanitisers against *L. monocytogenes*.
- Completed inactivation of *L. monocytogenes* was achieved by a commercially available hand sanitiser containing 62 per cent alcohol, in a 15-second timed exposure kill test.
- No data about the efficacy of conventional hand washing in removing *L. monocytogenes* from gloves or hands was retrieved in the literature.

Staphylococcus aureus

Staphylococcus aureus is frequently encountered on the skin and in the nose of about 30 per cent of individuals and animals (CDC 2011). Usually it does not cause illness in healthy people unless it is transmitted to food products, and is able to grow and produce exotoxin. “Exotoxin” is a toxin, or poisonous substance, that is secreted or released by bacteria into the surrounding environment. *S. aureus* can rapidly multiply in food products and produce several types of toxins that are responsible for foodborne intoxication – food poisoning (CDC 2011).

Due to its role as resident bacterium on human skin (Lowbury et al. 1964; Miller et al. 1994), *S. aureus* is often included in studies aiming to estimate efficacy of different hand washing products against hand bacteria, especially products to be used as an alternative to conventional hand washing and alcohol rubs (Gaonkar et al. 2005; Shintre et al. 2006; Kaiser et al. 2009; Edmonds et al. 2012b; Biagi et al. 2014; Czerwinsky et al. 2014). Conventional hand washing with water and soap can effectively remove bacteria from the outer layer of hand skin. Still, its use is not indicated in settings requiring a high frequency of washes. This is because repeated hand washing causes increased skin irritation and defatting of skin, leading to increased bacterial count (Larson et al. 1995).

Alcohol-based sanitisers have been reported to achieve rapid inactivation of various transient and resident hand bacteria (Fendler et al. 2002). However, some limitations, such as the drying effect on skin and lack of residual action after the product has evaporated, also prevent these sanitisers from being used as hand hygiene products (WHO 2009; McKenzie et al. 2011). For this reason, increasing interest in new formulations, to be used as an alternative to hand washing and conventional alcohol rubs, is being reported.

Alternative lotions tested against *S. aureus* include: new alcohol-based formulations such as gel and foams (Edmonds et al. 2012b); new long-acting alcohol-based products (Gaonkar et al. 2005); mixtures of alcohol- and quaternary ammonia–based products prepared with moisturisers or essential oils (Shintre et al. 2006); new water-based non-alcoholic antiseptic lotions containing benzethonium chloride (Kaiser et al. 2009; Czerwinsky et al. 2014); and natural compounds including pyrrolidone-2–carboxylic acid (PCA) and copper sulphate pentahydrate (CS) (Biagi et al. 2014).

Benefits demonstrated in vitro or ex vivo on simulated skin substrate included similar antimicrobial activity against *S. aureus* to conventional alcohol-based products. They also showed higher residual activity after use, and potentially reduced irritation after repeated used. However, no information about the efficacy of these preparations in various food settings was found. Further studies are needed to prove their effectiveness (used alone or after hand washing) against *S. aureus* on visibly soiled hands.

Key points

- *S. aureus* is often encountered on the skin and in the nose of about 30 per cent of individuals and animals. It usually does not cause illness in healthy people unless it is transmitted to food products, and is able to grow there and produce exotoxin.
- Conventional hand washing with water and soap can effectively remove bacteria from the outer layer of hand skin. However, its use is not indicated in settings requiring a high frequency of washes. This is because repeated hand washing causes increased skin irritation and defatting of skin, leading to an increased bacterial count.
- Alcohol-based sanitisers have been reported to achieve rapid inactivation of various transient and resident hand bacteria. However, some limitations, such as their drying effect on skin and lack of residual action after the product has evaporated also prevent these sanitisers from being used as hand hygiene products.
- No information about the efficacy of these preparations in various food settings was found. Further studies are needed to prove their effectiveness (used alone or after hand washing) against *S. aureus* on visibly soiled hands.

Escherichia coli

Escherichia coli comprises of a large group of bacteria including both harmless and pathogenic types. Various non-pathogenic types of *E. coli* normally live in the intestinal tract of animals and humans. Other types of *E. coli* can cause diarrhoea and can be transmitted through contaminated water or food, or through contact with animals or people. Pathogenic *E. coli* include six different categories. Of these, verocytotoxin-producing *E. coli* (VTEC) are reported to be one of the most common causes of human foodborne illness resulting in hospitalisation (CDC 2011). Main sources of transmission include raw meat, fruit, vegetables and infected workers through the faecal–oral route.

E. coli is commonly used as a challenge microorganism to prove the efficacy of various hand hygiene products, including: alcohol-based (Gaonkar et al. 2005; Kampf et al. 2010; Edmonds et al. 2012b); quaternary ammonia–based products (Shintre et al. 2006); new water-based non-alcoholic antiseptic lotions (Kaiser et al. 2009; Czerwinsky et al. 2014); and natural compounds (Biagi et al. 2014). It is also used to test various hand hygiene regimes in food settings (Paulson et al. 1999; Lin et al. 2003; Courtenay et al. 2005; Fischler et al. 2007; Edmonds et al. 2010; Pickering et al. 2011; Edmonds et al. 2012a) against transient flora of hands.

All the products tested against *E.coli* (alcohol-based and alcohol–free sanitisers) demonstrated over 99.9 per cent inactivation in both in vivo and ex vivo studies, suggesting high and rapid efficacy. Conversely, their use in various food settings never achieved complete inactivation of *E. coli* on treated hands. The level of bacterial inactivation did not usually exceed two to three $\log_{10}$ reduction (Lin et al. 2003; Fischler et al. 2007; Edmonds et al. 2010; Pickering 2011; Edmonds et al. 2012a). Also, the presence of organic compounds significantly affected their efficacy when hand sanitisers were used alone (Lin et al. 2003; Edmonds et al. 2010, 2012a).

However, increasing evidence suggests that the use of alcohol-based sanitisers after hand washing with conventional or antibacterial soap can significantly increase the level of bacterial inactivation. High removal rates ranging from four to five $\log_{10}$ reduction have been reported both from hands contaminated at various levels with *E. coli* alone (Paulson et al. 1999) and from hands contaminated with a mixture of food components and *E.coli* (Courtenay et al. 2005; Edmonds et al. 2010).

Key points

- *Escherichia coli* comprises of a large group of bacteria including both harmless and pathogenic types. The main sources of transmission include raw meat, fruit, vegetables and infected workers through the faecal–oral route.
- *E. coli* is commonly used as a challenge microorganism to prove the efficacy of various hand hygiene products.
- All the products tested against *E.coli* reported in the literature demonstrated over 99.9% per cent inactivation, suggesting high and rapid efficacy.
- However, their use in various food settings never achieved complete inactivation of *E. coli* on treated hands.
- There is increasing evidence to suggest that the use of alcohol-based sanitisers after hand washing with conventional or antibacterial soap can significantly increase the level of bacterial inactivation.

Efficacy of hand washing products on naturally and artificially soiled hands

The presence of food components such as fat, oil or other dirt is considered the main factor affecting the removal and inactivation rates of hand hygiene products against bacteria occurring in people handling food. Most hand disinfectants available on the market are designed to be effective in use in hospital or health care settings. However, they are generally considered not appropriate to meet the needs of food handlers (Charbonneau et al. 2000). The level of contamination reported for food handlers can vary widely between two and five $\log_{10}$ CFUs per hand. The bacterial flora is a mixture of *Enterobacteriaceae* and other mesophilic bacteria (microorganisms that flourish in moderately warm environments) in the presence of fat and other soil (De Wit and Kampelmaker 1981). The ideal hand hygiene regime to be used in a food setting should ensure maximum removal of dirt, oil, food components and food flora from soiled hands in order to minimise the level of transferable microorganisms by hands.

Experimental conditions most commonly employed to mimic a food handler's conditions include, for example, gloves, fingertips, and/or hands naturally contaminated with natural soil encountered in the food service industry (Charbonneau et al. 2000); or artificially inoculated with pure culture of bacteria mixed with crab cooking water (McCarthy 1996), chicken or beef broth (Lin et al. 2003; Edmonds et al. 2010, 2012a), ground beef (Courtenay et al. 2005; Edmonds et al. 2010, 2012a), dirt and cooking oil, (Pickering et al. 2011).

In contrast, other aspects also occurring in food preparation settings, such as the hygiene of nails and wearing of rings when handling food, have been minimally considered. Only two studies evaluated the efficacy of hand washing techniques in the removal of bacteria or viruses from natural and artificial nails (Lin et al. 2003) or from hands wearing rings (Wongworawat and Jones 2007).

Efficacy of hand products is estimated based on the enumeration (counted number) of microorganisms released from treated hands, or based on the enumeration of bacteria remaining on hands. Methods for enumeration of released bacteria included the "glove juice" technique (Wongworawat and Jones 2007; Edmonds et al. 2010; 2012a) and the "hand rinse" technique. Both techniques consist of enumerating bacteria released from washed hands previously placed into a glove or a bag filled with sterile water or another buffer (Courtenay et al. 2005; Pickering et al. 2011). Conversely, enumeration of bacteria remaining on the hands after hand washing or hand sanitising is usually estimated through image analysis or by pressing hand palms onto the surface of an "agar plate" (Charbonneau et al. 2000). (Agar is a substance that comes from algae, and is often used as a medium in which to culture microorganisms.)

Hand products and hygiene methods tested include: hand washing with soap and water (Charbonneau et al. 2000; Lin et al. 2003; Courtenay et al. 2005; Edmonds et al. 2010); antimicrobial or medicated soaps (Charbonneau et al. 2000; Paulson et al. 1999; Lin et al. 2003; Edmonds et al. 2010); alcohol-based sanitisers (Charbonneau et al. 2000; Lin et al. 2003; Wongworawat and Jones 2007; Edmonds et al. 2010; Pickering et al. 2011); use of soap followed by hand sanitiser (Lin et al. 2003; Edmonds et al. 2012a); and a new hand hygiene regime, "SaniTwice" (Edmonds et al. 2010).

The "SaniTwice" method (a registered trademark with James Mann, Handwashing for Life, Libertyville, Illinois) is a two-stage hand cleansing process. It involves first the application of an excess of alcohol-based sanitiser. This is followed by hand rubbing for 15 seconds, cleaning hands with a paper towel, and a final application of alcohol-based sanitiser.

Due to the absence of a standardised protocol to evaluate the efficacy of products used, and the use of different experimental conditions to mimic food service settings, there are conflicting reports about the efficacy of soaps and hand sanitisers in the analysed literature. However, the following general statements can be made:

- Hand washing with warm water and soap is reported to achieve more effective removal of bacteria and soil from hands and gloves (Charbonneau et al. 2000; Courtenay et al. 2005). It is also reported to be more effective than other products in the removal of bacteria and viruses from fingernails when applied with a nailbrush (Lin et al. 2003).
- Effectiveness of conventional hand washing is better on contaminated hands than on gloves (Courtenay et al. 2005). This suggests that frequent changes of gloves rather than washing gloves when visibly soiled would more effectively minimise the risk of bacterial contamination between different food preparation steps.
- Although conflicting results exist (Paulson et al. 1999; Charbonneau et al. 2000; Lin et al. 2003; Fischer et al. 2007; Edmonds et al. 2012a), the evidence seems to indicate that antimicrobial or medicated soaps can achieve a slightly higher level of bacterial inactivation on artificially contaminated hands without food residue present (Fischler et al. 2007); whereas their efficacy on soiled hands is similar to or lower than conventional soaps (Charbonneau et al. 2000; Lin et al. 2003; Edmonds et al. 2012a).
- Alcohol-based products used alone do not usually exceed two to three $\log_{10}$ bacterial reduction (McCarthy et al. 1996; Paulson et al. 1999; Courtenay et al. 2005; Pickering et al. 2011). Their efficacy also seems to be significantly affected ($\leq$1–2 $\log_{10}$ reduction) by the presence of food debris, as observed on both moderately (McCarthy 1996) and heavily soiled hands (Charbonneau et al. 2000; Edmonds et al. 2010). In contrast, similar bacterial counts between hands with and without rings as reported by Wongworawat and Jones (2007) suggests that the presence of rings does not significantly affect the effectiveness of hand products in removing hand flora.
- Alcohol-based hand sanitisers used alone seem not to be a reliable substitute for conventional hand washing when used by people who have been preparing food. However, their use following hand washing with either antimicrobial or plain soap (a “wash–sanitise” regime) seems to be the best hand hygiene choice (Paulson et al. 1999). This regime has been demonstrated to significantly increase the level of bacterial inactivation up to a level of four or five $\log_{10}$ reduction on both moderately and heavily soiled hands respectively (Edmonds et al. 2012a).

2 Understanding consumers' behaviour in the usage of hand sanitisers

Introduction

Over the past 20 years, increasing interest has been placed on the use of hand cleansing products with robust antimicrobial activity, particularly instant hand sanitisers including both alcohol-based and alcohol–free preparations. Alcohol-based hand sanitisers containing 60 per cent to 95 per cent ethanol or other alcohol compounds have documented activity against bacteria (Rotter 1999), fungi and some viruses (Fendler and Groziak 2002). Use of alcohol-based hand sanitisers is approved as a standard hand hygiene regime in hospital and health care settings when hands are not visibly soiled (CDC 2002). In contrast, their use in food establishments has historically been refused because of their inability to remove fat and food debris from hands (FDA 2009).

Very little information is available in the analysed literature about the frequency of use of alcohol-based sanitisers among consumers and about consumers' understanding of the efficacy and appropriate use of these products. The aim of this study was to assess consumers' behaviour and understanding in the usage of these products, compared to conventional hand washing, in preventing foodborne illness.

Materials and methods

An online survey was carried out in April 2015 to assess consumers' behaviour and understanding in relation to hand hygiene practices on the island of Ireland. The survey tool, composed of 34 items or questions, was designed to obtain information about the frequency and context of hand sanitiser usage amongst consumers. It also seeks information in relation to consumers' understanding about the efficacy of hand sanitising in preventing foodborne illness compared to water and soap. A further aim of the survey was to examine the existence of barriers to the use of soap and water.

The survey questionnaire included a brief introductory section of questions. This is designed to assess participants' general knowledge of the main foodborne diseases and food hygiene practices to prevent cross-contamination. The core of the questionnaire comprised four key sections to sound out:

(i) the frequency of use of hand sanitisers,

(ii) consumers' attitude to the use of hand sanitisers compared to water and soap,

(iii) hand washing practices among consumers, and

(iv) the existence of barriers to the use of water and soap.

Direct questions along with demographic characteristics (age, gender and education level) were also included in the last part of the questionnaire.

All the questions about behaviour were scored on a five-point "Likert scale", with answer options "never", "rarely", "sometimes", "fairly often" and "often". The scale is used to represent the participants' attitudes or approaches to the survey topic.

Questions about perceptions, the way participants regard or feel about things, were in a five-answer format: "very unlikely", "unlikely", "neutral", "likely", or "very likely". A five-point Likert scale[4] with options to "totally disagree", "disagree", "neither agree or disagree", "agree" or "totally agree" was used to score questions about consumers' attitude.

A pilot survey was conducted before this study in a "convenience sample" of 12 participants who were easy to reach. This was done to confirm that participants could understand the survey questions and to ensure the validity of the questionnaire content. Following the pilot study some of the items were rephrased or restructured to improve the clarity of the questions and to allow easier completion of the questionnaire by participants.

Ethical approval for the study was granted by the Research Ethics Committee within the School of Biological Sciences, Queens University Belfast (QUB). All data was entered in SPSS Version 20.0 (SPSS Inc., USA) using a standard coding procedure and checked for entry errors before analysis.

"Descriptive statistics" include: the means, or averages for a set of data; standard deviation, or amount of variation in the data; and ranges, or differences between the lowest and highest values in the data. These were calculated for continuous variables. "Continuous variables" are values that can fall anywhere within the data range, for example, the number of seconds participants take to wash their hands. Frequencies were calculated for categorical variables – where the data falls under a label, or category, for example, the number of participants who are sanitiser-users. One-way analysis of variance (one-way ANOVA) was performed, which a technique is used to assess differences between unrelated groups of data.

Results and discussion

Please note, the results in this report have been rounded to one decimal place, where appropriate.

Demographic information

A total of 192 participants completed the questionnaire. Three-quarters of these lived in Northern Ireland (75.9%) and one-quarter in the Republic of Ireland (24.1%). Survey sample data showed a higher number of female (83.7%) than male (16.3%) respondents. 36.2% of the sample participants were aged 18 to 29 years, 19 per cent were aged 30 to 39 years, 19.5 per cent were 40 to 49 years and 17.8 per cent were 50 to 59 years. Only a small percentage of participants (7.5%) were 60 or more years of age.

The majority of respondents were educated to postgraduate (49.4%) or undergraduate level (32.2%). More than half of the participants (58.4%) were employed full time, 12.1 per cent were employed part-time and 20 per cent were attending full-time higher education. A small percentage of respondents were retired (5.2%). 1.2 per cent were full-time homemakers, 0.6 per cent were at school or unemployed. Table 5 in Appendix 2 outlines the sociodemographic characteristics of survey participants.

Knowledge of food safety and hygiene practices

Most respondents recognised *Salmonella* spp. and *E.coli* 0157:H7 as sources of foodborne illness. A lower level of awareness was observed for other pathogens such as norovirus, hepatitis A virus and *Campylobacter* spp. A generally low level of risk of developing foodborne illness was also perceived by participants. Only 21 per cent of participants declared themselves to be worried about foodborne illness. 49.5 per cent indicated that they were not worried.

According to consumers, takeaway outlets and mobile food vans are the food preparation settings where foodborne illness is most likely to occur. A lower level of risk is generally perceived in bars, restaurants and in participants' own homes. A higher perception of the risk of food poisoning occurs when food is prepared by others (ready–to–eat sandwiches and salads, for example) as opposed to themselves (such as sandwiches and salads prepared and made at home).

In terms of hygiene practices to prevent cross-contamination of food, good knowledge and attitude among participants was generally observed. Over 80 per cent of respondents declared that they "always" wash their hands and utensils used after handling raw food and before handling cooked food. Conversely, a slightly lower percentage of people identified the importance of using separate chopping boards for raw and cooked food. Only 65.4% indicated that they "always" use separate chopping boards for raw and cooked food, whereas 15.9% indicated "fairly often", 11.2 per cent "sometimes", 4.3 per cent "rarely", and 3.2 per cent "never".

Hand washing and barriers to use of water and soap

Hand washing is perceived by vast majority of respondents as an effective hygiene practice to prevent foodborne illness, as shown in Figure 1. Hand washing was scored "very effective" by 54.7 per cent and "effective" by 39.6 per cent of participants. Only 3.1 per cent of respondents thought that hand washing was not effective in preventing foodborne disease.

A positive attitude toward hand washing was also generally observed. As shown in Table 1, around three-quarters of respondents reported that they wash their hands with water and soap more than six times a day (73.1%) and 67.2 per cent reported that they always dry their hands after hand washing. The use of soap and water seems to be to most frequent hand hygiene practice among consumers. Hand washing with water only is less frequent (twice a day in 71.2% of respondents). One-third of respondents reported more frequent hand washing with water only: 20.9% wash their hands three to five times a day with water only; 5.5 per cent six to eight times; and 2.5 per cent more than nine times a day.

In terms of knowledge of an appropriate length of time for hand washing, only 12.7 per cent of participants reported that they wash their hand for 20 seconds as suggested by Food Code 2013 (see Table 1). Over half of the participants (54.5%) wash their hand for 6 to 20 seconds, 25.4 per cent for 11 to 20 sec, and 7.41 per cent for less than five seconds. Apart from a slightly higher number of men who claimed to wash their hands for 20 seconds compared to women, no significant differences between male and female respondents were observed.

Barriers to hand washing most often faced by respondents included "no soap" (42.93%), "no adequate facility" (32.24%), and "unavailability of nearby washing facility" (14.75%). Other situations such as "no time", "inconvenience of waiting in a queue" and "far from sink" were generally indicated by respondents as "very unlikely" or "unlikely", so this data is not shown.

Figure 1: Perceived efficacy of hand washing in preventing foodborne illness

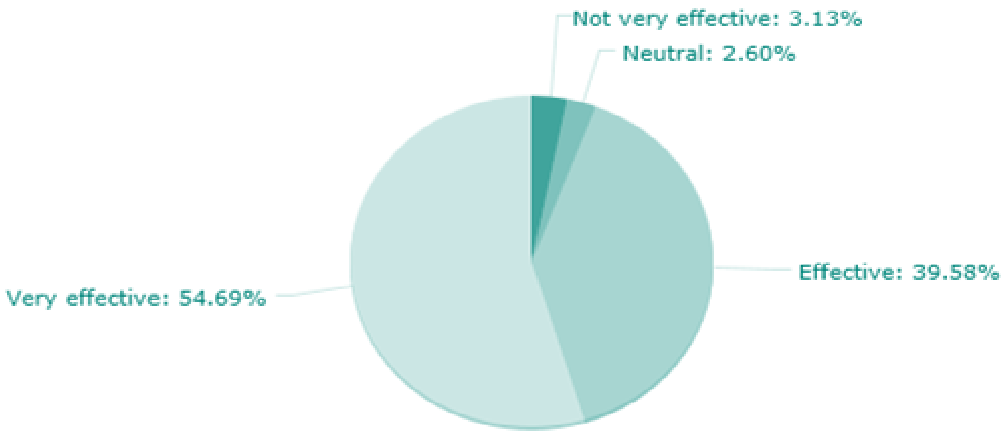

Table 1: Participants' hand washing practices

Question	Answer	Mean percentage (%)
How many times a day do you wash your hands with water and soap?	Two times	4.8
	3–5 times	22.0
	6–8 times	47.8
	Above 9 times	25.3
How many times a day do you wash your hands with water only?	Two times	71.2
	3–5 times	20.9
	6–8 times	5.5
	Above 9 times	2.5
When you wash your hands, approximately how long do you wash them for?	Up to 5 sec	7.4
	6–10 sec	54.5
	11–20 sec	25.4
	20 sec or more	12.7
How often do you dry your hands after hand washing?	Never	0
	Rarely	2.6
	Sometimes	5.3
	Fairly often	24.9
	Always	67.2

Frequency of the use of instant hand sanitisers

The vast majority of respondents (95% of females and 100% of males) declared themselves to have used instant hand sanitisers. Only a small percentage of women (5%) reported that they had never used hand sanitisers. Reasons for not using this type of hygiene product included "I don't think it's useful" (55.6%), "I have an adverse reaction" (22.2 %) and "I don't like to use it" (30%). Reported frequency of the use of hand sanitisers is generally less than once a week for both male and female participants.

Based on data collected, people generally have a good opinion about the level of cleanliness achieved by using hand sanitisers. Over 60% of participants feel their hands are "quite clean" or "clean" after using hand sanitisers. Only a small number of participants (4.6%) perceived their hands to be "not at all clean" after using instant hand products. Antimicrobial gels were the instant hand products more commonly used, with lotions and wipes used less frequently. No significant differences between male and female respondents were observed.

Perceived efficacy of hand sanitisers compared to water and soap

Table 2 presents the overall perception of the use of hand sanitisers compared to conventional hand washing. Hand sanitisers are generally perceived by consumers to be easier (48.2% agree, 8.9% totally agree) and quicker (57.0% agree, 12.2% totally agree) to use than water and soap. The vast majority of people also "agree" (39.3%) or "totally agree" (50.3%) that hand sanitisers are an alternative to hand washing when water and soap are not available. However, the efficacy of hand sanitisers compared to water and soap seems to be less clear. One-third of participants "neither agree nor disagree" whether hand sanitising is more effective (32.6%) or less effective (32.2%) than conventional hand washing. Another third of participants (32.8%) "agree" that waterless products are less effective than water and soap. 41.3 per cent "disagree" that these products are more effective than water and soap.

Table 2: Overall perception about the use of hand sanitisers compared to conventional use of water and soap

Perception	Totally disagree	Disagree	Neither agree or disagree	Agree	Totally agree
Higher level of cleanliness	10.1%	38.5%	33.7%	14.2%	3.4%
Quicker than water and soap	2.9%	11.6%	16.2%	57.0%	12.2%
Easier than water than soap	2.4%	18.5%	22.0%	48.2%	8.9%
More effective than water and soap	13.4%	41.3%	32.6%	9.3%	3.5%
Less effective than water and soap	5.3%	21.1%	32.2%	32.8%	8.8%
An alternative to hand washing when water and soap are not available	2.9%	3.5%	4.1%	39.3%	50.3%

Note: Results are mean of 174 respondents.

Table 3 presents the perceived efficacy of hand washing with soap and water compared to the use of hand sanitisers in different situations. The use of water and soap is perceived as the hand hygiene regime of choice to "clean dirty or visibly soiled hands" (28.8% agree, 50.6% totally agree). It is also perceived as the best way to clean hands "after changing a nappy" (35.9% agree, 38.2% totally agree); "before caring for a baby" (34.7% agree, 31.8% totally agree); "before having a meal at restaurant" (36.1% agree, 17.2% totally agree); "before handling food" (43.5% agree, 30.0% totally agree); "after using the bathroom at home" (40.2% agree, 27.2% totally agree); and "after using public restrooms" (40.8% agree, 27.8% totally agree).

In contrast, the choice about the most effective hand hygiene regime to clean hands "after shaking hands", "after touching money", "in the office" or "after using public transport" was less clear. No differences between male and female respondents were observed.

Table 3: Perceived efficacy of the use of soap and water to clean hands compared to the use of hand sanitisers in different situations

Situation	Totally disagree	Disagree	Neither agree or disagree	Agree	Totally agree
When hands are visibly dirty or soiled	5.3%	8.2%	7.1%	28.8%	50.6%
After changing a nappy	3.5%	6.5%	15.9%	35.9%	38.2%
Before caring for a baby	3.5%	8.8%	21.2%	34.7%	31.8%
Before having a meal in a restaurant	1.8%	13.0%	32.0%	36.1%	17.2%
Before handing food	2.9%	7.6%	15.9%	43.5%	30.0%
After using the bathroom at home	2.4%	8.9%	21.3%	40.2%	27.2%
After using public restrooms	2.4%	11.2%	17.8%	40.8%	27.8%
After shaking hands	3.0%	23.8%	38.7%	24.4%	10.1%
After touching money	2.9%	20.6%	29.4%	30.6%	16.5%
In the office	1.8%	19.4%	36.5%	31.2%	11.2%
After using public transport	2.4%	20.6%	32.4%	32.4%	12.4%

Note: **Results are mean of 174 respondents.**

Conclusions

Results achieved from 192 participants who completed the questionnaire showed overall a positive attitude towards conventional hand washing with water and soap compared to hand sanitisers.

A high level of awareness about the efficacy of hand washing in preventing foodborne illness was observed among respondents. A good general knowledge of hygiene practices to prevent cross-contamination of food was also detected.

A high level of awareness about the efficacy of water and soap does not necessarily reflect good hand washing skills, as demonstrated by the majority of respondents. Less than 15 per cent of people washed their hands with water and soap for 20 seconds as advised by the Food Code 2013. Around 30 per cent frequently washed their hands with water only. Barriers to the use of water and soap reported by respondents included lack of soap and lack of adequate facilities. These findings suggest that more information should be provided by food safety–promoting organisations about the importance of proper hand washing to minimise risk of foodborne illness. More effort should also be made to ensure availability of soap and adequate washbasins in public areas in order to minimise the spread of infections.

Instant hand sanitisers are well known among both male and female respondents. However, their usage for hand hygiene does not seem particularly widespread on the island of Ireland. Based on the data generated from the survey, people consider instant hand sanitisers an easier and quicker alternative to conventional hand washing – but not the hand hygiene regime of choice when water and soap are available.

Hand washing with water and soap is generally perceived by respondents as more effective than use of sanitisers in most cases where hand cleaning is required. However, for four of the situations, including “after using public restrooms”, “after shaking hands”, “after touching money” and “in the office”, participants did not have a clear idea about the most effective hand hygiene practice. In particular, the absence of a clear choice between hand washing with water and soap and use of hand sanitisers may suggest a low level of perceived risk by participants in such situations. Possibly they are perceived as situations not requiring hand cleansing, or not requiring particular care in the choice of hand hygiene products.

3 Project discussion and key findings

- Conventional hand washing with water and soap seems to be more effective in the removal of food components and transient microorganisms. Their use with a nailbrush demonstrated superior effectiveness in removing bacteria and viruses from contaminated fingernails.

- Alcohol-based products have shown rapid and high efficacy against bacteria but their inactivation rates against viruses are generally lower. Although there are a number of improved alcohol-based formulations available, these products cannot achieve complete sterilisation of treated hands. The level of bacterial and viral inactivation do not generally exceed two to three $\log_{10}$ reduction. Presence of food debris on contaminated hands clearly demonstrated to impact on their efficacy, reducing the level of inactivation by one to two $\log_{10}$ reduction.

- The efficacy of antimicrobial soaps over conventional hand washing with water and soap is debated. However, current evidence suggests that these products generally lack efficacy against viruses and do not perform better than soaps on naturally and artificially soiled hands.

- Scientific evidence has shown that the use of warm water has no effect on reducing the level of bacteria from hands. The use of warm water rather than cold water simply makes hand washing more comfortable. For this reason the combined activity of the soap, friction and rinsing are crucial to maximising the effectiveness of hand washing in removing harmful bacteria from hands.

- Hand washing with water and soap is perceived by people as the most effective practice for hand hygiene. A good level of knowledge about the importance of hand washing in preventing foodborne illness was generally observed among respondents. The responses also indicate a positive attitude toward hygiene practices to prevent cross-contamination of food.

- The results of this project show that the use of hand sanitisers is not very common among consumers on the island of Ireland. Instant hand sanitisers are considered a quick and easy alternative to hand washing, but not the hand hygiene practice of choice when water and soap are available also.

- Despite the knowledge and awareness of the importance of washing hands, generally poor hand washing skills were observed. Only a small percentage of people properly washed their hands for at least 20 seconds. One-third of participants reported that they frequently wash their hands with water only. Moreover, a high percentage of people reported lack of soap and adequate facilities as the main barriers to hand washing they faced. These findings suggest that more effort should be made to provide clear information about appropriate hand washing practices and to promote improved availability of soap and washbasins in public areas.

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5 Appendices

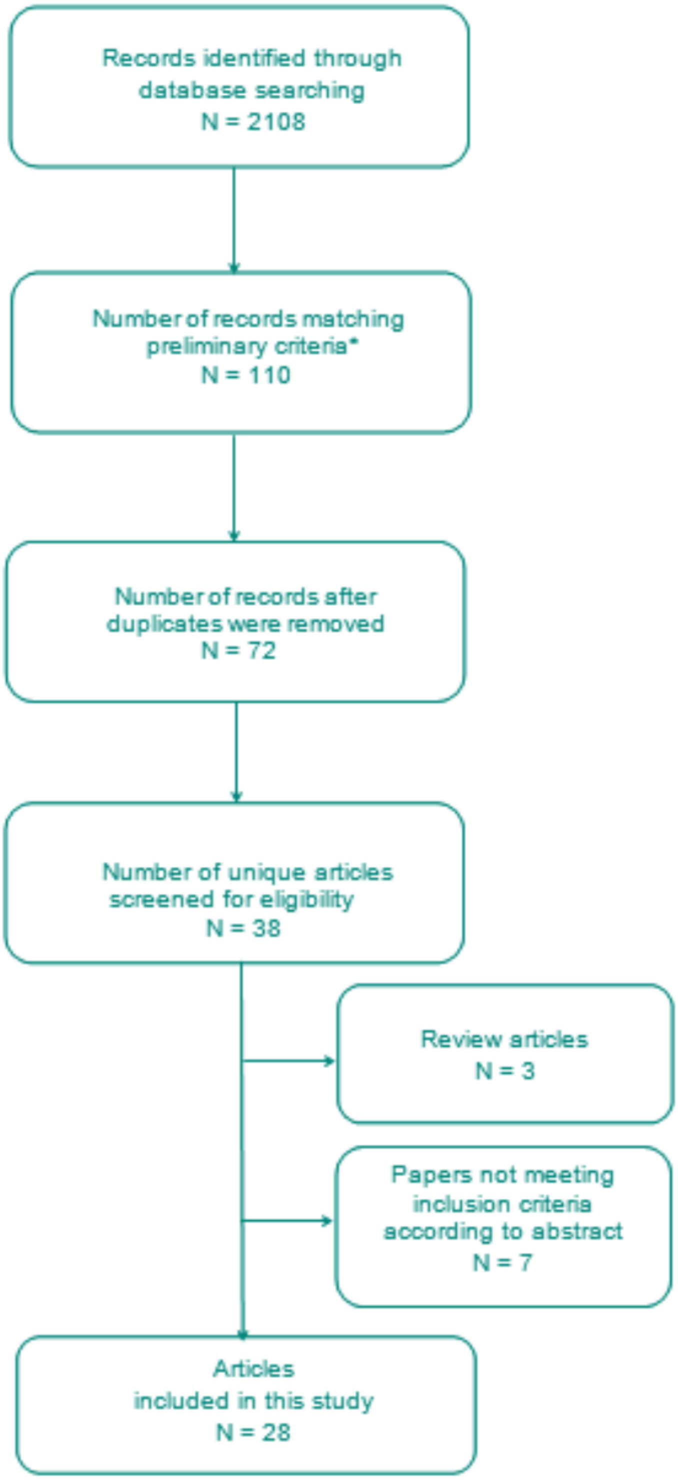
Appendix 1

From amongst 2108 records matching the search terms, after duplicates were removed 38 unique journal abstracts were screened for eligibility in the study (see Table 4). Subsequent analysis of full text journal articles allowed the selection of 28 articles, which are included in this review (see flow diagram in Figure 2). The journal articles are listed in Appendix 2.

Table 4: Number of scientific publications matching search terms retrieved from the literature in three different electronic databases

Search term	Web of Science	Scopus	Pub Med
A = "*Efficacy of hand washing*"	351	690	456
B = "*Efficacy of hand sanitisers*"	63	62	23
C = "*Evaluation of hand sanitisers*"	28	30	2
D = "*Effect of hand hygiene products*"	166	160	77
Number of unique journal articles retrieved	21	10	7

Figure 2: Flow diagram summarising literature search strategy and outcomes



*Only studies reporting inactivation rates of food-related pathogens were included.

Appendix 2: List of scientific publications retrieved through search terms

Biagi M, Giachetti D, Miraldi E, Figura N. 2014. New non-alcoholic formulation for hand disinfection. *Journal of Chemotherapy* 26(2): 86–91.

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Table 5: Selected sociodemographic characteristics of the survey participants

Variables		Number	Percentage (%)
Gender (172)	Male	28	16.3
	Female	144	83.7
Age (174)	18–29	63	36.2
	30–39	33	19
	40–49	34	19.5
	50–59	31	17.8
	60+	13	7.5
Do you live on your own? (173)	Yes	34	19.7
	No	139	80.3
Do you live with your partner? (167)	Yes	97	58.1
	No	70	41.9
Do you live with your children? (170)	Yes	51	30
	No	119	70
Level of education (174)	None	3	1.7
	Primary school	0	0
	Secondary school to age 15/16 or Junior Certificate, GCSE or 'O' level	4	2.3
	Secondary school to age 17/18 or Leaving Certificate, 'A' level or HNC	8	4.6
	Additional training (NVQ, BTEC, FETAC, FAS or other)	17	9.8
	University undergraduate, or nursing qualification	56	32.2
	University postgraduate	86	49.4
Occupation (173)	Full time paid work (30+ hours per week)	101	58.4
	Part-time paid work (8–29 hours per week)	21	12.1
	Part-time paid work (less than 8 hours per week)	3	1.7
	Retired	9	5.2
	At school	1	0.6
	Full time higher education	35	20.2
	Unemployed (seeking work)	1	0.6
	Unemployed (not seeking work)	0	0
	Full-time homemaker	2	1.2
Country of residence (170)	Northern Ireland	129	75.9
	Republic of Ireland	41	24.1
Type of residency (174)	Rural farm	15	8.6
	Rural non-farm	24	13.8
	Small town	34	19.5
	Suburb	32	18.4
	City	69	39.7

Use of public transport (172)	Yes	53	30.8
	No	119	69.2
Type of transport (159)	None	99	62.3
	Bus	30	18.9
	Train	20	12.6
	Other	10	6.3

safe**food**:

7 Eastgate Avenue, Eastgate, Little Island, Co. Cork

7 Ascaill an Gheata Thoir, An tOiléan Beag, Co. Chorcaí

7 Aistyett Avenue, Aistyett, Wee Isle, Co. Cork

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