

FOOD STANDARDS AGENCY REPORT

COMMISSIONED PROJECT MS0004

Evidence for the effectiveness of biosecurity to exclude *Campylobacter* from poultry flocks

Vivien M Allen¹ and Diane G Newell²

¹University of Bristol, Langford, Bristol and ²Veterinary Laboratories Agency, Addlestone, Surrey.

Consultancy Team

Prof G Mead

Dr G Manning

Dr R Davies

Report Date: February 2005

Executive summary

Practical biosecurity measures at the farm level, have been recommended by the FSA and ACSMF (Draft of the Second Report on *Campylobacter*) as a primary strategy to reduce the proportion of housed broiler flocks colonised with campylobacters entering the processing plant and hence the food chain. As a consequence a Biosecurity Campaign was initiated by the FSA in early 2004, involving publication of information together with workshops and other training events for area farm managers and other responsible industry personnel. In support of this programme, further evidence of the benefits of biosecurity in the control of campylobacters in poultry flocks was required. This review, which follows the FSA's review of poultry biosecurity measures published in 2002 (Newell 2002), specifically focuses on available evidence that biosecurity measures are effective in reducing *Campylobacter*. It is based on the published and unpublished, scientific, experimental and industry information available to date. The collection of data included discussions with ten poultry companies within the UK and research groups within Europe, Australia and USA. In the case of unpublished evidence, data, where available, was assessed by three experts and consensus derived.

As concluded in the FSA's strategy, present scientific evidence suggests that transmission of campylobacters among broiler flocks is mainly by the horizontal route. Vertical transmission from parent to progeny via the egg is considered much less likely. There is no scientific evidence to suggest that the focus for controlling *Campylobacter* pre-harvest should be switched from the broiler farm.

From the data reviewed, the evidence for the effectiveness of biosecurity measures to control campylobacters in poultry flocks is sparse and there are many gaps in our knowledge. Nevertheless, the available evidence indicates that the following measures are important in the control of *Campylobacter*:

- wearing protective clothing, house dedicated footwear and/or dipping boots
- washing or sanitising hands
- cleaning and disinfecting the house and any equipment entering that house

- controlling visitors and their equipment and vehicles both to the house and the farm
- controlling pests and other animals on the farm

Most of the other biosecurity measures assessed are logically important as part of basic hygiene practice to prevent and control the spread of avian diseases and therefore should also be part of the biosecurity procedures even if not specifically applicable to campylobacters.

Although numerous on-farm sources of campylobacters have been identified the relative importance of each of these in flock colonisation has yet to be established. Using such information the priorities for intervention could be ranked. In the absence of such information a programme including all feasible and practical (blanket) biosecurity measures is advisable. Such programmes appear to be at least in part successful compared with the use of little or no biosecurity, for example in free range farms where almost 100% of flocks are colonised. Although there has been no national survey of poultry flock colonisation at slaughter in the UK, limited unpublished company data suggests that levels of around 30% are achievable, prior to any depopulation, at least during the autumn and winter periods and this is consistent with studies on a limited number of flocks in Agency research.

Evidence from several countries, including Denmark, the Netherlands, Norway, Sweden and the UK, suggest that although best practice biosecurity measures can help to delay the onset of *Campylobacter* colonization, prevention of colonization cannot be guaranteed. Nevertheless even a delay may result in fewer positive birds at slaughter. However, practical biosecurity measures may only be effective during the months outside the seasonal summer peak. During peak times even stringent measures appear to be substantially reduced in their effectiveness and this is presumed to be a reflection of extreme exposure from as yet unidentified sources. The extent to which current biosecurity measures that can be used routinely on broiler farms, need to be enhanced to control *Campylobacter*, especially during the peak times, is still unknown. Research to identify sources during this peak time is urgently required before recommendations for control of flock colonisation at such times can be made. A component of such research should be the comparison of currently available industry data during the seasonal peak and non-peak times.

Background to the review

The control and prevention of campylobacteriosis remains an important public health objective of the Food Standards Agency. Contaminated poultry meat is considered a major vehicle of infection and many broiler flocks in the United Kingdom are asymptotically colonised with this organism. Control, using practical biosecurity measures at the farm level, has been recommended as a primary strategy (FSA strategy and ACSMF, Draft of the Second Report on *Campylobacter*) and as a consequence a Biosecurity Campaign was initiated in a first phase by the FSA in early 2004 with the publication and dissemination of a poster and leaflet. Education and training of poultry industry personnel is a major component of this campaign and to facilitate this, workshops and other training events for area farm managers and other responsible industry personnel will be undertaken within the second phase of the campaign. In support of this programme, evidence of the benefits of biosecurity in the control of campylobacters in poultry flocks was required. This review is based on published scientific, experimental and industry literature to date on the role of biosecurity in *Campylobacter* control and available unpublished data from industry and scientific contacts.

The project was completed under a very tight schedule and included discussions with ten poultry companies within the UK and research groups both within Europe, Australia and USA. In the case of unpublished evidence, data, where available, was assessed by V. Allen, G. Mead and D. Newell and consensus opinion derived as to the validity of the conclusions drawn based on standard peer review criteria.¹

¹ Where permission was given, data accepted under these criteria are presented.

Introduction

Campylobacters preferentially colonise the intestinal mucosa of birds, especially chickens, in extremely high numbers. Cross-sectional surveys indicate that up to 90% of flocks, entering the abattoir can be colonised. Spillage of gut contents and external faecal contamination during processing contaminates poultry carcasses. Although campylobacters do not grow in the environment, they have evolved effective survival mechanisms. A risk assessment model, under development in the Netherlands, indicates that the most effective approach to reducing campylobacteriosis cases, is likely to be the prevention of flock colonisation at the farm level (Havelaar *et al.*, 2004; Havelaar personal communication²). As approaches like vaccination are not yet feasible, biosecurity to exclude campylobacters from flocks is currently the only intervention available (Newell and Fearnley, 2004).

For the purposes of this project, biosecurity is defined as a set of management practices which, when followed, collectively reduce or prevent the introduction and spread of campylobacters into and between conventionally housed broiler chicken flocks.

Overall Biosecurity and *Campylobacter* colonisation

Campylobacters are ubiquitous in the environment, and although vertical transmission cannot be totally excluded, the current scientific opinion (12th International Workshop on *Campylobacter*, *Helicobacter* and Related Organisms, Aarhus, Denmark, 2003) is that the vast majority of sources of poultry flock colonisation are horizontally transmitted from the poultry house environment.

Campylobacter is not an essential component of the chicken gut flora and the chick gut is *Campylobacter*-free on hatching. Evidence suggests that *Campylobacter*-free flocks can be maintained under strict biosecurity procedures, for example in level 2 containment as clearly demonstrated by all of the numerous chickens in control groups described during *Campylobacter* colonisation experimental procedures. Reduction in the prevalence of *Campylobacter* colonised flocks with the introduction

² Acknowledgement as personal communications indicate that the sources of the information are prepared to be identified

and implementation of strict hygiene procedures has been reported (van de Giessen *et al.*, 1998; Gibbens *et al.*, 2001). Jacobs-Reitsma (2003) has reported the investigation of campylobacter colonisation in parent flocks and broilers derived from these on 2 commercial farms where the strictest hygiene procedures were applied. She concluded that in farms applying the strictest hygiene conditions, such measures are effective, however, even this could not completely prevent *Campylobacter* contamination.

Biosecurity is complex and for a ubiquitous organism, like *Campylobacter*, the essential biosecurity factors remain unclear. Lack of understanding is further complicated by seasonal variations in prevalence of flock colonisation with a peak in summer months which seriously confounds risk assessment and intervention studies. Such seasonality occurs in the poultry flocks of all countries (the Netherlands, Sweden and Denmark) studied to date (Newell *et al.*, 1999). In the UK there is no national data available but the little obtained from company sources over the last 5 years indicates the same seasonal trend. The length and extent of this peak varies from country to country and possibly reflects longitude (Newell *et al.*, 1999). On-going trials in one UK company showed that a farm with good biosecurity measures in place produced mainly negative flocks from December to April prior to any depopulation. However, in the peak season such measures failed to prevent colonisation in the majority of flocks. These findings are in agreement with on-going trials in Denmark (M. Madsen, DFVF, Denmark, personal communication). In that country national data shows that although the overall prevalence of *Campylobacter* in housed flocks in Denmark averaged 35% overall in 5,150 flocks during 2003 this varied from 11.4% to 78% according to season. The interpretation of this evidence is that there is a background risk of flock colonisation, which appears to be largely overcome by standard but well implemented and consistent biosecurity. However, during prevalence peak season (late spring and summer) it appears that these standard biosecurity measures are overwhelmed, possibly as a consequence of extreme pressure from some, as yet, unidentified new or seasonally increasing source. An alternative explanation is seasonally-related changes in standards of biosecurity. However, there is no evidence to suggest a significant change in biosecurity practices and even countries such as Sweden and Norway, where *Campylobacter*-specific biosecurity measures are adopted routinely across the industry, report the seasonal

peak suggesting that this is not the primary factor involved. Whether biosecurity measures can address this seasonal peak is unknown. Certainly, at present, given the outcomes of previous and ongoing trials expert opinion suggests that this seems unlikely. Thus, the primary objective at this time must be to ensure that biosecurity measures are sufficient to address at least the background problem occurring during winter and autumn.

The FSA's leaflet "**Cleaner farms better flocks: keeping out disease and harmful bacteria**", disseminated as part of Phase 1 of the campaign, provides a logical basis on which to develop effective biosecurity measures for the prevention of *Campylobacter* infection in chickens. This leaflet organises the levels of biosecurity on farm into 3 distinct sections: **protecting the birds, the poultry house and the farm**. For the purposes of simplicity this review will use the same structure.

Protecting the birds:

Biosecurity measures designed to protect the flock include:

- The washing of hands
- The wearing of protective clothing, including dedicated footwear
- The cleaning and disinfection of any portable equipment
- The prior cleaning and disinfection of the house as a whole
- The control of visitors
- Provision of *Campylobacter*-free water, feed and litter

The washing of hands, proper use of protective clothing and footwear, and disinfection of any equipment brought into the house, are components of a hygiene barrier approach to preventing flock colonisation by *Campylobacter* (Berndston *et al.*, 1996). The requirements of such an approach need to be fully established prior to flock placement and met throughout flock life. They can include a low, physical barrier between the ante-room and the birds, and a designated clean area that is only entered by personnel in protective clothing. It is logical that such a barrier would remind personnel of the separation of clean and dirty areas and act as to prevent the entrance of contaminated dirt etc into the live bird area.

In a cross-sectional survey in Danish broilers 53% of 88 randomly selected farms investigated had no, or an inadequate, hygiene barrier present and *Campylobacter*-positive flocks were significantly more prevalent (OR 3.1=1.1<OR<9.3) on those farms (Hald *et al.*, 2000). In a Norwegian study (Table 1) (M Hofshagen, veterinary institute, Norway, personal communication) the use of a hygiene barrier clearly reduced the risk of *Campylobacter*-flock positivity. Finally, in an ongoing UK investigation, presence of a hygiene barrier, with dedicated clothing, footwear and lime under doors in some houses, delayed or prevented lateral spread between flocks (unacknowledged personal communication).

Table 1. Norwegian study of risk factors in 193 farms with 110 *Campylobacter* positive and 83 *Campylobacter* negative flocks

	Odds Ratio		
Hygienic barrier at chicken room entrance	Not installed 4.2	Installed 1	
Water source	Private well 3.6	Other private source 2.1	Public source 1
Routine hand washing	Never/sometimes 3.3	Always 1	
Laying litter in broiler house with tractor	Yes 3.1	No 1	

Washing hands

Unpublished work from one UK poultry company (unacknowledged personal communication) demonstrates that hands can become heavily contaminated with bacteria during visits to poultry houses (Figure 1). Clearly, bacteria, including

campylobacters, can be transmitted around a farm via hands. Campylobacters have been recovered from the farm office and ante-room door handles and even from hand washing equipment (Project OZ0608). Such bacterial contamination constitutes a risk not only for the spreading of disease from one house to another but also, in the case of a zoonotic organism, a risk to farm workers, and, potentially, their families. Hand sanitisation after visiting houses is demonstrably effective at reducing the bacterial load (Figure 1). It is reasonable to assume that hand washing with appropriate detergents is also effective. This is a component of traditional hygiene practise and failure to hand-wash routinely increases the risk of Campylobacter colonisation in a flock (Table 1). Thus to ensure optimal effectiveness, washing or sanitising hands with an alcohol-based gel should be routinely undertaken between houses. Ideally, hand washing should be extended to include the forearms, if exposed.

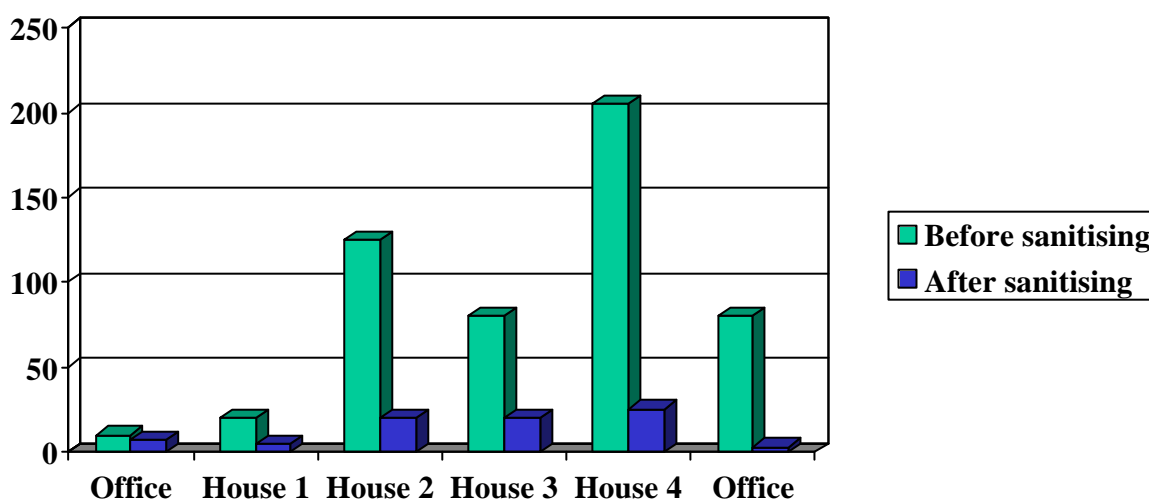


Fig 1 Microbial numbers (TVCs x 1000) recovered from hands after routine inspection of the poultry houses before and after hand sanitisation

Protective clothing

Protective clothing comprises boots and outer working clothes, such as overalls. Campylobacters have been recovered from the boots of farm personnel and the shoes of catchers (Project OZ0608). It is reasonable to assume that outer clothing can also be contaminated though this has not been demonstrated. Some of these boot-contaminating strains have been shown to be the same genotype as those later colonising the birds and therefore may have been the source of flock infection

(Project OZ0608). Laboratory experiments indicate that campylobacters are susceptible to disinfectants at the recommended levels (Avrian *et al.*, 2003). Thus boot dips should be effective if used properly e.g. sufficient contact time. Certainly the use of foot dips is associated with a lower risk of *Campylobacter* flock positivity (van de Giessen *et al.*, 1996). In some intervention studies effective boot dipping delayed, or even prevented, flock infection with *Campylobacter* (Humphrey *et al.*, 1993; Pattison, 2001,) especially when combined with changing outer clothing (Newell and Wagenaar, 2000; Gibbens *et al.*, 2001) and in one study the use of an unofficial entrance, unprotected by foot dips, at an experimental commercial house was associated with the initial points of flock infection (Shreeve *et al.*, 2000). However, in a French study of 75 broiler farms, the use of boot dips had no effect on flock positivity (Refregier-Petton *et al.*, 2001). Such differences may reflect the chemicals used, maintenance and use of the boot dips. Efficacy of boot-dip disinfectant is reduced over time, but phenols last at least 5 days (unacknowledged personal communication) (Figure 2). Efficiency is reduced by dilution with rain water if kept outside, by contamination with organic matter like mud and by reduced contact time. Thus, the training of farm staff in boot-dip use is inherently important. Boot-dips need to be routinely changed at least once per week (Humphrey *et al.*, 1993), and preferably twice weekly (Pattison 2001), or when visibly soiled. The efficiency of boot-dips can also be improved by pre-cleaning the boots each time using a hose and brush (Pattison 2001) or a pre-wash bath containing an amphoteric compound (R. Davis, personal communication). The use of double dips, one at the entrance to the house and a second at the entrance to the live bird area, was shown to be effective in one UK company (unacknowledged personal communication) (Figure 3).

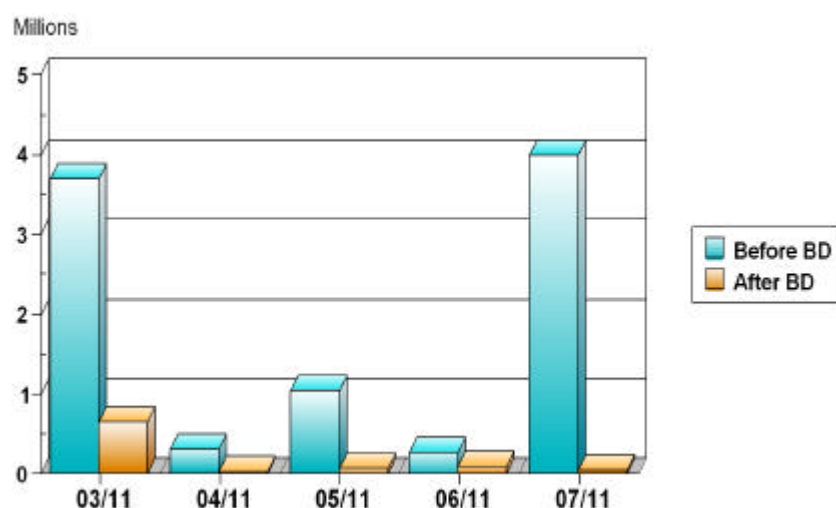


Fig 2 The efficacy of boot dips over 5 days in reducing microbial numbers recovered from footwear

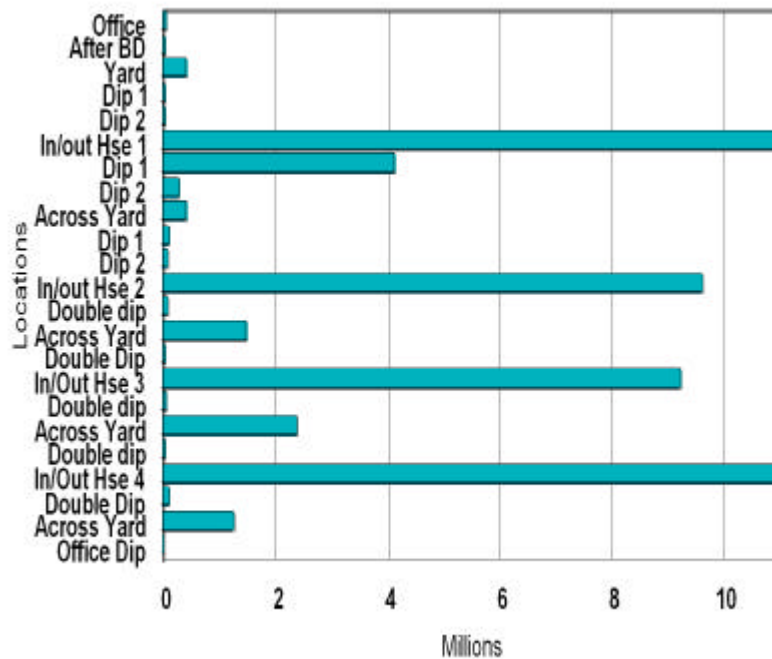


Fig 3 Microbial numbers recovered from footwear when working routinely across farm site

Given the inherent difficulties in operating boot dips effectively, the FSA and ACMSF conclude house dedicated footwear offers greater protection against *Campylobacter*. Both boot dips and dedicated boots are effective if used appropriately (R. Davies personal communication), however, it seems logical that compliance with the use of dedicated boots is the more reliable option. This assumption is supported by preliminary industry data (unacknowledged personal communication), which showed about a 50% higher level of flock colonisation with the use of boot-dips compared with dedicated footwear (27% of 1129 flocks compared with 48% of 344 flocks). Lack of farm personnel training in the use of boot-dips may have contributed to this effect. For optimal protection even dedicated boots should be dipped before

entering the live bird area, with evidence for this presented in Figure 4 (unacknowledged personal communication). This would minimise the amount of contaminated material in the anteroom. However, this foot-dip would need to be used only in conjunction with the dedicated footwear. The use of disposable overshoes is another alternative but their benefit is questionable, as experience demonstrates that they are easily dislodged or torn within the broiler house (R Davies, personal communication).

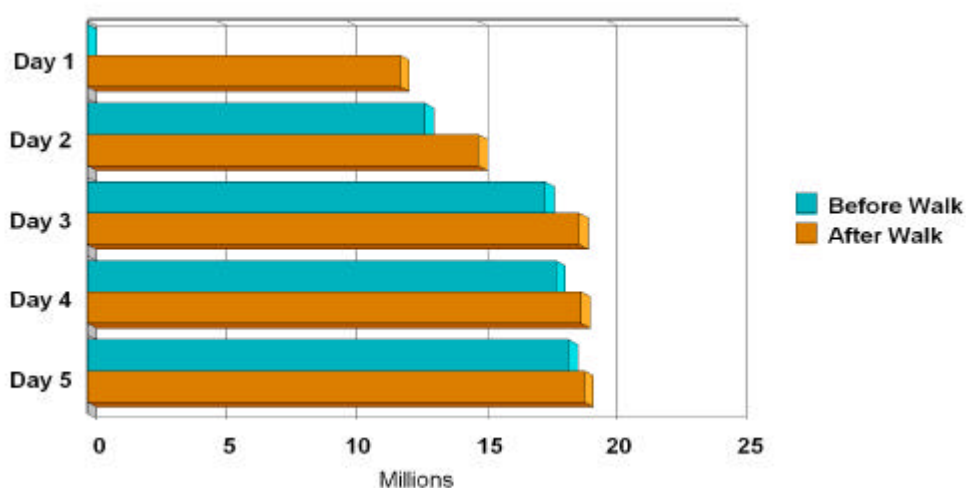


Fig 4 Microbial numbers recovered from barrier footwear (no footdip) when working routinely in a poultry house

Disinfection of portable/mobile equipment

Introducing contaminated equipment into a broiler house is an obvious potential source of *Campylobacter* infection. In particular, this is a probable means of transmitting infection from one house to another on the same farm if equipment, such as weighing machines or tool boxes are moved between houses. For example the use of tractors for laying litter is associated with a 3-fold risk of *Campylobacter* colonisation of the flock (Table 1).

Another potential source of contamination in the broiler house is the use of transport crates used to take the birds from the house to the abattoir. These crates are usually washed at the abattoir before returning to another farm; however, this washing is often

ineffective. In addition, the crates, for ease of handling, are stacked in modules, which can become caked with organic matter and are cleaned ineffectively. *Campylobacter* have been recovered, at levels of 10^5 organisms on the base of the crates (Project MO1023), on the modules (Project OZ0608) and even the forklift truck used to place the modules in the house (Project OZ0608). In one published study (Slader *et al.*, 2002) the crate-washing system in one UK poultry-processing plant was investigated. This comprised a long soak tunnel, allowing 20 seconds of exposure to detergent with agitation. The tunnel was linked to a shorter tunnel washer (10 seconds of exposure), which was followed by a pressure rinse with a quaternary ammonium compound. This study concluded that the cleaning process had little, if any, effect on the *Campylobacter* contamination status of the transport crates. Even after cleaning, organic matter was detected on the crates. It seems likely that the organism is embedded in this organic matter and therefore protected from the cleaning process. Inadequate cleaning of crates is well recognised (Mead *et al.*, 1994). Even following storage for up to 48 hours, which is unlikely to occur in practice, campylobacters can still be recovered from crates, albeit at lower numbers (Berrang *et al.*, 2004). Genotyping studies have demonstrated that campylobacters recovered from these crates are subsequently recoverable from the birds, either remaining in the house (P. Backall, Animal Research Institute, Queensland, Australia personal communication) or transported to the abattoir (Newell *et al.*, 2001). Thus contaminated crates would account for the increased *Campylobacter*-flock positivity during sequential rounds of batch depletion (thinning) (Hald *et al.*, 2000). These studies highlight the risk to the birds from equipment that is not house dedicated. Although crates may be introduced into the house only at the end of the flock life, the extremely rapid rate of colonisation and spreading, means that birds in flocks depopulated over 2-3 days can become infected on the first day and may be positive by the time they reach the abattoir (Project OZ0608).

Cleaning and disinfection of the house.

Houses occupied by *Campylobacter*-colonised chickens become heavily contaminated with campylobacters in the litter, water in the lines and drinkers/cups, on the walls, uprights and vents, in the dust and the atmosphere (Project OZ0608; Project FS3303; Stern *et al.*, 1997; Berndston *et al.*, 1996; I Ogden, personal communication). In the

UK, and most of Europe, litter is removed and houses cleaned and disinfected after each flock. In those countries, which reuse litter, it has been identified as a risk factor (P. Backall, Animal Research Institute, Queensland, Australia personal communication). The cleaning regimes and schedules vary enormously between companies. Nevertheless, evidence indicates that this process of cleaning and disinfection is usually adequate as campylobacters are rarely reported, even after occupation by a previously positive flock. Moreover, in studies from the UK and the Netherlands the same *Campylobacter* types are only infrequently found in sequential flocks in the same house (Shreeve *et al.*, 2000; Jacobs-Riestma, personal communication). However, in Denmark (Petersen and Wedderkopp, 2001) persistence of some *Campylobacter* clones has been observed. This may reflect differences in house disinfection or reservoirs of environmental contamination.

There is some evidence to suggest that the efficacy of cleaning and disinfection influences the risk of flock colonisation by *Campylobacter*. For example, the use of ground water for cleaning the broiler house is not recommended (van de Giessen 1996) as it enhances the risk of colonisation. The down time between flocks also appears to be very important. A down period of less than 14 days was identified as a significant risk factor for *Campylobacter* infection of broilers (Hald *et al.*, 2000). This down time is probably associated with the survival of campylobacters in the house environment. Campylobacters do not grow under such conditions but survival times can be very long and are increased by cool, damp conditions. Cleaning regimes should ensure that houses are thoroughly dry before placement of the next flock.

A further issue in house cleaning and disinfection is the ante-room, which because of electrical wiring may not be as easily cleaned as the live-chicken area. This assumption is supported by the recovery of campylobacters from the ante-room at the time of chick placement (Project OZ0608).

Control of Visitors

Clearly minimising the number of visitors to the live bird area is logical in relation to control of all avian diseases. The risk of *Campylobacter* colonisation increases with the number of persons tending the flock (Refregier-Petton *et al.*, 2001). Thus, it is logical that where essential visitors, like maintenance personnel, enter the houses then

biosecurity procedures should be rigidly undertaken, including the disinfection of any equipment they carry.

Provision of Campylobacter-free water, feed and litter

Campylobacters survive poorly in dry conditions so feed and litter can be considered *Campylobacter*-free initially unless contaminated by faecal material from vermin during storage. However, campylobacters can survive in water for long periods and are recoverable under experimental conditions using the best practise culture methodology for at least up to 4 months (Rollins and Colwell, 1986; Cools *et al.*, 2003). (Although chlorination at normal levels is effective against *Campylobacter*, free available chlorine concentrations vary substantially around broiler farm supply locations and may not achieve the recommended levels (Boxall *et al.*, 2003)). Poultry drinking water has been implicated as a risk for bird colonisation, especially when obtained from non-municipal sources (Kapperud *et al.*, 1993; Table 1). Nevertheless, campylobacters are rarely isolated from the header tanks and drinkers in houses (Jacobs-Reistma *et al.*, 1995; van de Giessen *et al.* 1998) unless the occupying flock is already positive (Gregory *et al.*, 1997; Ogden unpublished data). However, in one recent study, campylobacters were isolated from the drinking water prior to flock placement (Zimmer *et al.*, 2003). Moreover, the chlorination of stored water, and the regular cleaning and disinfection of the house water-lines, apparently reduces the risk of *Campylobacter* colonisation (Evans 1992; Evans and Sayers 2000; Gibbens *et al.*, 2001; Pearson *et al.*, 1993) though this is not a consistent risk factor (Hald *et al.*, 2000; Humphrey *et al.*, 1993). Despite these observations it is debatable from molecular studies in commercial houses and experimental colonisation studies whether campylobacters recovered from water are infective to chickens (Newell and Fearnley, 2003; Zimmer *et al.*, 2003).

Water acidification is often recommended to prevent colonisation of broiler flocks with *Salmonella* and other microbes. However, the risk of colonisation with *Campylobacter* increased with such treatment in one study (Refregier-Petton *et al.*, 2001). In a more recent study, the presence of organic acids in the drinking water reduced the number of campylobacters in the broilers compared with a control group given untreated water (Chaverech *et al.*, 2004)

For the majority of flocks in the UK nipple drinkers are used, often with spillage cups (Gibbens *et al.*, 2001). It is considered that open water receptacles, including troughs and suspended drinkers, contribute to the dissemination of the organism throughout the flock (Shane, 2000).

Protecting the poultry house

For the purposes of biosecurity, each poultry house should be considered a separate unit. Once the flock in any one house has become colonised, the reservoir of infection in that house is enormous (approximately 10^{13} campylobacters per flock of 20000 birds) and these organisms are shed continuously for the remainder of the flock's life (Newell and Fearnley, 2003). Following the flock becoming positive, campylobacters are recovered from all over the farm site, including house fan vents, farm office and ante-room doors, the grass and gravel around the house, etc (Project OZ0608). To prevent transmission from one house to another, high levels of biosecurity between houses are required and the following biosecurity measures are important in protecting the individual poultry house:

- Controlling pests
- Controlling other animals on the farm
- House management and maintenance

Controlling pests

Campylobacters have been recovered from the faeces of wild rodents, including rats (Project OZ0608), mice and bank voles (Ferne and Park, 1977), wild birds (Project OZ0608) and arthropods (Umunabuikie and Irokanulo, 1986). In the case of wild bird faeces, identical genotypes of campylobacters, isolated from around the broiler house, have been subsequently isolated from the flock (Project OZ0608). Most recently (Hald *et al.*, 2004), campylobacters have been cultured from over 8% of flies collected at broiler house air-intake valves in Denmark. When PCR was used over 70% of the flies collected were *Campylobacter*-positive. Ongoing intervention studies to prevent the ingress of flies into the houses have indicated that such flies are a risk for flock colonisation (M Madsen, DFVF, Denmark, personal communication).

Potentially, all these pests can be responsible for the spread of *Campylobacter* from one flock to another if they travel between houses, although flies are not perceived as a significant problem by the UK poultry industry (personal discussions with poultry industry technical managers). In a Norwegian study (Kapperud *et al.*, 1993) the presence of rats on the premises was found to be a significant risk factor and the presence of litter beetles in the changing room significantly increased the risk of *Campylobacter* colonisation in French broiler flocks (Refregier-Petton *et al.*, 2001). Subtypes of *C. jejuni* that have been identified in flies, beetles and vermin, have also been detected in chicken intestinal contents, highlighting the need to keep vermin and other animals away from the broiler house (Hald *et al.*, 2004, Hiatt *et al.*, 2002, Stern *et al.* 1997). In one of these studies (Hiatt *et al.*, 2002), however, it proved difficult to determine the exact source of the *Campylobacter* infection due to the fact that campylobacters were isolated concurrently from mice, insects and wild birds, all of which had free access into the broiler house.

In contrast, in studies in the USA (Gregory *et al.*, 1997) and the Netherlands (Jacobs-Reitsma *et al.*, 1995), *Campylobacter* was isolated from insects and beetles (darkling beetles in the Dutch study) only after the birds had become colonised, suggesting that these vectors may not necessarily be the source of initial infection, but may be responsible for spreading the organism throughout the house, and possibly between houses depending on proximity and numbers.

Effective rodenticide and other control programmes for the control of rodents are important. Similarly, insecticides, bait treatments and larvicides are available for the control of flies and other insects. In addition dead birds should be removed promptly from the house and, preferably incinerated immediately. If this is delayed, the carcasses should be covered during storage to avoid attracting flies and scavengers which can disseminate contaminated material (Project OZ0608). On-site disposal was found to increase the risk of *Campylobacter* infection, which may be due to environmental contamination (Evans and Sawyer, 2000).

Control of other animals on the farm

Campylobacter spp are found in the intestines of most mammals and birds and in the majority of cases this carriage is asymptomatic. The presence of other animals on the farm, such as dogs, cats, pigs, cattle and sheep, has been associated with an increased risk of flock colonisation (Evans 1992; van de Giessen *et al.*, 1996; van de Giessen *et al.*, 1998). In addition genotypically identical strains have been found colonising the flocks that were first isolated from cattle in fields adjacent to the broiler houses (Project OZ06508). It is logical that dogs and cats, which may intermittently excrete campylobacters throughout life, should always be kept out of broiler houses and several studies (Gregory *et al.* 1997; Hald *et al.*, 2000; van der Giessen *et al.*, 1996) have concluded that greater emphasis should be placed on hygiene routines when entering the live bird area of broiler houses on farms with multiple livestock, especially after contact with cattle, sheep and pigs.

Management and maintenance of the poultry house

Any dead poultry should be removed promptly from the house and site. On-site disposal was found to increase the risk of flock colonisation, which may be due to environmental contamination (Evans and Sayers, 2000). In one ongoing study (Project OZ0608) campylobacters were recovered from intestinal material on the concrete apron of a poultry house. This material was believed to have come from a disposal bin containing dead chickens from the previous flock, which was scavenged by a feral cat. Spent litter, too, may be a source of future flock infection and should be removed from the site promptly (P. Backall, Animal Research Institute, Queensland, Australia personal communication). The fabric of the house should obviously be kept in good repair to prevent access by vermin and wild birds. These pests can also be discouraged by cleaning up any spilled feed as soon as possible.

Protecting the Farm

The poultry farm as a whole should be treated as a protected environment. The protection aims to prevent the ingress of *Campylobacter* contamination from the surroundings. It is logical that the reduction of the environmental load of campylobacters in and around the poultry farm will reduce the risk of flock colonisation. Three major biosecurity measures will be considered at this level:

- Control of visitors to the farm site as a whole
- Cleaning and disinfection of vehicles and other equipment brought onto the farm
- Site maintenance

Control of visitors to the farm site as a whole

All visitors, including company staff from other sites or management locations, constitute a risk of bringing campylobacters onto the farm. Recording the identity of all site visitors is one way of ensuring that only authorised personnel are allowed access and visits are kept to a minimum. Other requirements, such statements about previous contact with poultry, tend to be company-specific. Nevertheless, even authorised personnel should be fully educated and use appropriate protective clothing and procedures. Vehicles should be parked well away from the broiler houses, preferably in a dedicated parking area. Once again this is basic hygiene practice applicable to disease control in general, and obviously is also relevant to *Campylobacter*, but no data on efficacy has been identified.

Cleaning and disinfection of vehicles and other equipment brought onto the farm

Campylobacters have been isolated from a variety of vehicles on the farm, including chick lorry steps and wheels, fork lift trucks, live bird transport lorry cab and steps and van wheels (Project OZ0608). In some cases strains of the same genotype have subsequently been isolated from the flocks on the farm. Clearly cleaning and disinfection of such vehicles is inherently important especially when lorries are coming from heavily contaminated locations such as poultry abattoirs.

Site maintenance

As mentioned previously pests such as rodents and wild birds carry campylobacters and deliver these onto the site in shed faeces. To avoid attracting pests on to the farm, all vegetation should be cut back and maintained in a well-trimmed condition. Also, the site should be kept free from any unnecessary items that could harbour such pests

(Warren 2001). It is common practise to plant trees and shrubs to shield poultry farms but this obviously encourages wild birds. Similarly, the generation of open ponds and water courses for drainage encourages water birds like wild ducks, which also carry campylobacters.

Most houses now have concrete aprons but frequently this concrete is poorly maintained with cracks and open puddles. Campylobacters are routinely recovered from such areas (Project OZ0608 and Project FS3303). Molecular typing has shown that these campylobacters have subsequently colonised the flock in the house. Whether transmission is via human traffic or other events, such as rodents or surface water entering the house is unknown. As the damp conditions favour Campylobacter survival adequate drainage or disinfection of such areas is clearly important.

Conclusions

1. There is no new scientific evidence to suggest that the focus for controlling *Campylobacter* should be switched from the broiler farm to other aspects of pre-harvest production or that vertical transmission from parent to progeny via the egg is an important source of *Campylobacter* infection. In the absence of any other control measures at the farm level, for example vaccination, only interventions based on biosecurity seem to be feasible at present.

2. The available evidence for the effectiveness of the individual components of such measures, to control campylobacters in poultry flocks, has been assessed. Overall, the evidence is sparse and there are many gaps in our knowledge. **Nevertheless, the evidence indicates that the following measures are important in the control of *Campylobacter*:**

- **wearing protective clothing, house dedicated footwear and/or dipping boots**
- **washing or sanitising hands**
- **cleaning and disinfecting the house and any equipment entering that house**
- **controlling visitors and their equipment and vehicles both to the house and the farm**
- **controlling pests and other animals on the farm**

Most of the other biosecurity measures assessed are logically important as part of basic hygiene practice to prevent and control the spread of avian diseases and therefore should also be part of the general biosecurity procedures.

3. We believe that biosecurity measures in use currently are at least partly effective in controlling *Campylobacter* colonisation. This is based on the fact that in conditions where biosecurity is impractical i.e. organic and free-range flocks, birds are almost always colonised at slaughter (Project OZ0608; Heuer *et al.*, 2001). Although there has been no national survey of poultry flock colonisation at slaughter in the UK, **limited unpublished company data suggests that levels around 30% prior to any depopulation are achievable at least during the autumn and winter**

periods. This is comparable with the prevalence in flocks from other European countries (Denmark and the Netherlands) with similar environmental conditions during non-seasonal peak periods.

4. Evidence from several countries, including Denmark, the Netherlands, Norway, Sweden and the UK, suggest that best practice biosecurity measures can help to delay the onset of *Campylobacter* colonisation but cannot guarantee its prevention. Nevertheless, even a delay may result in fewer positive birds at slaughter. However, practical biosecurity measures may only be effective during the months outside the seasonal summer peak. **During peak times the effectiveness of even the most stringent measures appears to be substantially reduced and this is presumed to be a reflection of extreme exposure from as yet unidentified sources and, possibly, seasonally-related changes in flock management.**

5. The extent to which current biosecurity measures that can be used routinely on broiler farms need to be enhanced to control *Campylobacter*, especially during the peak times, is still unknown. **Research to identify sources during this peak time is urgently required before recommendations for control of flock colonisation at such times can be made. A component of such research should be the comparison of available industry data during the seasonal peak and the non-peak times.**

6. The other occasion when high levels of environmental exposure to campylobacters may overwhelm routine biosecurity measures is during partial and/or extended depopulation. The evidence for this is extremely strong. The susceptibility of the flock at this time to such exposure may also be enhanced, for example, by the effect of feed withdrawal or harvesting on the bird. **We concur with the ACSMF draft report and FSA *Campylobacter* strategy, that investigation of biosecurity procedures during such depopulation events is urgently required to accurately identify the routes of transmission to enable targeted interventions. In addition, we recommend that other flock related factors, which may lead to increased susceptibility to *Campylobacter* in the bird and suitable counter measures, should also be investigated.** This is starting to be addressed through FSA research.

7. Numerous sources of *Campylobacter* have been identified, e.g. livestock, wild birds, mammals, vermin, wild birds, insects, and water. However, the relative importance of each of these in broiler colonisation has yet to be established. **We consider that appropriate research is needed to provide more detailed and, if possible, quantitative microbiological information on farm environmental contamination so that the priorities for intervention can be ranked.** This is starting to be addressed through Defra research. Once this is achieved then other transmission routes can be investigated such as airborne campylobacters.

8. In order to promote best practice with regard to biosecurity interventions as measured by prevalence of flock colonisation with campylobacters, **we recommend the establishment of an industrial and scientific forum in which information can be confidentially shared on the effectiveness of such measures.** To enable this, urgent publication of information regarding standard culture and sampling procedures of flocks for *Campylobacter* is required. This is starting to be addressed through FSA research.

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