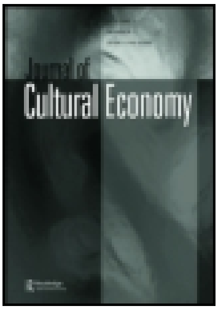

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'JUST-IN-TIME' DISEASE
Biosecurity, poultry and power

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Disease and profits make for interesting bedfellows in modern factory farming, especially where poultry is concerned. Profitable, cheap factory-farmed chicken is dependent on large-scale, industrial throughput, yet those very same intensive conditions pose real risks for disease outbreaks. Campylobacter *in poultry is now the main reported cause of food poisoning in the UK, responsible for more than 100 deaths a year. In this paper, drawing upon fieldwork from across the poultry supply chain, we argue that the intersection of just-in-time pressures, commercial and regulatory, with particular practices of biosecurity on farms and in processing factories, provides prime conditions for the amplification and spread of* Campylobacter. *We go on to argue that such ecologies of poultry production are best understood as part of a relational economy of disease, and that the very control exercised over the lives of farmed birds risks reversal into ever greater insecurity.*

KEYWORDS**:** just-in-time; biosecurity; disease; poultry; power

Introduction

Intensive animal farming and industrial food processing have delivered an unprecedented growth in meat production over the past half century in North America and Western Europe, as well as more recently across South-East Asia. In the case of broiler or table chicken, a corresponding increase in consumer appetite for poultry products has seen the worldwide average per capita consumption quadruple since the 1960s (FAO 2010). Once a luxury in 1950s Britain, chicken is now a staple in the British diet, due in no small part to its successful marketing as a cheap, lean meat (Godley & Williams 2009; Jackson et al. 2008). 'Cheap factory chicken', as food journalist Lawrence (2010) declared, 'is one of the defining commodities of our era'. So defining, in fact, that it is also the major source of foodborne disease in the UK, with *Campylobacter*, a bacterium relatively unknown until recently, the number one reported cause of foodborne illness. Of the estimated 460,000 cases in the UK in 2012, there were over 22,000 hospitalisations and 110 deaths [Food Standards Agency (FSA) 2013], with chicken widely believed to be asymptomatic carriers of the two *Campylobacter* strains that affect humans. Across the European Union, *Campylobacter* is also the top foodborne disease, with an estimated nine million cases to date (FSA 2013). Cheap factory-farmed poultry and disease, it seems, go hand in hand.

As we see it, the industrialisation of poultry production, with its characteristic high density, concentration, turnover and containment of birds, is part of the problem. The resulting ecologies of production, in combination with commercial pressures transmitted through the system, hold out the potential for already compromised bodies to reach a point where an economically reconfigured life is placed at risk. Disease, we argue, is less about contamination from an unhealthy outside, as it is about just-in-time pressures folded into an already entangled mix of dense 'intra-actions' (Barad 2007) of pathogens, animals, equipment, capital and people (Hinchliffe et al. 2013). It is, we contend, a landscape of intensities and pressure points rather than a series of breach points, in which disease can erupt as quickly as it can dissipate, and pathogens can mutate and rearrange in ways that push life beyond a threshold which has the potential to undermine both itself and profits alike.

In this paper, we aim to show how the standardisation, acceleration and concentration of factory-farmed animals have the potential to push life beyond such a threshold, but not as is often thought by corporate capital simply exercising control *over* life. Rather, in taking control of the farmed animal population and reducing it to 'mere' life (Honig 2009), the powers *of* life may actually be turned against itself. The outcome is closer to Esposito's (2008) observation that attempts to secure life, to immunise and protect life, when brought to a certain threshold, may end up negating it; that is, where the very management of life itself (in this case, non-human life) runs the risk of producing ever greater harms.

Such contentions involve us in two streams of academic inquiry into the industrial production of animals and disease, and which we bring into closer conversation in this paper. Firstly, we engage with recent work in geography and science and technology studies that has attended to the practices of biosecurity, and which understands disease as a relational effect of the socio-material relations constituted in such practices (e.g. Donaldson 2008; Enticott 2008; Hinchliffe & Bingham 2008; Lavau 2013; Law 2006; Law & Mol 2011; Mather 2014). Consistent with the 'critical' or 'post-human' strand of animal geographies (Buller 2013), the concern is one of the ongoing co-constitution of human and non-human lives, or the 'multi-species becomings' of animals, people and disease agents. Thus to speak of disease as 'in the making' not only signals the practices, agricultural or otherwise, that are implicated in producing diseased animals, but it also signals disease as being performed through these relations rather than being predetermined.

By following or tracing the shifting patterns of association and disassociation amongst a diverse array of materials, lives, institutions, texts and sites, these studies have variously interrogated farms, factories, government agencies and scientific institutions as spaces of biosecurity practice. One of our driving interests, however, is in how such 'sites' of biosecurity simultaneously practice other commitments and concerns, whether animal welfare, good governance, robust knowledge or corporate profit. In this, we engage particularly with studies of the political ecology of industrial animal farming and food production, which have demonstrated the intersections of biosecurity practices with particular forms of commercial practice (Davis 2005, 2009; Graham et al. 2008; Liebler et al. 2009; Wallace 2009; Wilbert 2006). Such work prompts us to pay closer attention to the ways in which biosecurity on farms and factories is managed and negotiated alongside and through various corporate, labour and regulatory demands. Together, these various practices constitute what we refer to as the relational economy of disease. Rather than reify corporate power, we seek a more distributed and non-deterministic account of the various human and non-human agencies that come together in industrial animal production, and through which disease comes into being, multiplies and spreads.

In the first part of the paper, we first set out the range of just-in-time pressures – commercial, regulatory and biological – which intensify the production of factory-farmed poultry meat and, less obviously, the production of viral and bacterial foodborne diseases. After that, we argue for a particular disease pathology, one understood as a relational effect rather than a predetermined outcome of a particular pathogen or a particular agro-ecological system. Using the example of UK poultry farms, factories and their supply chains, we show how commercial and regulatory pressures are folded into ecologies of production that have the potential to 'tip' a stripped down, economically reconfigured life over on itself. We focus specifically on the case of *Campylobacter* and the spread of this disease on and between poultry farms, and thereafter into processing plants. Finally, we go on to outline how, when corporate power exercises control over life through the industrialisation of animal production, it also runs the risk of reversal into ever greater pathological insecurity.

Such claims are grounded in our fieldwork conducted across the UK supply chain for 'table chicken', and in allied food safety and animal health services. Semi-structured interviews and discussions were conducted with poultry farmers, poultry catchers, labour providers, quality assurance and welfare managers, factory floor staff, retailers, micro-biologists, vets, food inspectors, government policy-makers and industry advisors. Given our particular interest in the ways in which biosecurity is dealt with in practice, where generously made possible by our informants, we visited various sites across the supply chains of three of the five major poultry processors in the UK. These visits involved a combination of work shadowing and participant observation on farms and in processing factories, allowing us to observe first-hand the techniques, people, materials, animal bodies and infrastructure that intersect in the efforts to manage foodborne disease. Through these discussions and observations, we learnt much about the pressures, constraints and affordances through which biosecurity policy is made more or less operational in the various sites that chicken passes through between farm and fork. Conducted between 2010 and 2013, our research coincided with the rise of *Campylobacter* as the number one reported cause of food poisoning cases and outbreaks in the UK.

Factory-farmed Meat and Foodborne Disease

With the industrialisation of poultry production, large-scale producers now control more or less every stage of the supply chain, from breeding and hatching, to growing, to slaughter and processing. In the USA, the big feed supply companies dominate, integrating forward up the chain, whereas in the UK, the big food retailers, the supermarkets, control supply lines through their market power, with the major food processors picking up the task of backwards integration (Boyd & Watts 1997; Godley & Williams 2008).

Regardless of such differences, however, size speaks volumes when it comes to realising the economies of scale that come through concentration, high throughput and product uniformity. Profitability rests upon low unit costs and turning volume; that is, churning the numbers out cheaply. In the UK, almost 1.3 million tonnes of broiler meat was produced in 2011, or 855 million chickens slaughtered (Crane et al. 2012; DEFRA 2012), with the average throughput per slaughterhouse increasing by a third between 2005 and 2010 (FSA 2011). Poultry production in the UK is a highly concentrated affair, consolidated into fewer and larger vertically integrated companies that, between them, control almost the entire market for chickens in the UK (Crane et al. 2012; Yakovleva & Flynn 2004). These large corporate processors are now collectively responsible for over three quarters of the UK slaughter throughput supplied to the commercial retail market (FSA 2010). The numbers matter, but our interest lies with the range of just-in-time pressures that they bring with them and which do not always sit well together.

Just-in-Time Poultry

With profit dependent on churning out the numbers of a highly perishable product on an industrial scale, guaranteed throughput and turnover have become essential. A type of just-in-time system, as outlined by Boyd and Watts (1997), is practised to integrate the rapid throughput of thousands of animals from breeding through to growing and processing, and onto the supermarket shelf. Boyd and Watts (1997) set out how, over a relatively short timeframe in postwar USA, the poultry industry changed from one comprised of small independent firms operating on a largely informal market basis to a vertically integrated industry managed through a system of formalised contracts. In place of specialised independents at different stages of the supply chain, large corporates, such as Tyson Foods, integrated the whole operation on an industrial basis under a single ownership and management structure. Tight control over throughput at each stage of the process – from delivering the right number of day-old chicks to contract farmers, to ensuring the collection of full-grown birds to keep up with the factory production line, for example – transformed the industry into a system that they tellingly refer to as 'agro-industrial just-in-time'.

The system is not just about tight coupling and numbers though. A constant throughput of birds is critical to the process, but so too is product uniformity and growth rates, in terms of size, weight and body shape, responding to retailer demands for standardised products of particular quality. As Boyd and Watts (1997) outline, these big corporate integrators have relied on a whole host of technologies to create a uniform gene pool selected for fast growth and higher meat yields, which together with rigid feed and antibiotics regimes, produces birds of the requisite market weight and growth pattern. Advances in animal genetics, the rolling out of protein-enriched diets, and the exploitation of pharmaceutical technologies to improve disease resistance, effectively combined to take out the vagaries of biological life that, in past times, disrupted supply chains and prompted swings in profitability across the industry. Under corporate agribusiness, over the past 50 years or so, the lifetimes of the chicken population in the USA has halved and its growth rate doubled, so that the numbers ballooning through the system just-in-time are also, significantly, at just the right weight and price point.

In the UK, over much the same period, a similar pattern of integration, consolidation and standardisation has taken place in the poultry sector, although in this case driven not by corporate 'integrators' but by corporate retail, in the shape of the large supermarkets (Godley & Williams 2008; Morgan et al. 2008; Wrigley 2002). Commercial rather than industrial capital took the lead, with Sainbury's prominent in pushing the leading food processors to exploit the potential economies of scale available by integrating backwards along the supply chain. Many of the innovations in animal genetics, feed regimes and disease control already referred to took place in the UK at the behest of the supermarkets (Godley & Williams 2008). Market power is concentrated in the hands of a small number of big retailers, who exercise arm's length control of the food supply chain, through management rather than ownership-style integration, to ensure that chickens bulk up at just the right time in the right numbers.

There are just five major processing companies in the UK poultry sector, each with contracts to a number of the largest supermarkets for a fairly regular throughput of standardised birds at predetermined prices. The UK-based 2 Sisters Food Group is one of the leading processors, together with the US conglomerate Cargill, the Dutch-based Vion, Moy Park, a subsidiary of the Brazilian multinational, Marfrig and Faccenda, a smaller, privately owned UK business. Each, in its own way, exercises close control over their growing programmes, through a combination of own farms and contract farms, as well as through the ownership of hatcheries and feed mills (Figure 1). As one agricultural manager for a major UK processor recounted:

> We are very much a virtually integrated agricultural system, but the vast majority of the growers are contract growers … But [the birds] are grown under our management system. We supply the feed, we supply the chicks so we've got our own hatchery, we've got our own parent and grandparent stock, and our own feed mill. So we are very much in control of the growing programmes and the agricultural side. (Interview)

But what the processors control, in terms of numbers and throughput, is not totally down to them; that specification is laid down for them by their customers, the supermarkets. Chicks may fail to hatch, flocks may grow more slowly or there may be losses to injury or ill-health, but the supply to and from the factory has to be kept constant to keep up with customer demand:

> To have 1.3 million birds in here every week, it has to be carefully calculated from a hatching perspective in the hatchery, how many birds are put down on the farms, which

FIGURE 1
A quality assurance officer from a major UK poultry processor visits an 'own' farm to inspect the current 'crop'.

> farms, just to ensure a smooth supply of poultry into the plant because our customer demands are such we couldn't have a million one week and then 1.6 the next week. It's got to be 1.3 every week. (Interview with major poultry processor)

The logistics of the planning operation, to grow birds to market weight and other specifications on time, involves not only decisions about turnover, but also which breeds to place and where, how to maximise production per square metre on farms, managing the growth cycle of the birds, scheduling flocks for slaughter and the line speed adopted in the processing plants. Much of this is calculated backwards, as it were, from the supermarket shelf down to the hatcheries, so that the processors and, in turn, the farmers are under constant pressure to match the throughput of numbers and live weights on a just-in-time basis.

Keeping Out Disease

The profitability of these integrated systems, however, also rests on delivering safe, disease-free products to the consumer, especially given that chicken meat is responsible for a significant proportion of foodborne disease. The economic efficiencies that size can bring are also said to be matched by large-scale efficiencies in biosecurity. After recent scares over avian influenza, as well as growing concern over bacterial foodborne diseases such as *Campylobacter*, the arm's length control by the supermarkets also extends to the implementation of tighter biosecurity measures along the food chain (BRC and BPC 2010; FSA 2010). The same organisational coupling and integration of the supply chain that is held to be so effective in delivering a consistent throughput of table chicken is also assumed to offer similar advantages of scale and reach when it comes to rolling out hygiene protocols and barrier systems to prevent the incursion of pathogens into live birds on farms and dead birds in factories (Figure 2). This demand for standardisation of biosecurity measures is passed down from supermarket, to processor, to farms:

> Whichever way you do it, [by owning farms or contracting the growing], you make sure you have full control to make changes on farms … Biosecurity is more straight-forward with your management structure. (Discussion with major UK poultry processor)

Barrier systems for changing footwear, boot dips at entries and exits to farms and sheds, hand sanitisation, high-pressure washing of vehicles and equipment allowed on site, limiting access onto farms and into sheds: such on-farm measures to prevent the incursion of disease are seemingly as standardised as the factory-farmed birds (FSA 2004, 2006; Red Tractor Farm Assurance 2010). On industrial poultry farms, biosecurity is thus practised as exclusion, that is, enclosing agro-ecosystems to prevent the introduction of disease (Hinchliffe et al. 2013; Waage & Mumford 2008).

The securing and controlling of such distant outcomes on farms and in factories by the retailers works because of the tight coupling and the contractual integration of suppliers, backed up by the threat of exclusion from the consumer marketplace. The surveillance of animal health and food safety by government agencies, industry bodies and accreditation schemes is not deemed sufficient by retailers to secure their supply chains. Retailers conduct their own programmes of surveillance to ensure that the system is biosecure, so that the growing programmes deliver not only a certain weight and quality

FIGURE 2
A fence acts as a barrier between the 'unclean' outside and the farm, limiting access onto the premises and enforcing passage through certain hygiene and cleaning protocols for people, vehicles and equipment before entry.

of bird at just the right time, but also a flock that is disease-free, or at least of known disease status. According to one poultry vet:

> Tesco's probably knows more about the farms than the integrators know about the farms. They will have a file on every farm supplying them, they'll know their mortality, their records, they'll know antibiotics used – because they're absolutely petrified of having anybody saying they've got any problem after eating their food because the financial effect is so great on them. (Interview)

Surveillance by retailers also includes a regular schedule of site visits to check their standards are adhered to at the factory and farm. As one manager explained as we toured the factory floor, these standards are more onerous even than government requirements:

> The EU only say, 'You have to take care', whereas the retailers give you a 200 page manual on how to take care. Yes, at least 200 pages. (Discussion with major UK poultry processor)

Such surveillance aims to police closure to external disease threats, confirming healthy animal lives or bodies on the inside (or at least animals that are disease risk-free to consumers), and assuring the delivery of safe food from farm to fork. Clear reporting lines, where the responsibility for putting their house in order is placed at the farm and factory door, enables the big corporate retailers to shore up their defences against diseases reaching the shop floor.

Scaling-up biosecurity and its surveillance is a modern integrated industry's answer to the incursion of disease. Tight integration of the supply chain means that there is no room for operational failure, whether that be a failure of supply of birds or a failure of closure, where an outside world of disease breaks through into 'clean' premises. This 'contamination' approach (Leach et al. 2010) to understanding and managing disease risk on farms and in factories is consistent with policy and advice from UK regulatory agencies such as the Department for Environment, Food and Rural Affairs and FSA, which understand the task of biosecurity as '*keeping out* disease and harmful bacteria' (FSA 2004; italics added).

Harbouring Disease Within

The threat of disease, however, is not necessarily something that is external to industrial farming systems. For some, the risk of disease is less to do with the incursion of infectious diseases from the outside and rather more to do with their incubation, amplification and circulation within. An intensive, tightly coupled food operation, on this understanding, may actually harbour disease and accelerate its mutation and spread. In this view, and one which we broadly share, the disease risk is not so much at our door, as already inside, embedded within modern factory farming (Davis 2005, 2009; Liebler et al. 2009; Wallace 2009).

Life behind the barrier systems in the confined environments of intensive animal production is seen as the problem, in that the dense and standardising ecologies of production are themselves conducive to the circulation of zoonotic pathogens amongst increasingly susceptible birds. The sense in which disease may be said to be embedded within modern factory farming thus turns, somewhat paradoxically, on many of the same features already stated. The high throughput of large numbers of animals with short life spans, raised under highly controlled, intensive conditions in confined spaces, rather than offering a more effective, scaled-up biosecure environment is thought to actually pose greater risks for the amplification and spread of viral and bacterial diseases across the many sites of agribusiness (Davis 2005; Wallace 2009). Barriers to protect from a diseased 'outside', on this view, are of little significance when thousands of confined animals in close proximity seem to provide a ready-made disease pool. Indeed, a well-honed, biosecure operation may actually make matters worse, not better, simply by 'walling' in disease and intensifying pathogenic exposure (Graham et al 2008; Waage & Mumford 2008).

House tens of thousands of virtually genetically identical animals indoors in densely crowded conditions, pump them full of enriched feeds and veterinary medicines that stimulate growth and weaken their immune systems, and you have what is said to be more or less a perfect ecology for disease incubation (Graham et al. 2008; Lawrence 2008; Wallace 2009). It comes down, so the argument runs, to the way that food is produced. The tightly integrated, industrial scale operations are said to not only facilitate the transmission of disease, they also enable the exchange of pathogens between animals in close quarters which, in turn, create opportunities for new pathogenic strains to develop. In Wilbert's (2006) terms, such large-scale operations have helped to facilitate the involution, as opposed to the evolution, of viruses into highly pathogenic new forms, where viruses turn in on themselves, mixing and swapping segments to create ever more virulent strains that could result in more effective transmissions from animals to humans.

For Davis (2005), as much as for Wallace (2009), such concentrated animal feeding operations, CAFOs as they are known, are more or less disease cauldrons. The recent spread of the US model of integration, especially across South-East Asia and China, is thought to be the reason why disease outbreaks have been so common at large-scale poultry operations in places like Thailand and South Korea. When thousands of susceptible animals, anything from 15,000 to 70,000 in the case of poultry, are placed in overstocked industrial sheds, their accelerated lives may leave them with compromised and stressed bodies, increasing their vulnerability to circulating diseases. As one poultry vet observed:

> The modern bird is very close to diarrhoea shall we say. You're putting a high nutritional value product in one end and you can tend to get looser droppings out of the other. You're growing a 3.5 kilo bird in 38/39 days, which used to take, even ten years ago, would have been five days longer. (Interview)

The mass demand for a cheap animal product thus goes further than simply a factory farm model designed for scale and volume, and foregrounds the compromised lives of the birds themselves.

The resulting ecology of factory-farmed meat draws attention to a quite different economy of disease, where a disease outbreak may now be understood as a 'normal accident' (Perrow 1999), that is, one that is embedded within the very workings of the system itself. This system failure is more or less a predictable outcome of the way that industrial scale food production is organised; it is an 'inadvertent biotic fallout of efforts aimed at steering animal ontogeny and ecology to multinational profitability' (Wallace 2009, p. 919). Disease is said to be endemic to such intensive environments, ever present as a risk by virtue of the agro-ecological set-up. Biosecurity measures, designed to prevent the passage of disease from the outside, in effect turn their back to (or even exacerbate) the incubation of disease within.

There is, however, often a predetermined logic to this disease scenario that we are reluctant to share. As we understand it, the emergence of disease is not something that can be 'read-off' from given farm or factory environments, as if the presence or absence of disease can be traced to particular agro-ecosystems. Ecologies of production are critical, of course, but only, we would argue, in the sense that they are part of a relational landscape where commercial and regulatory pressures are folded into a mutable world of hosts, pathogens and immunological stresses with variable outcomes.

Relational Economy of Disease

In understanding disease as *relational*, we draw attention to disease as produced in particular encounters between bodies, pathogens and materials of various kinds (Greenhough 2012; Hinchliffe et al. 2013; Lavau 2013; Law & Mol 2011). Disease is neither a property nor an inevitable consequence of a given virus or bacterium, nor the outcome of a particular industrial farm setting or factory. Instead, we would argue that it is a *contingent* outcome of particular mixings, for instance, of pathogens, animal bodies, agricultural equipment, farm labourers, feed additives and other materials; mixings that are generated in practices of animal and food production, as well as related regulatory, commercial and labour processes.

In signalling this as a relational *economy* of disease, we are concerned with the significance of these sets of interactions, transactions or even 'intra-actions' (Barad 2007) in producing disease. It is not just mixtures of things that are produced through these practices, but also the things themselves, for example microbes and animal bodies. Karen Barad (2007) uses the concept of 'intra-action' to emphasise that such encounters are not between ready-made things (i.e. as suggested by 'interaction'), but rather that these things are constituted in these encounters.

There is a sense in which the bundle of things that are jumbled together in poultry houses, for instance – birds, equipment, pathogens, feed technologies, contract labour – are not reducible to so many discrete objects that merely interact. The likes of pathogens and hosts do not just bump into one another as separate, predetermined entities to produce an effect called disease; they intra-act, that is, they work through one another to cogenerate something that was not necessarily in evidence before, and is not easily reducible to a combination of pre-existing entities. Disease, when seen in this light, is the outcome of a continuous interplay between animals, microbes, people and materials that intra-act as they circulate, producing a shifting landscape of immunological and pathogenic forms (Hinchliffe et al. 2013; Lavau 2013). Disease is thus neither the result of some predetermined, discrete causal mechanism located within the pathogenic agent, nor indeed of a particular factory or farm setting.

As Barad (2007) suggests, such intra-action is not bounded by the constraints of a particular place or time, but rather takes its shape topologically, cutting across or rather dissolving any simple inside/outside geographies (see Allen 2011). There are, of course, physical demarcations between the inside and outside of factory farms or processing plants, but the already entangled phenomena take their shape as much from the world of commercial and regulatory pressures beyond the confined environments, as they do from more immediate encounters within. For example, the agricultural routines and materials of animal standardisation, growth acceleration, stock concentration and confinement are immediate embodiments of commercial pressures from further up the supply chain. In particular, the imperative from retailers to produce just the right number of birds at the right weight and price point at the right time is, as we shall describe in detail later, also part of a relational economy of disease. Such commercial pressures are not 'external' to disease. They too may be constitutive of disease, for instance choreographing a certain 'dance of encounters' (Haraway 2008, p. 4) between stressed chickens, opportunistic pathogens, feed supplements, noisy machinery, poultry catchers, a daily kill plan, month-old litter and transport crates, a heterogeneous assemblage of things in which disease may or may not be produced.

Commercial pressures, such as the demand for 'just-in-time' production, are not something experienced at one remove in modern factory farming. It is not simply that such conditions naturally produce factory environments which harbour disease, but rather that to produce just-in-time birds has ramifications for much of what enters the relational mix: the growth regimes installed, the stocking densities, the timetable for clearing the sheds for slaughter. The same is true of regulatory requirements for animal welfare and practices of subcontracting agricultural labour. Through the encounters or intra-actions choreographed by these combinations of commercial, regulatory and labour practices, the potential for disease is just that much greater.

Campylobacter: Foodborne Enemy Number One

Within the UK poultry industry, as noted earlier, one of the main foodborne pathogens of concern is *Campylobacter* (FSA 2010). A UK survey in 2007–2008 found that 65% of fresh chicken meat tests positive for *Campylobacter* at point of retail (FSA 2010). The pathogen only becomes a human health issue, however, when chicken meat is not thoroughly cooked, or when other foodstuffs or kitchen utensils become contaminated through contact with raw chicken meat.

Although the bacterium grows well in chickens, it does not grow so well in culture and was not successfully isolated until the early 1970s. The difficulty in culturing this bacterial pathogen has delayed and complicated attempts to characterise its physiology and ecology, to develop reliable tests for its presence, and to identify infection pathways. As one major UK poultry grower admitted, the relationship between trialling a biosecurity intervention in a poultry shed and the flock subsequently testing green (negative) or red (positive) for *Campylobacter* seems somewhat random. *Campylobacter* also surprises in terms of its rapidity. A typical shed of 30,000 birds can become positive for *Campylobacter* virtually overnight. As one major UK poultry processor observed:

> Typically if you've got broilers, say at 40 days, it can be clear of *Campylobacter*, and then, within 24 hours, the whole flock can be [positive]. (Interview)

Campylobacter seems to defy attempts to map or control it, and there is a degree of frustration within the poultry industry about not being able to pinpoint any clear biosecurity breach or indeed identify what triggers an outbreak. *Campylobacter*, as such, is perhaps less an outbreak and more of a 'continuing, if virtual, presence/absence' (Hinchliffe et al. 2013, p. 10), something that always shadows the process of food production and is difficult to disentangle from the various elements that come together within industrial chicken sheds and factories. What is widely acknowledged within the poultry industry, however, is that there seems to be an association between *Campylobacter* and the process of 'thinning' the flock, which keeps the density of birds within a shed within animal welfare regulations, whilst maximising the profitability of the shed space (Allen et al. 2008).

The process of thinning brings a variety of different elements into play, so that cheap protein, pathogens, profit margins, just-in-time delivery, stocking densities, subcontract labour and animal welfare standards all come together in what appears to be an uneasy coexistence. Poultry production on an industrial scale, as we have had cause to stress, leaves little room for manoeuvre in already tight production schedules when the profit margin per bird is so low. Thinning flocks is deemed essential to maintaining the industry as a viable business. As one manager of a processing plant explained:

> From an economic perspective, within this country if we were to stop the thinning that may be a problem. That may help as a solution [to *Campylobacter*], but from an economic perspective it's just not achievable. We wouldn't be able to have a poultry industry in this country if we weren't allowed to thin and grow birds, because of best use of buildings and the land and the economics surrounding that. At the moment, the profit per bird is very, very small. (Interview)

Chicken sheds are stocked at densities (kg/m^2) that have to comply with animal welfare regulations. As the birds put on weight, the poultry houses are not only at risk of breaching the legal limit, but they are also in danger of growing beyond the right commercial price point. Thinning flocks, that is the removal of 20–25% of the stock when the birds are roughly 35 days old, keeps the bird density in check, while the remaining birds are left to grow on to the next desired price point (Figure 3). The effect is to raise the productivity of the sheds as a whole, in terms of poultry meat per square metre, by effectively producing two crops of birds each cycle, at two different price points. In the end it all comes down to the growth rate of the birds and when they hit the desired price point, with each retailer dictating its own product specifications down the line (for example, one retailer specifies thinning at 1.9 kg and a kill at 2.2 kg).

However, whilst such practices do indeed make sense in commercial and animal welfare terms, some research suggests that the stress of the thin may leave the remaining birds vulnerable to opportunistic infection by *Campylobacter* (Humphrey 2006), whether already present within the flock or having been introduced during the thin. Stretched by accelerated growth cycles, and at a life stage when their immunity is at its least effective, such avian bodies may tip from healthy to diseased:

> Another challenge I think is control at thinning. You've got stress of the birds at that time. I think that probably reduces their resistance and also you're then introducing catching teams, so the hygiene of the catching teams, equipment as well is coming in at that stage. So it's not so much the birds going out, but it's the birds that are left which are the ones that are at risk of infection. (Interview with major UK poultry processor)

Crucially, however, it is not the thinning process itself that is at issue here, but rather the different elements that come into play in the act of thinning, one of which, as mentioned

FIGURE 3
One last module filled with chickens is removed from the shed and transferred to a waiting lorry, leaving the 'thinned' flock behind to grow for another week and reach the desired 'price point'.

above, is the introduction into the mix of the catching teams. It falls to them to keep the weights, price points and densities in balance by moving from farm to farm to clear the sheds or to thin a flock. The catchers' work is choreographed by the processor through what is colloquially known as the factory's 'kill plan', or more euphemistically referred to as the 'daily collection schedule', so that trucks, forklifts and modules, catching teams and fully grown birds come together at just the right time.

Intra-active Lives

The just-in-time imperative applies not only to perishable goods arriving at the supermarket door, but also likewise to live chickens arriving at the processing plant on schedule. On the one hand, the processor needs to maintain a steady throughput of birds through the factory, to have the plant constantly working at full capacity. A reliable and constant supply of birds must be collected from the farms and delivered to the factory gate. On the other hand, animal welfare concerns (in the form of government regulation, industry scheme rules, and retailer requirements) dictate that the birds should not be left to wait for long periods in the lairage before being sent to slaughter. It is in no one's interest for the birds to perish too soon. On a hot day, they do not want chickens sitting in the lairage if the factory is not ready for processing them. They will call the trucks still on the road and tell them to slow down, and sometimes send a truck back onto the road to drive its load around to keep the birds cool. It is all about the timing. From the processor's point of view, the birds must arrive in time to keep up with the pace of the production line and workers. But the birds must not arrive ahead of time at the factory, as they may unnecessarily suffer or die inappropriately. The birds, having achieved a specific weight, must arrive at the plant just-in-time.

Catching is physically demanding work performed in humid and 'stupidly hot' conditions, as one catcher put it, in differing degrees of darkness to keep the birds calm, wearing clothing that is protective and washable, yet cumbersome to move around in. It involves trudging through a heavy, smelly muddy quagmire of month-old litter, all the time breathing poultry dust, which contains an unhealthy combination of fine particles and perhaps pathogens (few catchers wear masks as they quickly get humid and uncomfortable to work in). In the semi-darkness, the catchers approach the huddled birds, collecting handfuls at a time. They slide the spindly chicken legs between their fingers, turn the birds upside down, up to eight birds in each hand, and deposit them in the module trays left by the fork lift driver, filling the drawers one by one. It takes a catcher around 1½ minutes to fill a drawer with 24 birds. Each module has 12 drawers, making a total of 288 birds per module, and each lorry carries 22 modules, adding up to over 6000 birds per lorry. It takes around 45 minutes to an hour for a team to complete a lorry's load, with teams catching around 5500 birds an hour, 34,000 birds per shift, depending on the requirements dictated by the processor. The catchers know these numbers well. They have to keep up with them, for these are the numbers that feed the high throughput at the plant, which, in turn, helps to keep the price of chicken low.

The majority of poultry catchers in the UK are employed on a contract basis by the processor and they occupy a niche role in the large scale industrialisation of poultry production. Some processors do employ their own in-house catchers, but the contract relationship suits the dynamics of a tightly coupled integrated system as it offers the processors a degree of flexibility over the timing of the catch, one that coincides with the not entirely predictable growth rate of the birds and their price points. Whilst the logistics of the catch are planned well in advance to match the growth cycle of the birds, the schedule is not finalised until the last minute, so if any delay occurs, such as a breakdown in production at the plant, the catching team absorbs the pressure. There is little slack in the system and time has to be made up to ensure the throughput of numbers. Crucially, a small change in the pace of collection or in the schedule itself can have a knock-on effect, not only on profit margins, but also on the relationship between human and avian bodies that are already living and working in intense conditions.

Whether or not disease is subsequently detected in the flock is contingent upon the relational economy of the thin, a production practice that holds together such diverse elements as the logic of cheap chicken, commercial pressures on the factory, regulatory demands about the treatment of animals, subcontracted labour practices and the not entirely predictable growth cycle of chickens. But it is a contingency that to date shows no pattern. The intra-actions of stressed chicken bodies, human bodies, pathogens and so forth may, or may not, produce a diseased flock. It is not that one change in isolation will tip a flock over the threshold, but rather that when such diverse pressures are folded into the volatile ecological mix, the potential may be there for such a critical point to be reached. Even if the infection pathways and the pathogen's behaviour remain unclear, the thinning process carries with it an association with *Campylobacter* and is indicative of a tipping point, a moment where an already compromised life is open to ever greater risk.

Powers of Life

In conventional accounts of disease outbreaks, the power exerted over the poultry supply chain, and indeed over life itself, by the big retail corporates only concerns itself with one side of the disease arrangement: the commodification of poultry as factory-farmed meat and the application of genetic and pharmaceutical technologies to produce birds that grow just-in-time to the right shape and price point. The reduction of life to a biological threshold in an attempt to control for future risks is a part of that process, but such control also points to one of the *paradoxes* of such straightforward instrumental power: that the exercise of power over life to just the right weight and size, when effective, may actually work against itself. Following Esposito (2008), the very attempt to manage life, to make it safe, has the potential to open up unanticipated and unforeseen threats where a different kind of power, that of the powers of life, may threaten life itself.

The breeding of industry standards, the application of pharmaceuticals to manage behaviour and stimulate growth, the optimisation of a particular body shape and the rolling out of a strict feed regime, all have as their aim the standardisation of life, its correction as it were, so that risks to the supply chain or the dangers of infection no longer readily pose a threat to profitability.

But, by commerce taking charge of life in this way, that is, by stripping it down to the bare minimum required for the production of cheap animal protein, life is also reduced to the edge of 'living'. For factory-farmed birds in tightly cramped, stressed conditions, their compromised immune systems, as we have seen, leave them vulnerable to infection. As such, the very attempt to make the life of the birds safe from an outside world of disease may have quite the opposite effect, and flip over into a pathogenic threat.

On this view, too tight a control over life risks reversal into the production of harms that hitherto were unknown or not perceived as a threat. In taking charge of the farmed animal population and reducing it to 'mere' life (Honig 2009), the powers of life, the potential for its pathogenic proliferation, may actually be turned against itself. This account, then, whilst recognising the role that corporate and regulatory powers play in an attempt to secure life, goes a step further to argue that such regulation and control runs the very risk of an economically standardised and reduced life threatening itself. It amounts to an argument drawn from Esposito that foregrounds the powers *of* life folding over into the power *over* life and undermining its very possibility. What Esposito (2006, 2008) adds to the argument is that it is the very development of a population's immunity or, in this case, protection from threats which emanate from outside of the factory farm system, that runs the risk of exposing animals and humans to ever greater harm. Securing life by enclosing it behind barrier systems, one of the aims of modern factory farming, in this sense may actually risk a reversal into ever greater insecurity.

The view that disease risk is embedded within the factory farming system is one that we broadly endorse, but the account of power that often underpins such a view, that of a system with a centre that is somehow rotten, offers a somewhat excessive confidence in the capabilities of instrumental power. The sense in which instrumental power, the power over life, exercised by the retail corporates reaches beyond itself when faced with the contingent economy of just-in-time pressures and immunitary stresses, reminds us of its limits. It also reminds us that the powers of life, the possibilities afforded by life's excesses, are part of an arrangement for which the logic of more control may not be the answer. Tighter, more extensive controls over the lives of farmed birds and a scaled-up biosecurity system designed to prevent incursion may prove self-defeating in that they also produce better conditions for disease incubation.

Esposito's (2008, 2011) line of argument crosses over from the legal and political to the biomedical and, of course, is wider ranging in its implications for securing lives in the face of a multitude of risks. Here, however, we have drawn upon it to show the paradox of instrumental power and its uses in producing cheap factory-farmed meat. That paradox, we would argue, runs through much of modern factory farming and its practices, and takes different forms in different settings. In the case of the poultry industry, when understood though the lens of a relational economy of disease, it takes something like the just-in-time pressures behind the process of thinning poultry to reveal the limits of corporate domination over life and its exploitation.

Conclusion

The aim of this paper has been to draw attention to the diverse array of just-in-time pressures, both commercial and regulatory, that are folded into modern factory farming, arguing that these are constitutive of, rather than external to, disease risk. The pressures themselves, whilst the result of attempts to produce cheap, disease-free meat, contribute towards the very agro-ecological conditions that put at risk the lives of those that the tightly integrated systems were designed to protect. In that context, biosecurity measures enacted to keep disease out may inadvertently contribute towards the incubation of disease within and run the risk of ever greater pathological insecurity. When the well-honed, well-planned logistics of biosecurity work well, in terms of disease, as we have seen in the case of *Campylobacter*, they may well work against themselves.

There is, however, nothing predetermined about a given agro-ecological system that suggests that disease is an inevitable outcome of the commercial and industrial systems deployed. As we see it, ecologies of production are part of a relational economy of disease, in which disease is a *contingent* outcome of the intra-actions among pathogens, animals, equipment, capital and people in commercial, regulatory, farming and food production practices. As important as it is to acknowledge the incubation of something like *Campylobacter* within a factory farm setting, it is equally important to recognise that disease is not simply a matter of bacterial or viral presence; it is a relational achievement, one that is generated through the entangled interplay of environments, hosts and pathogens. It is, as we have argued, a landscape of intensities and pressure points that have the potential to 'tip' a stripped down, economically reconfigured life over on itself.

What is also drawn into question by such a relational economy is our understanding of how power is expressed in the practices of modern factory farming, and agribusiness more generally. The exercise of corporate power, not just over the food supply chain, but over the very liveliness of life itself, has had, as we have seen, the paradoxical effect of reducing life to a biological threshold in an attempt to control for future risks. When brought to a certain threshold, attempts to secure life, to protect it, following Esposito's line of thought, may actually end up negating it, with life transgressing all attempts to control it. It is in that sense that the powers of life have to be grasped in relation to the more familiar instrumental powers over life, which tend to dominate accounts of the disease risks evident in today's corporate agribusiness and gloss over the non-human elements at its core.

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