



Centennial Review: A revisiting of hen welfare and egg safety consequences of mandatory outdoor access for organic egg production

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ABSTRACT Mandating free range husbandry as a requirement for organic egg designation remains a prevailing sentiment within a segment of the organic community. The proponents maintain that such management practice ensures high hen welfare and enhanced wholesomeness of the egg. However, evidence from the field, especially in the European Union (EU), contradicts these assumptions. In many cases, hens allowed outdoor access were more subject to increased injury from predators and from flock mates, disease was more prevalent and generally more severe, and, as a result, higher mortality was routinely observed in these individuals compared with those raised indoors. The safety of eggs from free range hens is also questionable. Outdoor access compromises

biosecurity efforts to curtail interaction of hens with rodents and wild birds, increasing the risk of flock *Salmonella enterica* serovar Enteritidis infection and consequent production of *Salmonella*-contaminated eggs. Even more serious, soil contaminated with dioxins and polychlorinated biphenyls, carcinogenic industrial by-products widespread in the environment, can be ingested by hens foraging outdoors. These compounds will subsequently be deposited into the egg yolks, many times at high levels, creating a serious food safety issue for the consuming public. Such findings provide evidence that hens exposed to a free-range environment may exhibit neither an enhanced welfare nor produce the safe wholesome egg that consumers expect.

Key words: free range, hen welfare, egg safety, poultry disease, Five Freedoms

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INTRODUCTION

The sentiment of many within the organic egg community is that outdoor soil/vegetation access enhances the hen life experience and therefore should be a mandatory part of organic production. Indeed, such a requirement is part of the guidelines for organic designation in the United Kingdom (Egg Info, 2021) and the European Union (Commission Regulation (EC) No 889/2008, 2008). A similar proposal was put forth by the Agricultural Marketing Service National Organic Program (NOP) of the US Department of Agriculture (Department of Agriculture, 2017). These guidelines stipulate that, for organic egg designation, the birds producing the eggs must be provided outdoor access and 50% of the outdoor access space must be soil. Further,

structures attached to the indoor living quarters and have a solid roof cannot be considered part of the outdoor space calculation.

As outdoor access for hens, for these purposes known as free range or pasturing, is perceived to allow the bird to express her full repertoire of behaviors, this will ultimately result in an improved quality of life for the animal. The question arises, however: How natural for the bird is the provided free range access? If ranging was preferred by the individuals, then a logical expectation would be that the bulk of the birds would be outside at any given time. However, this does not seem to be the case. A review by Pettersson et al. (2016) on ranging behavior in commercial free-range hens found that range use by commercial birds was less than 50% and, on occasion less than 10%. Bubier and Bradshaw (1998) found range use in 3 of 4 British study flocks to be 12% while the 4th flock was 42%. Gebhardt-Henrich et al. (2014) in Switzerland showed that while up to 90% of flock members ventured out at least once during the life of the flock, the percentage of the flock out at the same time was low, 20% or less. Gilani et al. (2014) in Great Britain

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observed that the percentage of hens outside ranging at any one observation point varied greatly (1-58%) but the average range use for all the flocks studied was 14%. Broiler chickens in Great Britain were just as reluctant to venture out as less than 15% were observed out of the house at any one time (Dawkins et al., 2003). This observation is not universal, however, as other studies in Great Britain (Richards et al., 2011) and in Australia (Campbell et al., 2017; Larsen et al., 2016) showed that a large proportion of hens ventured outdoors regularly. Richards et al. (2011), however, provided no information how far the hens ranged out past the exits. It was noted earlier by Hegelund et al. (2005) that, even when venturing out, hens generally remain close to the house. The lower-than-expected ranging activity again begs the question of how “natural” outdoor behavior really is for the bird. It very well may be a perceived natural behavior because we humans think it should be and, further, those benefits of free range would only apply to that portion of the flock that actually venture outside. Pettersson et al. (2016) noted that consumers, influenced by the serene and relaxing image of country life, generally assume that the bulk of the birds will take advantage of the outdoor space provided. However, such does not appear to be the case in many situations. Furthermore, a search of the literature indicates that outdoor access can lead to significant negative effects on hen welfare and on the safety of the eggs produced by these individuals. The following review provides the results of this investigation and calls into serious question the advisability of a free-range requirement.

Hen Welfare

Mortality Any discussion of welfare necessitates the inclusion of mortality data for that particular housing system. First, the livability of a flock is a good indicator of the health and wellbeing of the birds and poor livability suggests bird health problems. Second, because the animal generally suffers during the time leading up to death, they are experiencing a poor quality of life and therefore poor welfare status during this period. Increased mortality stems from multiple causes such as disease, bird aggression, suffocation, and predators (Knierim, 2006; Lay et al., 2011). The number of studies comparing pasturing versus enclosed housing for laying hens is not large but the evidence for a problem is mounting. A study published by Sherwin et al. (2010) found that mortality was higher in barn housing compared with free range. Conversely Häne et al. (2000) found significantly higher mortality in Swiss hens allowed outdoor access compared with confined hens as did Black and Christensen (2009) in New Zealand birds. Similarly, hen deaths in Danish organic (free range) flocks ranged from 2 to 91% with a mean of 20.8% compared with 7% for confined flocks (Stokholm et al., 2010). Elson (2008) noted a cumulative mean mortality in the United Kingdom of 14% in pastured flocks compared with 4.5 and 6% in aviary- and barn-raised hens, respectively. A higher, though nonsignificant, mortality

was observed in other UK free range hens compared with those raised indoors (Burch, 2012; Weeks et al., 2016).

Infectious Disease Disease also constitutes an important component of welfare as the health, or lack of, of the bird will impact the survivability and productivity of that individual. With the transition of laying hens from cages to floor and free-range environments, diseases not seen in laying hens for decades are now re-emerging (Teuling, 2015). Histomoniasis, commonly known as blackhead, is a systemic disease affecting multiple organ systems but primarily the liver and large intestine. The disease is caused by the protozoan *Histomonas meleagridis* and is associated with consumption of the parasite from the soil or from intermediate carriers such as the nematode *Heterakis gallinae* or from earthworms (Esquenet et al., 2003). Histomoniasis is therefore extremely difficult to eradicate once it has become established. An outbreak of histomoniasis in a Belgium free range layer flock caused 6% mortality and 11% decreased egg production (Esquenet et al., 2003). Stokholm et al. (2010) reported blackhead in 6 of 15 Danish organic flocks studied compared with no *H. meleagridis* isolations from the deep litter confined flocks. Popp et al. (2011) presented a case report of an organic turkey flock that became infected with histomonas. Three years later a second flock became infected followed by a flock of broilers 2 mo later and 2 more broiler flocks 4 wk after that. Mortality in the broilers reached 67%. Similarly, Araújo et al. (2015) reported an outbreak of histomoniasis in a free-range flock in Brazil resulting in a mortality rate of 43.7%. The authors noted that the flock had a mixture of different aged birds which could be a risk factor for the severity of the problems.

A second resurgent disease, Erysipelas, has long been a turkey disease problem and is now observed more frequently in laying flocks. The disease is caused by the soil-borne bacterium *Erysipelothrix rhusiopathiae* and is a systemic infection in poultry leading, in many cases, to death as well as a significant decrease in egg production (Eriksson et al. 2010). Erysipelas is most prevalent in outdoor flocks, although it can be found in confined flocks as well. In a Swedish study, outbreaks of erysipelas occurred in 10 of 129 (7.8%) of flocks raised in indoor litter-based houses and 6 of 23 (26%) of free-range systems (Fossum et al., 2009) while in a Danish report, erysipelas was detected only in organic (free-range) flocks (Stokholm et al., 2010).

An uptick in parasitic infections has also been observed as fecal worm eggs and coccidial oocytes were more frequently found in droppings from pastured vs. confined birds (Permin et al., 1999; Häne et al., 2000). These organisms can also reside in intermediate hosts such as grasshoppers, earthworms, and beetles (Yazwinski and Tucker, 2008) which are part of the diet of birds, particularly free range, and increases the difficulty of eliminating the parasites from the environment. Parasitic infections can affect chicken feed efficiencies; modify the course of other diseases (Shane et al., 1985;

Qin et al., 1995; Eigaard et al., 2006) or act as a vector for disease organisms such as *Salmonella* (Chadfield et al., 2000) and *Histomonas* (Esquenet et al., 2003). Perhaps the most disturbing aspect of a particular parasitic infection is the ability of the nematode *Ascaridii galli* to enter table eggs during egg development (Reid et al., 1973), resulting in live intact roundworms in the egg contents and an unpleasant surprise for the consumer. The worms should be found during the candling portion of egg processing, but such discovery is dependent upon the efficiency and competence of the operation.

Other, more common, disease organisms also occur more frequently in free range flocks. Colibacillosis, a systemic disease produced by the bacterium *Escherichia coli*, causes significant losses to the poultry industry worldwide. This disease exerts its most serious effects in layer flocks when they are in peak lay and infections can result in significant mortalities (Vanderkerchove et al., 2004). The incidence of systemic colibacillosis was substantially higher in Danish organic vs. confined flocks (Stokholm et al., 2010) and Kaufmann-Bart and Hoop (2009) noted that colibacillosis incidence increased in Swiss laying flocks following the introduction of free-range management in 1998. On the positive side, however, the authors also noted a decrease in *Salmonella* Enteritidis incidence as well as viral and parasitic diseases in the same timeframe, citing the importance of vaccination and hygiene as preventative strategies. Fossum et al. (2009) found that *E. coli* infections tended to be higher in litter-based systems, including free-range birds, but did not distinguish between confined and free-range systems. Another bacterial pathogen exhibiting increased incidence in free range flocks is *Pasteurella multocida*, the causative agent of fowl cholera, a systemic and potentially devastating disease in poultry (Glisson et al., 2008). This organism can infect both mammalian and avian species which therefore increases the difficulty of preventing introduction of the organism into flocks, especially in those allowed outdoors. Genetic characterization of fowl cholera strains isolated from waterfowl in Denmark showed them to be very closely related to strains infecting Danish free-range flocks (Christensen et al., 1998). In a study by Stokholm et al. (2010), 3 of 15 Danish organic flocks were infected with *P. multocida* compared with none of the confined flocks. Two of the organic flocks posted mortalities of 62 and 91% of which *P. multocida* was the cause of death in 46.1 and 22% of the cases, respectively. Christensen et al. (1999) demonstrated that approximately 80% of fowl cholera in Danish poultry was found in flocks having outdoor access. While not all studies demonstrate fowl cholera problems in free range birds (Fossum et al., 2009), the above studies demonstrate the potential for catastrophic infections in birds allowed access to the outdoors.

Avian influenza virus (AIV) continues to cause problems in the poultry industry worldwide. The highly pathogenic avian influenza (HPAI) causes fowl plague, a devastating infection in avian species resulting in high

morbidity and mortalities up to 100%. An estimated 250 million birds either died or were euthanized due to HPAI worldwide (Monke and Corn, 2007; Swayne and Halvorson, 2008). A major HPAI outbreak occurred in the United States in 2014–2015 where the virus was detected in 21 states and resulted in a loss to industry of almost 50 million birds (Department of Agriculture, 2015). Originally only infecting avian species, HPAI was observed to change in 1997 when humans became sick and died from infection by these viruses, becoming a serious human health threat in addition to being a significant poultry industry problem (Sims et al., 2003). Influenza viruses infect hosts via hemagglutinins (HA), proteins which attach to and initiate invasion of cells within the body of the host. There are 16 subtypes of this protein labeled H1-H16 (79) and fowl plague viruses possess either the H5 or H7 hemagglutinin. However, not all H5 or H7 AIV produce fowl plague, and these are termed low pathogenic avian influenza (LPAI). These viruses produce mild to moderate morbidity, but they can mutate to become HPAI (Swayne and Halvorson, 2008) so identification of any flocks infected with H5 or H7 LPAI generally means the eradication of those birds. Many of the AIV possessing hemagglutinin types other than H5 or H7 also infect poultry and are considered LPAI, producing symptoms ranging from undetectable to moderate morbidity although, when combined with other infections such as *E. coli*, mortality may be significant (Halvorson, 2009). Sources of these viruses are generally feral birds, in particular waterfowl (Capua and Marangon, 2006) and these have been implicated in serious outbreaks of LPAI in multiple states (Halvorson, 2009), especially in turkeys. Turkeys were originally raised free range which allowed significant interaction between those birds and waterfowl. However, following the 1997 outbreak of HPAI H5N1 in Hong Kong where human infection was also observed, the turkey industry in Minnesota decided to cease raising turkeys outdoors. More recently, less than 1.0% of Minnesota turkey flocks were range reared, resulting in a decline of AI introductions into turkey populations from an average of more than 5 per year to less than 1 (Halvorson, 2009). Similarly, Terregino et al. (2007) found that backyard free range farming in Italy was at high risk for the introduction of AIV from waterfowl. Eliminating outdoor access dramatically decreased the incidence of AIV in the flocks and therefore improved the health and wellbeing of those birds. Conversely, requiring outdoor access for organic laying hens could increase the incidence of AIV in these flocks and decrease their health and wellbeing.

Noninfectious Problems Problems need not be infectious in nature as cannibalism, piling, foot troubles, and predation also present their own welfare issues. Cannibalism and feather pecking pose significant problems for commercial poultry and can be the most prevalent non-infectious cause of hen mortality. Stokholm et al. (2010) found that, among dead hens submitted to the laboratory for examination, the prevalence of mortality due to cannibalism ranged from 0.8 to 36.1%. These problems

were observed in all housing systems and, in some cases, little difference could be observed between free range and confined systems (Häne et al. 2000; Sherwin et al. 2010; Stokholm et al., 2010) while other studies have shown difficulties. Swarbrick (1986) noted that cannibalism and feather pecking was a severe problem in several free-range flocks studied in the UK and Fossum et al. (2009) found that cannibalism was the main reported cause of mortality in four of 23 (17.4%) of Swedish free-range flocks compared with five of 129 (3.9%) of confined flocks. Piling, also known as smothering or clumping, occurs when birds mass together in response to different stimuli with a resultant loss of animals due to suffocation. Mortality can be substantial. Bright and Johnson (2011) reported that smothering was responsible for 40% of the mortalities in 4 of 10 free range laying flocks. Stokholm et al. (2010) noted that piling resulted in 7 and 8% mortality in 2 Danish organic flocks and 1 to 2% in 5 other organic flocks compared with 0.8% or less observed in confined flocks. Foot health is another parameter that will affect hen wellbeing as foot pain increases bird suffering and lameness impacts the ability of the bird to reach feed and water. Some studies have shown minimal difference between housing systems (LayWel, 2006; Lay et al. 2011). Conversely, Elson (2008) noted foot problems in 14.8% of confined flocks compared with 32.8% or higher in birds raised free range and Shimmura et al. (2010) in Japan found significantly greater foot damage in birds raised free range compared with confined individuals.

Allowing hen access to the outdoors also provides predators access to the hen. Predation is essentially a part of the free-range experience with which producers, and especially the hens, must contend. Stokholm et al. (2010) reported mortality due to predation ranged from 0 to 3.7% in Danish organic flocks while indoor flocks experienced no mortality from predators. Losses due to predation in the United Kingdom and Switzerland amounted to 1.97 (Moberly et al. 2004) and 1.4% (Kaufmann-Bart and Hoop, 2009), respectively. Bestman and Wagenaar in 2014 noted an average mortality of 7.8% (all causes) at 60 wk in Dutch organic flocks and found that 40% of the flocks did have mortality due to predation. Providing hens free range access allows them to express more varied behaviors with the potential concomitant welfare benefits. However, these benefits come at too high of a cost, both from an economic and a welfare standpoint.

The “Five Freedoms” developed in the 1970s and 1980s by the Farm Animal Welfare Council in the United Kingdom, were a set of guidelines for the care and welfare of livestock (Farm and Animal Welfare Council, 2012). These freedoms provided the standards for judging how well a particular husbandry system met the welfare needs for the animals kept within it. Free range access for hens has generally been considered the ultimate in animal welfare and should excel in all Five Freedoms. Does it? Pasturing certainly should meet the First Freedom, from hunger and thirst, as these are standard husbandry criteria which should be met by all

housing systems. Similarly, the Second Freedom, from thermal and physical discomfort, should be met by all systems in that they provide adequate shelter from inclement weather conditions. Free range may provide the hen even a little more freedom, allowing her to move to a more comfortable resting spot. For the Third Freedom, from pain, injury, and disease, pasturing fairs rather poorly. Numerous studies showed hens allowed outdoors exhibit higher mortality (Häne et al., 2000; Elson, 2008; Stokholm et al., 2010), and a greater and more varied incidence of disease, especially bacterial infections (Christensen et al., 1999; Permin et al., 1999; Fossum et al., 2009; Stokholm et al., 2010). Mortality and disease are 2 strong indicators that flock well-being is diminished under free range conditions. Further, increased feather pecking and cannibalism were also found in some studies (Swarbrick, 1986; Fossum et al. 2009) as were foot problems (Elson, 2008; Shimmura et al., 2010) and piling/smothering (Stokholm et al., 2010; Bright and Johnson 2011). Free range fairs very well in the Fourth Freedom, to express normal behavior, in that it allows hen access to the outdoors in the sunshine and fresh air to forage in the dirt for insects and grubs and to dust bathe. However, many of these behaviors can also be expressed indoors with space provided for dust baths, materials on the ground for the hens to peck and forage through, and a screened porch for hen access to sunshine and fresh air. Indeed, Gebhardt-Henrich et al. (2014) showed that a higher percentage of hens in Swiss free-range flocks exhibited a preference for the veranda, a covered run with a concrete floor with litter, than out on the range – in essence, a porch without the screen. Finally, the Fifth Freedom, from fear and distress, is also questionable in a free-range situation. While Lay and colleagues demonstrated in their 2011 review paper on hen welfare in different housing systems (Lay et al. 2011) that indicators of stress were observed to be lower in free range compared with confined hens, stress situations in the field generally occurred more frequently under free range conditions. Again, feather pecking, and cannibalism can be a significant problem in this system and present an extremely distressful situation for the chickens involved. Predators are essentially only a free-range problem and can exact a significant toll on the flock (Moberly et al., 2004; Stokholm et al., 2010). Besides the physical loss of productive animals, each predator attack will not only be distressful for the individual hen involved but for the flock at large, resulting in “panic smotherers” where hens pile up, and ultimately suffocate, to escape from the threat (Bright and Johnson, 2011). Therefore, the superiority of free range over confined housing is questionable as it exhibits significant flaws regarding the welfare of the birds allowed outdoors. As Elson (2008) summed it up well in 2008 “Allowing poultry outside access increases their freedom and behavioural repertoire but is accompanied by greater risks to important aspects of their well-being. The term ‘welfare-friendly’ must take all these factors into account.” The current mandate of free-range hen management as a requirement for the

organic egg designation is based much more on welfare perception rather than on actual welfare scientific facts.

Egg Safety

Salmonella Contamination *Salmonella enterica* serovar Enteritidis (*S. Enteritidis*) surprised egg producers, health care workers, and infectious disease experts in the 1980s after the discovery of the organism inside intact table eggs, posing a significant new foodborne threat for the consuming public (St. Louis et al., 1988). Subsequent research showed that, following infection of the hen through consumption of the organism, *S. Enteritidis* invaded the hen reproductive tract and entered the egg in utero prior to shell formation (Keller et al., 1995; Okamura et al., 2001) or through shell pores during transit of the egg down the oviduct into the cloaca (Messens et al., 2005). Significant effort has been expended to reduce the incidence of *S. Enteritidis* on the farm and subsequently in the consuming population. The effort has been largely successful in that the incidence of human *S. Enteritidis* infections has decreased dramatically in the United States (Braden, 2006). However, the one-half billion egg recall and more than 2,000 illnesses due to *S. Enteritidis* in the summer of 2010 brought into sharp focus that *S. Enteritidis* egg contamination was still a significant threat and diligence by the producer, processor, retailer, and consumer was crucial to prevent future such outbreaks. The Food and Drug Administration published document 21 CFR Parts 16 and 118 “Prevention of Salmonella Enteritidis in shell eggs during production, storage, and transportation; Final Rule” (Food and Drug Administration, 2009), also known as the Egg Rule, which outlined procedures to prevent on farm infection of hens with *S. enteritidis*, and the potential production of contaminated eggs, coupled with the proper treatment of eggs after lay. One stipulation of the Egg Rule is to “prevent stray poultry, wild birds, cats, and other animals from entering poultry houses”. Wildlife has been shown to be ample carriers of *Salmonella* organisms. Rodents (Henzler and Opitz, 1992; Kinde et al., 1996a; Davies and Breslin, 2003), birds (Cizek et al., 1994; Craven et al., 2000; Davies and Breslin, 2003), foxes (Davies and Breslin, 2003), skunks (Kinde et al., 1996a), opossums (Kinde et al., 1996a), cats (Kinde et al., 1996a), and insects (Gray et al., 1999; Mian et al., 2002; Davies and Breslin, 2003; Wales et al., 2007) have all been shown to harbor *Salmonella*. Indeed, Wales et al. (2007) found that the prevalence of *Salmonella*-positive samples from wildlife vectors at or near poultry houses was double that of positive samples from the houses. Reducing interaction of hens with wildlife is critical to preventing infection of hens with *Salmonella*, and is, in fact, mandated by the FDA for inside the house. By allowing hen access to the outdoors, the biosecurity of a facility is compromised as hens can freely interact with wildlife vectors currently residing in the area. Further, by providing exit sites to allow hen outdoor access, the biosecurity of the

building is again compromised, allowing entry of birds, insects, rodents, and other wildlife into the house. The incompatibility of the Egg Rule with the mandated hen outdoor access for organic egg designation was recognized by the FDA who provided a draft compromise guidance to egg producers in 2013 for management of outdoor access laying facilities to reduce *Salmonella* risk in flocks (Food and Drug Administration, 2013). Time will tell how this compromise will affect *Salmonella* biosecurity on these farms.

The bulk of the studies examining *Salmonella* recovery from free range versus confined facilities were conducted in the EU and most found little difference between facility types. Mahé et al. (2008) and Snow et al. (2010) recovered *Salmonella* in 11.5 and 7.69% of barn facilities compared with 8.55 and 6.29% free range in France and the United Kingdom, respectively. Van Hoorebeke et al. (2010b) reported similar results in a cumulative study of farms in Belgium, Germany, Italy, and Greece. Mollenhorst et al. (2005) reported an increased incidence of *Salmonella* in Dutch flocks provided an outdoor run but this was only observed in farms with same age flocks. In Switzerland, Kaufmann-Bart and Hoop (2009) actually found a marked decrease in the incidence of flock *S. Enteritidis* following the implementation free range husbandry. The movement from caged, confined housing to free range is a fairly recent situation, however, and the facilities are therefore new. Van Hoorebeke et al. (2010a) found that facility age increases the incidence of *Salmonella* contamination and as the number of flocks raised free range on a site increases over time, with the subsequent buildup of *Salmonella* in the soil, wildlife, and buildings (Davies and Breslin, 2003), the free-range *Salmonella* incidence may change. Because of the limited number of free-range flocks in the United States, a paucity of studies exist which examine *Salmonella* incidence in confined versus free range flocks. However, Kinde and colleagues in 1996 (Kinde et al., 1996a) reported an outbreak of *S. Enteritidis* on an egg farm in California. No *S. Enteritidis* was recovered from any birds or eggs in 2 of the 3 barn-type houses, and, in the third house, the organism was recovered from 1.67% (1/60) of birds examined and egg contamination was 2.03/10,000 eggs. Isolation of *S. Enteritidis* from free range birds was 1.67% (1/60) in one house and 50% (30/60) in the second. Egg contamination was 14.87/10,000 eggs in the first house and 19.06/10,000 eggs in the second, an extremely dangerous food safety situation. The ultimate source of contamination was found to be a stream that flowed past the farm (Kinde et al., 1996b). While all houses were equally exposed to the stream, the *S. Enteritidis* problem was primarily found only in the free-range hens, bringing into sharp focus the inherent risks imposed upon hens allowed access to the outdoors. Hopefully, implementation of many of the FDA suggested guidelines will prevent a similar problem from occurring in the future.

Chemical Contamination Polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and polychlorinated biphenyls (PCBs) are

natural and man-made chemicals toxic to humans and other animal species and are considered one of the most toxic substances in the human food chain (Schechter et al., 2006). Human exposure to these compounds results in a wide range of health problems including cancer, immune deficiencies, reproductive and developmental abnormalities, central and peripheral nervous system pathologies, and endocrine disruption, including diabetes and thyroid disorders (National Research Council, 2006; Schechter et al., 2006).

The chemicals PCDDs and PCDFs, often referred to simply as “dioxins”, are produced as unwanted by-products in many manufacturing processes (Schechter et al., 2006) and during incineration activities including municipal waste incinerators and backyard trash burning (Lemieux et al., 2000; Hsu et al., 2010; Hoogenboom et al., 2016). Dioxins can also occur naturally during wildfires and volcanoes (Urban et al., 2014). PCBs are industrial chemicals manufactured in high volume prior to 1980. Both classes of chemicals are widespread and persistent contaminants in the environment (Van den Berg et al., 1998; Schechter et al., 2006). Environmental levels tend to be highest in and near urban industrialized regions (Hsu et al., 2010) or where contaminated agents were stored (Hong et al., 2014) but winds and rains disperse the chemicals long distances (Environmental Protection Agency, 2010). Farming areas may exhibit significant soil contamination originating from air pollution (Chang et al., 1989; Hsu et al., 2010), trash burning (Hoogenboom et al., 2016), and improper/illegal dumping of dioxin- and PCB-containing wastes (Vizard et al., 2006; Environmental Protection Agency, 2010). Old building materials have also been shown to be sources of soil contamination both from rains leaching the chemicals off the buildings and roofs and in soils fortified with building debris (Hoogenboom et al., 2014).

Hens consuming these highly lipophilic (fat-loving, will dissolve into fat-containing tissues) chemicals will bioaccumulate the compounds in their bodies, primarily the fat, which is then transported into the egg (Stephens et al., 1995). Some researchers speculate that the egg therefore serves as dioxin elimination pathway for the hen (De Vries et al., 2006). Where would hens encounter these agents? Background contamination of feedstuffs by dioxins/PCBs was observed to be low (Kijlstra, 2005; De Vries et al., 2006) and feed constituents such as corn exhibited no detectable dioxin in the kernels of plants grown in dioxin-contaminated soil (Hundal et al., 2008). However, hens allowed to forage on dioxin- or PCB-contaminated ranges readily accumulate the contaminants in their bodies and ultimately into their eggs. Chang et al. (1989) showed that eggs from free range hens in Northern California raised 1.5 to 4.5 km from the site of a pentachlorophenol wood treatment plant fire had dioxin levels up to 100 times that of eggs from hens raised indoors. Even low levels of the chemical in the soil could result in significant egg contamination if hens could forage over wide ranges (Harnly et al., 2000). Schuler et al. (1997) reported that

eggs from free range hens in Switzerland possessed high levels of dioxins in their contents and the egg concentrations correlated with levels found in the soils used for foraging. Investigations by Kijlstra et al. (2007) on Dutch organic farms did not observe such a correlation but did find egg dioxin content exceeded the EU limit on 25% of the farms and noted that restricting the amount of time hens could forage outdoors reduced the levels of egg dioxin and PCB contamination. In an EU survey, eggs from free range hens exhibited higher dioxin and PCB levels than those from indoor hens and 10% of the eggs exceeded the EU maximum residue limit (MRL) in eggs of 3 pg dioxin toxic equivalency (TEQ)/g of lipid (Schoeters and Hoogenboom, 2006). Eggs exceeding the MRL were banned from being sold and were required to be destroyed. The authors also observed that dioxin and PCB contamination was highest in eggs from free range hens near urban industrial areas but could also be found in free range eggs on rural farms. More recently, Sørensen et al. (2014) studies on Danish flocks found highest levels of dioxins in eggs from small free range/organic farms followed by larger organic farms. A number of the eggs from the small free range/organic farms exceeded the MRL (Sørensen et al. 2014). The distribution of contaminated eggs across Denmark could not be explained by urban pollution but rather was speculated to be due to improper disposal of waste and fireplace ash onto the foraging area. Piskorka-Pliszczynska et al. (2014) demonstrated that free range hens on a Polish farm foraging on contaminated soil produced eggs containing dioxins at levels that, if consumed by humans, would be 25% of Tolerable Weekly Intake (TWI) for adults and 145% TWI for a 3-yr-old child. In Taiwan, Hsu et al. (2010) found extensive dioxin contamination of eggs from free range hens which was 5.7 times higher than eggs from similar hens raised indoors. Like the EU survey, a portion of these eggs exceeded the EU MRL and the highest egg contamination occurred in eggs from hens located on farms near urban industrial areas while lower, although significant, levels could also be found in free range eggs from rural settings.

While farmland contamination of dioxins and PCBs pose the most serious threat to the safety of eggs from free range hens, other potential chemical risks also exist. Bioaccumulation into eggs of heavy metals such as lead and mercury and pesticides such as DDT has also been reported in the EU (Van Overmeire et al., 2006). In Brazil, Vieira et al. (2001) found high levels of DDT in eggs from free range hens compared with those from hens raised indoors, even though DDT application had ceased in the area for the past 10 yr, indicating the persistence of this chemical in the environment. In the United Kingdom, a food safety alert/recall was issued for organic eggs from the company Waitrose Ltd., a result of lead shot consumption by the free-range foraging hens (Food Standards Agency, 2008).

The above information indicates that environmental chemical contamination poses a real threat to the safety and integrity of free-range eggs. In the Netherlands and Belgium, if eggs from a farm exceed the EU dioxin limits,

that farm is out of business until the problem is rectified (Dr. Aize Kiljstra, Wageningen University, Netherlands and Dr. Luc Pussemier, Coda-Cerva Veterinary Research Center, Brussels, Belgium, respectively, *personal communications*), which may take some time. In the United States, soil levels of dioxin mirror those in the EU. Urban et al. (2014) collated and summarized the data from a number of studies conducted by the EPA and other laboratories across the United States. The final analysis found that rural US soil contained dioxin levels ranging from 0.1 to 22.9 ng TEQ/kg dry weight soil (pg TEQ/g dry weight soil by EU designation). These levels closely match those found by Schuler et al. (1997) and Kijlstra et al. (2007) of 1.3 to 13 pg TEQ/g dry weight soil and 0.9 to 5.9 pg TEQ/g dry weight soil, respectively, where, as noted above, hens pasturing on those soils produced eggs contaminated with dioxins, in many cases exceeding the EU limit for those compounds. Mandating free range husbandry for an organic egg designation is ill advised and dangerous, putting the consumer at significant risk for dioxin intoxication, ironic considering that organic products are purchased due to their presumed low pollutant load. Further, what happens if FDA follows the precedent of the EU and begins mandatory egg dioxin testing? Free ranging hens have already been identified as a major risk factor for producing dioxin-contaminated eggs in the EU and will certainly be targeted for in depth testing. Like with the *S. Enteritidis* situation, farms identified as producing contaminated eggs, will probably not be able to ship any eggs until the problem is remediated. The free-range mandate therefore puts an undue burden upon the producer who will face the costly task of remediation or put out of the organic egg business altogether. Producing organic eggs should not be an all or nothing proposition, and alternative husbandry practices should be included to retain the viability of the organic egg industry. Hens raised indoors in houses with screened porches allows for bird access to sunshine and fresh air while preventing contact with and subsequent consumption of toxic agents present in the soil environment. These facilities should be included as an acceptable method for producing the healthy, nutritious, untainted organic egg expected by the consuming public.

CONCLUSIONS

This review is by no means meant to be an indictment of free range/pasturing husbandry for poultry. Under many scenarios, outdoor access will be greatly beneficial for the hens and the eggs they produce. It is hoped that this review will open a dialogue regarding the wisdom of mandating this management practice across the board for an organic designation. The NOP guidelines that include the hen outdoor access requirement for organic egg designation have since been withdrawn (Department of Agriculture, 2018) but the issue is far from settled and will probably resurface again. The free-range

premise that the more freedom the birds experience, the better their welfare, and the subsequent wholesomeness of their eggs, will be is just not accurate. Requiring free range husbandry is therefore a potentially high-risk proposition and the NOP should continue to proceed cautiously with regards to implementation of this practice for organic egg production.

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DISCLOSURES

The author declares no conflict of interest.

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