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Dear Professor Porter,

Holt et al.'s (2010) narrative (non-systematic) review of the impact of different housing systems on egg safety ignores a large body of evidence. In lieu of the completed phase-out of barren cage systems in the European Union (EU) in 2012 (European Commission, 1999), an EU-wide study was launched to determine the *Salmonella* prevalence in large-scale commercial cage, cage-free (barn), free-range, and organic egg production. Fecal and dust samples were taken from more than 5,000 operations across 25 countries, yet Holt et al. (2010) chose only to cite individual studies from 4 of the countries covering but a fraction of the data.

The published European Food Safety Authority (EFSA) analysis of all 5,310 operations found that without exception, for every *Salmonella* serotype grouping reported, and for every type of production system examined, there was significantly higher *Salmonella* risk in cage operations (EFSA, 2007). Compared to cage systems, there was significantly lower prevalence of *Salmonella* Enteritidis (SE) in all three cage-free systems (barn: OR = 0.57, *$P = 0.04$; free-range: OR = 0.02, ***$P < 0.001$; organic: OR = 0.05, ***$P < 0.001$); significantly lower prevalence of *Salmonella* Typhimurium in all three cage-free systems (barn: OR = 0.23, *$P = 0.022$; free-range: OR = 0.07, ***$P < 0.001$; organic: OR = 0.07, *$P = 0.018$); and significantly lower prevalence of other *Salmonella* serovars in all three cage-free systems (barn: OR = 0.04, ***$P < 0.001$; free-range: OR = 0.01, ***$P < 0.001$; organic: OR = 0.02, ***$P < .001$).

It is not possible the authors missed the EFSA analysis, as they cite it in their paper to discuss the sampling methods used, but fail to mention the results of the 30,000+ samples taken from the same source. Based on analyses of those samples, EFSA concluded: "Cage flock holdings are more likely to be contaminated with *Salmonella*." (EFSA, 2007). To omit the results of the EFSA analysis—by far the most comprehensive investigation into the impact of different housing systems on the overriding issue of egg safety—calls the objectivity of the American Egg Board-funded (Study, 2010) review into question.

Also notably missing is Van Hoorebeke et al.'s (2010) study of *Salmonella* shedding in 292 farms in Belgium, Germany, Greece, Italy and Switzerland. A multivariable analysis that controlled for the age of the houses found floor-raised and aviary flocks were significantly less likely to be found actively shedding *Salmonella* compared to flocks in cage systems (OR = 0.05, **P < .01). Though potentially published too late for inclusion, Holt et al. include citations to even more recently published work (Snow et al. 2010, though miscited as Vet. Rec. 163(2009):649-654 rather than 166(2010):579-586). Other findings missing from the review include research previously published in *Poultry Science* noting faster declines in *Salmonella* shedding in experimentally infected cage-free hens compared to those in conventional cage housing (De Vylder, 2009) and evidence suggesting exposure to bedding (as in many cage-free settings) may result in the acquisition of natural gut flora that competitively inhibits *Salmonella* colonization (Santos, 2008).

Holt et al. cite 4 sources purporting to show a lower incidence of *Salmonella* in cage systems (Kinde et al., 1996; Schaar et al., 1997; USDA/APHIS, 2000; Mollenhorst et al., 2005). Kinde et al. (1996) examined a single farm that included 3 battery cage sheds and 3 cage-free barns. 0.49% of the pooled egg samples from caged hens were positive for *Salmonella*, compared to 0.24% of the cage-free (barn-raised) samples. Though the farm's free-range hens were found to be at higher risk, this was attributed by Kinde et al. (1996b) to exceptional circumstances, in that a creek "entirely composed of sewage effluent" bordered the property. The differences found in Schaar et al. (1997), via bacterial culture and serology, were not statistically significant (P = 0.73 and P = 0.49, respectively[*]) and USDA/APHIS (2000) doesn't address cage-free egg production at all. The fourth source they cite (Mollenhorst et al., 2005) shows the opposite of what they assert when the model is applied to typical U.S. cage systems (dry as opposed to liquid manure management (USDA/APHIS, 2000b; Spelling and Whiting, 2007)). Using the Mollenhorst et al (2006) model with standard U.S. flock sizes (Cutler, 2003, Bell, 2006), flocks in dry manure cage systems would have a 32% or 38% chance of testing positive for SE, depending on whether the operation has hens of the same or different ages. In contrast, in cage-free (deep litter) systems the calculated chance of positive SE serology would only be 6% or 17%. So none of the studies they cite show significantly lower *Salmonella* rates in conventional cage versus cage-free systems.

The "manufacturing of uncertainty" by scientists to defend potentially hazardous products and the "funding effect"—the tight correlation between the reported results and those desired by a study's funder—are well known phenomenon in the public health literature and antithetical to the premise that decisions should be based on the best available evidence (Michaels, 2006). The EFSA analysis is only one of the large majority of studies showing elevated *Salmonella* risk in cage systems. Not one of the last 10 published studies comparing *Salmonella* rates in conventional cage and cage-free systems found higher rates in cage-free housing (Snow et al., 2010; Van Hoorebeke et al., 2010; Huneau-Salaün t al., 2009; Namata, et al., 2008; Mahé, et al., 2008; Pieskus, et al., 2008; EFSA, 2007; Snow et al., 2007; Methner et al., 2006; Mollenhorst et al., 2005).

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[*] per Fisher's exact test

Holt et al. mischaracterize flock size as a confounding factor when it is in fact inexorably linked to commercial cage production. The ability to place more birds in a given house is one of the explicit reasons given for using cage systems (Bell 2001). The survey by USDA/APHIS (2000a) found the average *Salmonella* positive house confined 109,777 hens (median = 120,000), many times greater than what cage-free operations typically hold. There is no need to "dissect the relative roles of hen densities and housing systems in exacerbating Salmonella problems" (doi:10.3382/ps.2010-00794), since higher stocking density is an intrinsic quality of commercial cage systems.

Other causal rather than confounding factors inherent to cage production include the concomitant increased volume of contaminated feces (Davies and Breslin, 2004), the restriction of hen movement that may make cage houses more attractive locations for *Salmonella*-carrying rodents (Carrique-Mas et al., 2009), and the difficulty in effectively accessing and disinfecting the cage equipment itself (Carrique-Mas and Davies, 2008). While management decisions can play a critical role in food safety, these are problems intrinsic to all cage systems. Cage-free farms can choose not to use pentachlorophenol-treated wood shavings for litter, but cage operations by definition are burdened with the risks attached to using cages. A parallel exists in the welfare debate: the "severe spatial restriction" and consequent behavioral deprivation are inherent qualities to even the best managed conventional cage system (LayWel, 2006).

Even before the Wright County Egg/Hillandale Farms recall (CDC, 2010), the Food and Drug Administration (FDA) estimated that 142,000 Americans are sickened by *Salmonella*-tainted eggs every year (FDA, 2009). And even under the new egg safety rules, the FDA estimates tens of thousands of Americans will continue to be stricken by eggborne *Salmonella* (FDA, 2010). Given that *Salmonella* can survive common cooking methods, such as scrambling, over-easy, and sunny-side-up, (Davis, 2008) it is incumbent on the industry to make all reasonable science-based steps to decrease risk at the source. The weight of evidence (EFSA, 2007) clearly shows cage systems have higher rates of *Salmonella* contamination, suggesting that the U.S. egg industry could reduce the risk at a consumer level (Mølbak and Neimann, 2002) by phasing out cage confinement.

Sincerely,

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