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Infection-interactions in Ethiopian village chickens

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ABSTRACT

Chickens raised under village production systems are exposed to a wide variety of pathogens, and current or previous infections may affect their susceptibility to further infections with another parasite, and/or can alter the manifestation of each infection. It is possible that co-infections may be as important as environmental risk factors. However, in cross-sectional studies, where the timing of infection is unknown, apparent associations between infections may be observed due to parasites sharing common risk factors. This study measured antibody titres to 3 viral (Newcastle disease, Marek's disease and infectious bursal disease) and 2 bacterial (*Pasteurella multocida* and *Salmonella*) diseases, and the infection prevalence of 3 families of endo- and ecto-parasites (*Ascaridida*, *Eimeria* and lice) in 1056 village chickens from two geographically distinct populations in Ethiopia. Samples were collected during 4 cross-sectional surveys, each approximately 6 months apart. Constrained ordination, a technique for analysis of ecological community data, was used to explore this complex dataset and enabled potential relationships to be uncovered and tested despite the different measurements used for the different parasites. It was found that only a small proportion of variation in the data could be explained by the risk factors measured. Very few birds (9/1280) were found to be seropositive to Newcastle disease. Positive relationships were identified between *Pasteurella* and *Salmonella* titres; and between Marek's disease and parasitic infections, and these two groups of diseases were correlated with females and males, respectively. This may suggest differences in the way that the immune systems of male and female chickens interact with these parasites. In conclusion, we find that a number of infectious pathogens and their interactions are likely to impact village chicken health and production. Control of these infections is likely to be of importance in future development planning.

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1. Introduction

Poultry kept in village production systems are exposed to a wide range of potential pathogens, yet most epidemiology studies have tended to focus on single infections. The importance of interactions between pathogens has been shown in humans (Pullan and Brooker, 2008; Nacher, 2011), wildlife (Jolles et al., 2008; Telfer et al., 2008) and extensively farmed livestock species (Thumbi et al., 2014). However, determining the direction and strength of any interactions remains a complex issue.

There is widespread recognition of the importance of village poultry in developing countries (Copland and Alders, 2005; Mack et al., 2005). Poultry are easily accessible, even to the poorest households or those with a lack of able-bodied workers, as they require minimal land, labour or financial inputs. They can scavenge for food, and do not compete for food resources with humans. They are normally in close proximity to the household, enabling them to be managed by women and children while placing few additional burdens on these groups, as they may be kept under minimal supervision. This role in managing a household asset gives women greater control over the income from sale of poultry and eggs, and this can be used to support child education. As such, the improvement programs for family poultry have the potential to contribute to several of the UN's Millennium Development Goals (Alders and Pym, 2009).

Infectious disease is recognised as one of the major constraints to developing backyard poultry production (Guèye, 1998; Mack et al., 2005). Control of Newcastle disease virus (NDV) has been identified as the most critical intervention in numerous studies throughout Africa, and other interventions such as improving feed, housing or controlling parasites are only effective if used in conjunction with vaccination (Dwinger and Unger, 2006). A number of seroprevalence surveys have demonstrated exposure to NDV in several areas of Ethiopia (Tadesse et al., 2005; Mazengia et al., 2010; Chaka et al., 2012), although little attention has been paid as yet to control strategies. However, NDV is not the only problem; chickens under a village production system are exposed concurrently or consecutively to a number of different pathogens. In Ethiopia seroprevalence surveys in village chickens have identified the presence of infectious bursal disease (Mazengia et al., 2010; Chaka et al., 2012; Jenbreie et al., 2012), salmonellosis (Berhe et al., 2012; Alebachew and Mekonnen, 2013), pasteurellosis and mycoplasma infection (Chaka et al., 2012). Marek's disease has also been identified in village chickens kept under intensive management (Duguma et al., 2005). Parasitic diseases, including coccidiosis (Ashenafi et al., 2004; Luu et al., 2013), helminths (Tolossa et al., 2009; Molla et al., 2012) and ectoparasites (Belihu et al., 2009; Tolossa et al., 2009) have also been demonstrated to be highly prevalent in the country.

Host survival may be severely affected by multiple, coincident infections (Jolles et al., 2008) and there is evidence from studies of wild rodents that existing infections may pose greater risks for further infections than environmental variables (Telfer et al., 2010). Associations between diseases may be the result of direct interactions between the pathogens themselves or indirectly, via the bird's immune system, such that their impact on the host may be altered. Pre-infection with Marek's disease has been observed to alter the clearance of certain *Eimeria* species (Biggs et al., 1968), while both *P. multocida* and *Salmonella enterica* serovar Enteritidis infections have been shown to be more severe in the presence of pre-infection with the nematode *Ascaridia galli* (Dahl et al., 2002; Eigaard et al., 2006). Many of these interactions are thought to be mediated through the altered differentiation of T-lymphocytes; whereas protective cell-mediated responses to intracellular microbial pathogens are primarily driven by T helper 1 (Th1) cells, protection to extracellular infections, including macroparasites, usually requires antibody and primes the immune system towards a Th2-type response. Hosts in a natural environment may have limited ability to effectively mount both types of immune response simultaneously, particularly where they are constrained by limited resources (Jolles et al., 2008). The helminth *Ascaridia galli* has also been shown to reduce the antibody response to vaccination with NDV (Horning et al., 2003), therefore determining pathogen interactions may have implications for disease control programmes. Indeed, the health consequences of multiple low-grade infections may become more significant as interventions reduce the impact of single diseases (Pullan and Brooker, 2008).

However, apparent interactions between infections may arise simply because diseases have other risk factors in common, such as similar transmission routes, temporal patterns of exposure, or host factors, such as sex, age, socio-economic status or behaviours (Hellard et al., 2012). The use of generalised linear mixed models, as proposed by Fenton et al. (2010) for the analysis of macroparasite data, can account for such factors, but may be less useful for serological surveys which measure the host's adaptive immune response rather than the pathogen itself. Serological data present the added difficulty that they do not necessarily represent a current infection; the order of infection is important in determining the immune response to each single infection, and it is thought that susceptibility to new co-infections may return to normal soon after the clearance of the first infection (Telfer et al., 2010). Therefore models which assume a directional relationship are unsuited to cross-sectional serological data (Hellard et al., 2012).

Although there have been several laboratory studies of interactions between pairs of pathogens in poultry, in a village situation pathogens exist in communities, with the possibility of multiple interactions occurring. This study therefore investigated the epidemiology and ecology of co-infection with a range of pathogens in Ethiopian backyard chickens, with the main objectives being (i) to assess patterns of co-infection, and (ii) to identify common risk factors for co-infections. The range of pathogens studied necessitated the collection of both serological and parasitological data, and a method of combining these different infection measures was sought. Ordination methods are commonly used in ecology for community analysis: Here they have been applied to this community of pathogens, where each bird may be thought of as a "site", which has the potential to be exploited by any of the micro- and macroparasite species.