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Small-scale poultry and food security in resource-poor settings: A review

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ABSTRACT

Small-scale poultry production systems are mostly found in rural, resource-poor areas that often also experience food insecurity. They are accessible to vulnerable groups of society, and provide households with income and nutritionally-rich food sources. However, they also improve food security in indirect ways, such as enhancing nutrient utilisation and recycling in the environment, contributing to mixed farming practices, contributing to women's empowerment, and enabling access to healthcare and education. Further, they may contribute to several of the Sustainable Development Goals, and to future food security through maintaining biodiverse genomes. In extensive small-scale poultry production systems, significant impediments to achieving these contributions are disease and predation, which can be reduced through improved agricultural and livestock extension and community animal health networks. For small-scale intensive systems, feed price fluctuations and inadequate biosecurity are major constraints.

1. Introduction

Small-scale poultry (SSP) production systems have been integrated with human livelihoods for thousands of years, enhancing diet, income, and food and nutrition security of the rural poor (Alders and Pym, 2009). Currently, global livestock production systems are under scrutiny, given the projected environmental and food system impacts of increasing livestock production to meet the growing demand for animal-source foods (ASFs) (Delgado, 2003). This review highlights literature that demonstrates and describes linkages between SSP production and food security in low- and middle-income countries (LMICs) with limited resources (resource-poor settings). The potential contributions and impacts of extensive, small-scale scavenging poultry production systems in rural, resource-poor areas differs significantly from more intensive systems in urbanised settings; these differences are highlighted while the contributions of SPP to each dimension of food security – availability, access, utilisation and stability – are explored. Lastly, common constraints to small-scale poultry production in resource-poor areas, and, should these be addressed, their potential contributions towards achieving the United Nations' (UN's) Sustainable Development Goals (SDGs) are presented.

2. Methods

2.1. Review of literature

The terms "small-scale poultry", "scavenging chickens", "village chickens", and "backyard poultry" were searched in Web of Science, BIOSIS Previews, CAB abstracts, and Medline, yielding 1176 results. The search was refined by research area (eliminating 254 results), then assessed for relevance to SSP production, resource-poor areas, and food and nutrition security by article title (eliminating 749 results), then abstract (eliminating 141 results), leaving 32 articles reviewed in full. The Food and Agriculture Organization of the United Nations (FAO) document repository, reference lists from selected documents, and the knowledge of co-authors were also utilised to source relevant publications. Information related to rural, family, or backyard poultry were included if they were relevant to SSP production. Results are grouped by relevance to each dimension of food security. As the majority of SSP production systems raise chickens, this review will use the terms "poultry" and "chickens" interchangeably.

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2.2. Poultry system definitions

Small-scale poultry production systems, largely comprised of chickens, account for the majority of the poultry population in LMICs (Gilbert et al., 2015). The term "family poultry" is used for systems which rely on family labour and, generally, locally available feed resources (FAO, 2004; Thieme et al., 2014). Thieme et al. (2014) describes four categories of family poultry production: small extensive scavenging (1–5 adult birds), extensive scavenging (5–50 birds), semi-intensive (50–200 birds), and small-scale intensive production (> 200 broilers or > 100 layers). Although this spectrum of systems may be viewed as a continuum, SSP farmers utilise the production system that best suits their situation and objectives (Rota et al., 2014). More intensive poultry raising systems require reliable access to inputs, including commercial stock, feed, labour, and health services as well as efficient marketing channels (Branckaert and Guèye, 2000; Mack et al., 2005; Thieme et al., 2014). In rural areas, access to markets, cold chains, and veterinary services is typically limited (Thieme et al., 2014).

The largest number of households worldwide are engaged in "village poultry" production, which encompasses the first two systems, and are comprised of mostly indigenous or sometimes crossbred species (Alders and Pym, 2009). In these free-ranging systems, birds largely scavenge for feed, although supplementary feed may be given, and housing, if provided, is simple and made from locally-available materials (Sonaiya, 2004; Thieme et al., 2014). Small-scale poultry production is commonly incorporated into mixed production systems with crops and other livestock, and are a way for vulnerable households to spread risks (Alders et al., 2013; Thieme et al., 2014). Flocks are self-propagating, with broody hens laying 30–80 eggs per year in 2–4 clutches, and spending time between clutches to rear chicks (Fotsa et al., 2014; Mapiye et al., 2008).

3. Dimension one: availability

The availability dimension of food security generally refers to national food availability, taking into account domestic food production, stores, imports, and aid (WFP, 2009), however, it is also considered at the household level. Food availability refers to foods of "appropriate quality", and those which are culturally and socially acceptable by a given population (FAO, 2006). Poultry are generally the most numerous livestock in resource-poor areas, where their contributions to food availability are both direct, through supplying nutrient-rich and culturally acceptable products for human utilisation, and indirect, through enhancing crop, vegetable and other livestock production with the provision of manure and pest control.

3.1. Availability in vulnerable areas

Despite small flock sizes, in aggregate, rural poultry flocks account for 60–90% of the poultry population in many LMICs across Africa and Asia (Akinola and Essien, 2011; Guèye, 2000a; Mapiye et al., 2008). Dolberg (2007) and Gilbert et al. (2015) noted the relationship between income and poultry production systems, showing that extensive, scavenging poultry systems are most commonly found in rural, resource-poor areas. Fig. 1 highlights the overlapping distribution of extensive poultry production systems and food insecure areas.

It is common for livestock to fulfill multiple roles within households in resource-poor settings, and livestock ownership does not necessarily translate to increased utilisation of ASFs (Turk, 2013). However, Azzarri et al. (2014) found that ownership of poultry is associated with increased chicken utilisation. This is likely due to their small size and short production cycles, factors which make households more likely to decide to slaughter or sell in times of need, compared to larger livestock (Kariuki et al., 2013). Rural poultry supply 70–90% of poultry products in Africa (Alabi et al., 2006; Branckaert and Guèye, 2000; Kitalyi, 1998; Mack et al., 2005), and contribute 20–32% of total animal protein intake (Kitalyi, 1998; Tadelle et al., 2003).

There is high demand for meat from indigenous chicken breeds, due to their suitability to local taste preferences and cooking methods (Aini, 1990; Choprakarn and Wongpichet, 2008; Kitalyi, 1998; Umaya Suganthi, 2014). The persistence of SSP production systems in regions where large-scale commercially-produced poultry products are available is an example of food sovereignty, where communities have chosen a sustainable production system that produces healthy, culturally appropriate food.

3.2. As a food source

Meat (both muscle and organ meat) and eggs from indigenous chickens constitute a high-quality food source, densely packed with essential macro- and micronutrients. Animal-source foods are particularly concentrated in highly bioavailable iron, vitamin A, vitamin B12, zinc, and riboflavin - nutrients that are often deficient or absent in the largely vegetarian diets common in rural, resource-poor settings (Bwibo and Neumann, 2003; de Bruyn et al., 2015; Demment et al., 2003; Murphy and Allen, 2003; Turk, 2013). Slaughter of livestock for home consumption is conducive to use of the entire carcass, including organ meats and bones, which are good sources of high bioavailable vitamin A, vitamin B12, iron, riboflavin, niacin, thiamin and folate (Williams, 2007). Consuming foods with high concentrations of bioavailable nutrients is particularly important for infants and young children, with limited gastric volume, pregnant and lactating women who have increased nutrient requirements, elderly people who may have decreased intestinal absorption capacity, and those who are ill (Olaoye, 2011).

Eggs, containing all nutrients required to support the development of a chick, have a "nearly perfect balance of nutrients" (Vizard, 2000) to meet human nutrition requirements. Eggs have been recognised as the lowest-cost source of protein, vitamin A, vitamin B12, riboflavin, iron and zinc (Drewnowski, 2010), and are also a good source of folate, selenium, vitamin D, and vitamin K (Applegate, 2000). Liver and eggs are among the best sources of vitamin A available (Vizard, 2000). Although ASFs are significant contributors to dietary energy and protein, it is their concentration of micronutrients and their ability to counter multiple micronutrient deficiencies that make them particularly valuable food sources. It has been shown that regular ASF consumption has significant positive benefits for children's nutritional status, linear growth, and educational outcomes, leading to increased income and productivity in adulthood (Bwibo and Neumann, 2003; Demment et al., 2003; Murphy and Allen, 2003). Thus, the cumulative benefits of SSP product utilisation are far greater than being an available food source alone. Dolberg (2007) stressed that the consumption of ASFs in LMICs should not be tempered by the known health risks associated with overconsumption of ASFs seen in high-income countries.

3.3. Enhancing food availability and production

One of the major food security concerns related to livestock production is the diversion of potential human food sources to livestock feed, particularly in the case of monogastric livestock (Flachowsky, 2002). However, the scavenging feed resource base (SFRB) utilised in extensive and semi-intensive poultry production transforms feed ingredients in the environment that are less suitable or unavailable for human consumption, including plant seeds, earthworms, and insects, into palatable and nutrient-rich food products for people (Sonaiya, 2004, 2014a).

Small-scale poultry production is commonly used as part of mixed or integrated farming systems, which allows farmers to use resources efficiently, spread risk and protect against shocks (Alders et al., 2013; Prein, 2002). In Bangladesh, Helen Keller International reported great

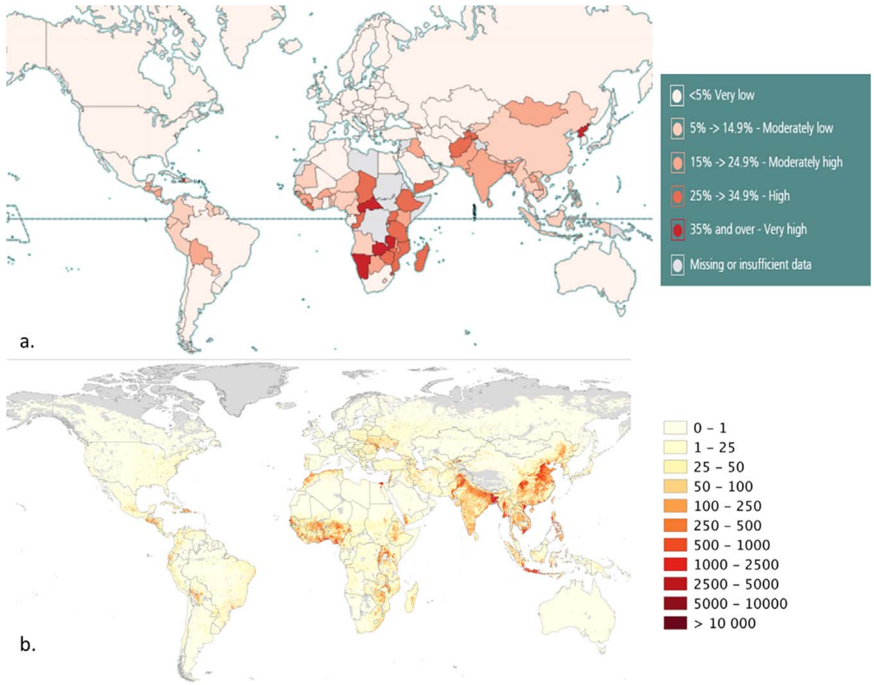

Fig. 1. Globally, the regions of a. higher hunger and food insecurity correlates with b. the distribution and density of extensive poultry producers, showing their importance as a food and income source to these resource-poor areas. Images from a. FAO (2015) and b. Gilbert et al. (2015).

success in the introduction of village poultry to home gardens to enhance homestead food production (Talukder et al., 2010). In other parts of Asia, integrated farming systems make use of chicken manure from overnight housing to fertilise underlying fish ponds, sediment from which is then used as organic fertiliser for crop production (Udo et al., 2006).

Aside from the use of manure, SSP production enhances food production by controlling pest species. Controlled access to crops and vegetables allow chickens to remove pests (Guèye, 2000a), and for livestock species such as cattle, mixed farming with chickens has been shown to decrease the numbers of tick species in the environment and on animals (Dreyer et al., 1997).

4. Dimension two: access

The access dimension of food security refers to the ability of people to obtain available food, which is more difficult for economically, physically, or socially disadvantaged population groups (WFP, 2009). The low-input nature of extensive and semi-intensive SSP production makes it accessible to these vulnerable or marginalised groups who are at a higher risk of food insecurity, in contrast to large-scale or intensive systems which require greater inputs and are often kept by wealthier households (Dolberg, 2007). Village chickens can make significant economical contributions to households, both as a small source of regular income, or as a liquid asset, which can be used by households to access food. When SSP are reared by women, it is possible for this income to be under the complete control of women, increasing their empowerment, which in turn enhances household food security.

4.1. Village chickens and vulnerable groups

Access to a year-round adequate, nutritious diet can be a challenge for all members of resource-poor communities. However increased difficulties are often faced by poorer subsets of society, along with women, children under five years of age, people who are chronically ill, and the elderly (FAO, 2011a). When extensive management systems are used, small-scale poultry production requires few inputs and no land, making it particularly accessible to those with limited income sources (Riise et al., 2005). Alabi et al. (2006) found that 35% of women's income is derived from family poultry, while Dolberg (2007) found that poorer households more commonly kept poultry and pigs than wealthy households. Small-scale poultry have minimal care requirements, which is important for people living with a disability or those affected by chronic illness, such as HIV & AIDS. They are accessible to people living in remote areas, and to disadvantaged cultural groups (Ahlers et al., 2009; Alders et al., 2010; Copland and Alders, 2005; Mutenje et al., 2007). “Chickens are the most popular and the most democratic livestock species raised by households” (Bagnol, 2009), because all members of the household - even children - can own them. For people with limited resources, poultry may be the only livestock they can keep, with Aklilu et al. (2008) reporting that “poultry are the first and the last resource a poor household owns”.

4.2. A liquid asset

One of the central roles of livestock is income generation. In resource-poor settings, chickens are amongst the most affordable livestock, and they may be sold or exchanged for sequentially larger and higher-value species, building a household's asset base, or used to provide income in times of need. As such, they are the first rung on the livestock ladder – “Poultry are the seeds you sow to get the fruits, cattle” (Aklilu et al., 2008). For larger livestock species the highest market price is earned when a mature animal is sold, requiring households to commit much time and resources to raise these animals to the point where they are most profitable. Therefore, the sale, consumption, or offering as gifts of large animal species is infrequent. When households are faced with food insecurity, the decision to sell large livestock at a sub-optimal price is a difficult one, however, small livestock species including poultry mature rapidly, and are consistently available, so they are often the first livestock species sold by households to meet their immediate needs (Mapiye et al., 2008; Maxwell and Smith, 1992).

The economic contributions of SSP to households vary by production system and location. Village poultry brought an average annual income of USD13 to households in Ethiopia (Muhiye, 2007); USD27 in Haiti (Nchinda et al., 2001), USD55 in Mozambique (Woolcock et al.,

2004) and USD124, or 50% of the per capita income, to households in Nigeria (Alabi et al., 2006). Alabi et al. (2006) estimated that ten laying hens can earn Nigerian households USD100 per annum, and in Indonesia, ten laying hens vaccinated against Newcastle disease can generate more than 25% of the monthly household income (Moerad, 1987).

In Lao PDR, village poultry production produced a net household annual income of USD67. With control of Newcastle disease and Fowl Cholera, net household incomes from meat production were between USD97 in remote areas, USD120 in rural villages, and USD108 in regions with access to the cold chain (Alders, 2004). In India, net income from indigenous poultry production differs by socioeconomic status: households with incomes in the middle and upper 20% earned a greater profit from their poultry, however they delivered a lower net profit margin ratio than producers in the lower 20% income group due to higher expenditures on inputs (Ahuja et al., 2008). Wantasen et al. (2014) found that purchased feed was the greatest cost in small-scale semi-intensive chicken production in Indonesia, although farmers earned a net annual income of IDR4,329,038.

There is typically a consumer preference for local chicken meat due to suitability of taste and texture, and the minimal use of pharmaceuticals during production (FAO, 2010; Guèye, 2000a; Melesse, 2014; Umaya Suganthi, 2014). Although production is low and markets are limited, local chickens and eggs fetch a significantly higher market price, from 1.5 to 3 times the cost of a commercial product, (Barua and Yoshimura, 1997; Choprakarn and Wongipechet, 2008). Income from the sale of SSP products allow households to purchase a greater variety of food, and cover schooling and healthcare costs (Alam, 1997; Mapiye et al., 2008). Small-scale poultry products have an advantage over larger livestock species in that although market access greatly aids the sale of SSP products, they are mostly sold or bartered locally and do not require the presence of formal markets (Akinola and Essien, 2011).

4.3. *Women's empowerment*

In many LMICs, poultry are often the only livestock under the independent control of women (Bagnol, 2009; Thieme et al., 2014). In Zimbabwe and Ethiopia, it was found that village chickens belong almost exclusively to women (Mapiye et al., 2008; Tadelle and Ogle, 2001), who are responsible for the care of the birds, and for selling chickens and eggs. Men are often involved in the construction of shelter for the chickens, or in their treatment or slaughter, however even in male-headed households, women are often responsible for decision-making on issues related to chicken production (Dolberg, 2007; FAO, 2010; Kusina et al., 2001; Muchadeyi et al., 2004).

Income from the sale of poultry products is often the main source of income for female-headed households, whereas male-headed households usually have multiple income sources (Aklilu et al., 2008; Muchadeyi et al., 2004). It has been found that 90% of income under the control of women is channeled back into their households or local communities, in contrast with only 30–40% for men (OECD, 2009), and that women use their income to increase the quantity and variety of foods purchased, on medical care, and on schooling for children (Meinzen-Dick et al., 2011). In this way, women's income leads to greater improvements in household health, education and nutritional status than men's income, and has a positive impact on household food security (Guèye, 2000b; Meinzen-Dick et al., 2011; Muchadeyi et al., 2004). Village poultry production systems are a particularly important income-generating activity for women, as they place little demand on mothers' time, allowing adequate time allocation to child care, a crucial element to achieving good nutrition (Quisumbing et al., 1995).

The inclusion of women in SSP training programs to become community vaccinators increases the knowledge and standing of women within their household and the wider community (Alders et al., 2010; Bagnol, 2012). Livestock interventions that target species under the control of women, including SSP, may enhance the impact upon household food and nutrition security through the empowerment of women.

5. Dimension three: utilisation

This dimension refers to both household and individual utilisation of nutritious and safe diets, acknowledging elements such as health status, sanitation, feeding practices, and food safety, which can all impact utilisation and nutrient waste (WFP, 2009). It is found that in many contexts taboos prohibiting the consumption of eggs by children and pregnant women exist (Bagnol, 2001), meaning that even if nutrient-rich food items exist in the household, it might not be utilised by all the members in the same way. In the absence of Newcastle disease control, it has been observed that households very rarely utilise chicken and eggs, preferring to keep the eggs to produce chickens that can be sold, often to allow the purchase of staple foods and other less nutritious food (Bagnol, 2001). Control of Newcastle disease increases the availability of eggs and healthy chickens for consumption (Alders et al., 2010). Poultry meat can be consumed on the day of slaughter, and eggs do not require storage facilities, although care needs to be taken with zoonotic diseases. The concentration of *haem* iron increases the bioavailability of other nutrients in food, and income from the sale of SSP products can also be used to provide access to healthcare and improved sanitary environments.

5.1. *Nutrient bioavailability*

Due to similarities between human and animal physiology, ASFs contain a variety of nutrients in a readily available form. Animal proteins have a digestibility of up to 98%, compared to 75–85% for foods from plant sources (Bhutta, 2005). Iron is pre-bound in a *haem* molecule, allowing direct absorption, whereas iron from plant sources requires transformation within the gut before absorption is possible (Allen, 2003; Murphy and Allen, 2003). Similarly, vitamin A is found as pre-formed retinol, ready for direct absorption (Allen, 2003; Murphy and Allen, 2003). As iron and vitamin A are two of the most widespread micronutrient deficiencies (Ahmed et al., 2013), particularly in LMICs, regular utilisation of highly bioavailable micronutrient source foods can help to ameliorate these deficiencies.

Micronutrient absorption is of particular concern when diets largely consist of cereal and tuber staple foods and vegetables. High levels of fibre, phytate and oxalate decrease micronutrient bioavailability from plant-based diets, with absorption of iron, zinc and calcium being particularly affected (Allen et al., 1991; Gibson, 1994; Libert and Franceschi, 1987). The addition of even small amounts of ASFs to a largely vegetarian diet counteracts this inhibition, thereby enhancing overall micronutrient absorption (Allen et al., 1991; Fairweather-Tait and Hurrell, 1996; Hallberg and Hulthén, 2000; Leroy and Frongillo, 2007; Miller and Welch, 2013; Welch and Graham, 2000).

A final contribution of SSP to utilisation is through the use of income generated from poultry and egg sales allowing greater access to health services, household sanitation and hygiene and providing opportunities to purchase a greater quantity and variety of foods (Guèye, 2000b).

5.2. *Food safety*

Poultry products are well-sized for immediate utilisation. Eggs, when their shell is intact and when stored under appropriate conditions, are sterile and easy to cook (Board et al., 1994). Chickens can be slaughtered and consumed by households in a single meal, eliminating the need for meat storage, which is required for larger livestock species (Aklilu et al., 2007). However, zoonoses such as highly pathogenic avian influenza (HPAI) and bacterial contamination with *Salmonella* and *Campylobacter* species are potential public health risks, especially given the common practice of slaughtering and consuming sick birds or recently dead birds (Conan et al., 2012; Alders et al., 2014). Effective husbandry and disease control leads to increased flock sizes and provides assurance of stability of supply of poultry products. Such strategies increase the availability of healthy chickens, and can help to reduce the likelihood that food-insecure households will resort to eating diseased or dead chickens (Alders et al., 2013).

5.3. Environmental interactions between humans and livestock

Recent literature has raised concerns regarding the potential for shared environments with poultry to have adverse effects on child growth outcomes. In resource-poor settings, chickens are often housed within human dwellings overnight, to prevent predation and theft. There is evidence to indicate a positive association between exposure to livestock faeces and diarrhoea in children (Zambrano et al., 2014), and suggestions that even non-pathogenic bacteria can contribute to a subclinical condition of the gastrointestinal tract (environmental enteric disorder; Mbuya and Humphrey, 2015) – potentially contributing to poor nutrient absorption and a heightened risk of chronic growth restriction or stunting (Korpe and Petri, 2012; The SHINE Trial Team, 2015).

A cross-sectional study of rural households in Ethiopia reported an overall positive association between poultry ownership and height-for-age *Z*-scores in children (with stunting defined as Z-scores below −2), but a negative association if poultry were housed indoors (Headey and Hirvonen, 2016). By contrast, longitudinal findings from Tanzania indicate no significant association between poultry ownership or the practice of keeping chickens indoors overnight and the height-for-age or incidence of diarrhoea in children (de Bruyn et al., 2016). Elsewhere, studies have found no relationship between livestock ownership and growth outcomes in children (Headey and Hirvonen, 2016; Mosites et al., 2016). For children over six years of age, exposure to livestock and higher levels of microbial endotoxin in the home environment has been shown to enhance innate immunity and associated with decreased levels of respiratory disease (Stein et al., 2016).

Clearly, the interactions between human immune systems, livestock and the environment are complex and further research is needed in this sphere.

6. Dimension four: stability

The fourth dimension in food security is stability in food availability and accessibility, and resilience in adapting to economic or environmental shocks or changes (FAO, 2006). Small-scale poultry can be a year-round source of food when threats to production, particularly Newcastle disease, are addressed and controlled. Village chickens are hardy, well-adapted to their environments, and genetically diverse; inherent characteristics that, when combined with their extensive production system, can improve survival rates in the short term during disease outbreaks, and in the long term, through climate change. As extensively-raised monogastrics that do not require land clearing for production, their carbon and water footprints are low, and their manure contributes to soil health (Chantalakhana, 2000) – in contrast to intensively-raised poultry whose largest greenhouse gas contribution is from feed production (Gerber et al., 2013). Increasing the availability of SSP products for consumption may also play a role in wildlife conservation. Lastly, income earned through SSP production is often used to pay for children's education. Through increased opportunities for schooling and the empowerment of women, SSP production systems can contribute to the food security of future generations.

6.1. Genetic diversity of indigenous chickens

Biodiversity loss is a great threat to ecosystems, with genetic losses having strong negative impacts on ecosystem function, efficiency and stability (Cardinale et al., 2012). At present, up to 70% of the word's livestock breeds are found in LMICs (Rege and Gibson, 2003). A review (Eltanany and Distl, 2010) of the genetic diversity within and between chicken breeds and populations found higher genetic diversity within indigenous and village chickens compared to commercial breeds, a finding shared by Elkhaiat et al. (2014), Lyimo et al. (2014), Mahammi et al. (2016), and Mercan and Okumus (2015) highlighting their value in genetic conservation.

Indigenous poultry breeds have co-evolved with their environments, and have the highest likelihood of survival in harsh conditions due to their disease resistance, ability to scavenge and avoid predators, and their broodiness (Besbes, 2009; Fotsa et al., 2014; Guèye, 1998; Umaya Suganthi, 2014). The introduction of commercial breeds to these environments has often been hampered by high mortality rates, and crossbreeding between local and commercial breeds can have negative effects on broodiness and mortality rates (Pym, 2013; Udo et al., 2011), although some successes are reported in Section 8.1.

An assessment of heat tolerance found that commercial chicken breeds have lost the coping mechanisms that allow village and red jungle fowl to tolerate higher ambient temperatures (Soleimani and Zulkifli, 2010), although genetic feather variations including Naked-neck allow a greater degree of heat tolerance (Melesse et al., 2011). With increasing climate variability, extremes in weather conditions are expected to become more frequent, feed quality and water availability will decline, and the incidence of illness in livestock increase (Thornton et al., 2009). Future food production challenges are unpredictable and likely will include new diseases or more virulent recurrent diseases, and environmental changes necessitating alternatives. Therefore, a healthy and diverse genetic reservoir in food-producing animals remains as crucial as ever (Pym and Alders, 2016). Muir et al. (2008) suggested that non-commercial flocks, including those found in many LMICs, could potentially represent the reservoir opportunity for alleles 'missing' from commercial pure line stocks.

Thus, conservation of the indigenous genepools raised under SSP production systems may not only contribute to ecosystem health, but may ensure the long-term survival and productivity of poultry as livestock.

6.2. Environmental footprint

Adverse environmental impact is a predominant concern in agriculture, particularly in livestock production, which accounts for around 15% of greenhouse gases (GHGs) arising from human activity (Gerber et al., 2013). For intensively raised livestock, 61% of emissions are attributed to beef and dairy cattle production, nine percent to pig meat production, and eight percent to poultry meat and egg production (Gerber et al., 2013), with the most significant emissions arising from ruminant enteric methane production, nitrous oxide from feed production, and land use (Herrero et al., 2015). Gerber et al. (2013) reported that subsistence-driven chicken production is less efficient than intensive production, so emission intensities are higher in the former systems, however they account for less than 10% of poultry's greenhouse gas emissions.

Despite inefficiencies of production, SSP contribute to environmental health in ways that have not yet been adequately understood. The interaction between crop and livestock production in mixed farming systems allows nutrient cycling to improve soil fertility, and the use of manure adds organic matter to soils, improving water-holding capacity and structure (Chantalakhana, 2000; Devendra and Chantalakhana, 2002).

Despite a distinct lack of published data on the nutrient content of ASFs produced in resource-poor settings (de Bruyn et al., 2016), available data indicates protein production to be more nutritionally and ecologically efficient in poultry meat and eggs than in beef or pork (Flachowsky, 2002; Pelletier and Tyedmers, 2010). Improvements in SSP management systems that increase production efficiency could lower emission intensities while maximising ecosystem benefits. With increasing urbanisation, and population and income growth in LMICs, the increasing demand for ASFs is predicted to continue (Pica-Ciamarra and Otte, 2011). Sourcing ASFs from livestock species and production systems with lower GHGs emissions would be the optimal choice.

6.3. Role in wildlife conservation

The hunting and consumption of non-domesticated animals (bushmeat) can be a significant source of protein and micronutrients for rural families (Alders and Kock, 2017; Foerster et al., 2012; Golden et al., 2011), however, hunting of threatened or endangered species is unsustainable and leads to loss of biodiversity (Foerster et al., 2012; Harrison et al., 2016). Studies have found that the primary goal of hunting by rural, resource-poor households is for consumption (Albrechtsen et al., 2005; Brashares et al., 2011; Foerster et al., 2012). These studies concluded that increasing access to affordable alternate protein sources would decrease hunting pressure on wildlife, and contribute to the conservation of endangered species. Increasing the output and efficiency of SSP production in communities living in close proximity to protected environments increases the availability of ASFs, and has the potential to decrease other income-generating activities such as tree felling (Ahlers et al., 2009; Chantalakhana, 2000; Dumas et al., 2016).

7. Constraints to small-scale poultry production

The ability of SSP production to achieve maximal contributions to food and nutrition security can only be realised if the constraints to production are addressed. Major constraints include inherent low production, disease, and predation in extensive systems, and fluctuations in feed prices and inadequate biosecurity in intensive systems. In addition, inadequate nutrition, housing, and access to veterinary services and appropriate extension materials all present potential barriers to production. To successfully address these barriers, management practices need to be assessed for local sustainability, cost-effectiveness and the greater involvement of women.

7.1. Low productivity

When judged by conventional measures of productivity commonly used in the commercial poultry sector such as feed conversion ratios or daily weight gain, local chicken breeds are low and slow producers of eggs and meat. Even under ideal housing and feeding conditions, productivity in indigenous breed chickens is much lower than in their commercial counterparts (Sørensen, 2010). Indigenous birds kept under village settings expend a significant amount of energy scavenging for feed and evading predators, lowering their growth rate and egg production, and hens spend up to 75% of their time hatching eggs and rearing chicks (Pym and Alders, 2012). Notwithstanding this, these birds survive and reproduce in the harsh village environment where commercial breeds perform very poorly. In conjunction with their other contributions to the household, comparative productivity as measured by benefit-cost ratio or net profit margin ratio, is higher in the indigenous breeds (Ahuja et al., 2008).

7.2. Disease

The most common cause of the high mortality rates observed in SSP flocks, particularly in tropical countries, is Newcastle disease (ND) (Alders et al., 2010; FAO, 2014; Spradbrow, 1993). Newcastle disease virus is highly infectious among chickens, and virulent strains can cause up to 100% mortality annually (Samal, 2011). Alders et al. (2010) found that the training of community vaccinators to administer thermotolerant ND vaccines every four months was effective in controlling ND, and greater sustainability was associated with the involvement of women as community vaccinators and farmers paying a small fee for vaccination services to assist in cost-recovery. The benefits of ND control included increased income for female-headed households, increased utilisation of poultry products, and increased trust between community and government (Alders et al., 2010). Aklilu et al. (2007) found that ND control in SSP production systems can enable incomes to be doubled and nutrient intake to improve. Fundamental in the success of ND control through vaccination is the establishment of a network of community vaccinators who receive payments from farmers to compensate them for their efforts (Bagnol et al., 2013).

The control of ND is particularly important in the face of an HPAI outbreak, as the two diseases are clinically indistinguishable (Gardner and Alders, 2014). The emergence of and response to HPAI placed a heavy burden on SSP producers, directly, due to the loss of birds, and indirectly, as initial control measures resulted in massive depopulation, often with inadequate or no compensation (Mack et al., 2005). These measures lead to decreased trust between SSP farmers and authorities, and discouraged many farmers from continuing with SSP production (Mack et al., 2005; Otte et al., 2008). Studies examining the impact of HPAI and its control found devastating effects on smallholder flock sizes, livelihoods and children's nutritional and educational status, with women and poor to very poor households most affected (Alders et al., 2013; Bagnol, 2009; FAO, 2009). However, the rapidly fatal course of disease, relative fragility of the virus and lack of interconnectedness between SSP inputs and outputs means that SSP farms are at lower risk of exposure and propagation of HPAI (FAO, 2008, 2011b; Otte et al., 2008). These factors and the importance of SSP flocks to their farmers are now recognised, with the FAO stating that although achieving biosecurity in SSP systems is difficult, “it is neither feasible nor desirable to limit scavenging poultry as a livelihood option for the poor” (FAO, 2008).

Importantly, the control of ND facilitates the early detection of HPAI, allowing a more rapid response in order to control losses. Once ND control is established, other diseases may rise to significance. Currently, the economically significant diseases include fowl cholera in Southeast Asia, and fowl pox in south-eastern Africa (FAO, 2014).

7.3. Predation, housing and nutrition

In addition to disease outbreaks, a significant constraint to SSP production is the loss of chicks through predation, inadequate nutrition, and environmental stress (Ahlers et al., 2009). These issues can also affect adult chickens, however, chicks are more vulnerable and typical attrition rates range from 50% to 70% (Ahlers et al., 2009; FAO, 2010). The provision of dedicated nests for hens to brood, more intensive management of chicks including the provision of protective housing, and food and water supplementation, can help to reduce losses and contribute to increased flock size (Ahlers et al., 2009; Melesse, 2014).

Adult chickens can be protected from predation through the provision of simple night-time housing designed to minimise predator access (Ahlers et al., 2009; Melesse, 2014). Housing at night time also protects chickens from weather extremes, while still allowing full use of the SFRB during the day, and facilitates feed supplementation, inspection or vaccination of chickens as required (Ahlers et al., 2009).

The SFRB provides the greatest input for extensively-raised chickens, and consists of plants and insects found in gardens, fields and forests, household wastes, and crop by-products (Roberts, 1992). It is subject to seasonal change, may result in suboptimal nutrition during particular months of the year (Ahlers et al., 2009; Ncobela and Chimonyo, 2016; Raphulu et al., 2015). Supplementary foods from local ingredients that include protein and mineral sources can improve nutritional status during these times (Ahlers et al., 2009), and is particularly important for chicks. The SFRB is a limiting factor in SSP production, as exceeding maximal capacity will lead to undernutrition of all birds utilising the resource (Roberts, 1992), sometimes resulting in clinical manifestations of hypovitaminosis A, amongst other micronutrient deficiencies. With increased SSP production, farmers will need to actively manage their flock, planning to sell chickens or eggs at times when prices are higher or when the SFRB is insufficient (Ahlers et al., 2009).

For small-scale semi-intensive systems, especially in rural areas, availability of nutritionally-balanced, age-appropriate feeds is a major constraint. Wantasen et al. (2014) found that poultry feeds were the greatest expense for farmers using this system. Fluctuations in feed costs can have a major impact on economic return and sustainability of production, and to manage this risk, farmers would need to have access to credit or microfinance (Sonaiya, 2014b).

7.4. Veterinary and extension services

In many rural areas in LMICs, the widespread area and a lack of resources and infrastructure can result in limited veterinary and extension services (FAO, 2014). Where they exist, they are often focused on crop or ruminant production, with little health care or advice accessible to SSP keepers (Bagnol, 2009). This negatively impacts farmer access to information, including about adequate biosecurity practices, a major concern for small-scale intensive poultry producers (Alders et al., 2014). However, the formation of networks of community-based animal health workers, where training and knowledge is passed between veterinarians, governments and communities, has been found to be effective in both delivering services such as vaccination or health care, and reporting, investigating, or controlling animal diseases (FAO, 2010; Leyland et al., 2014).

A lack of consideration of gender issues can also limit the effectiveness of extension services. Data from the FAO indicate that female farmers receive only 5% of agricultural extension services; that only 15% of extension workers are women; and that only 10% of agricultural aid goes to women (FAO, 2016). This situation indicates the current bias towards men in the agriculture sector. Much of the training, communication and extension materials are directed at men, and women, who are the main carers in SSP production systems, may not receive the information they need (Bagnol, 2012; Guèye, 2000a). Lower literacy levels among women also decrease the utility of written communication materials, with oral or visual materials being more effective in these settings (Bagnol, 2012). Ensuring gender equity in the selection of community animal health workers can allow more effective communication with male and female poultry keepers (Bagnol, 2012), and a gender sensitive approach at all levels of the intervention is necessary to ensure that women benefit from interventions involving poultry-raising activities (Bagnol et al., 2013; Guèye, 2000a).

8. Looking ahead

8.1. Innovations towards market orientation

For many farmers, village poultry are raised for home utilisation and for emergency income, requiring minimal inputs, often as part of mixed farming systems. Choprakarn and Wongipechet (2008) stated that these systems are still appropriate for most SSP farmers in Thailand, and changes in management systems are not always suitable. However, as economies develop and access to inputs and markets improve, use of high-value SSP stock can enable some households to move to more market-oriented production (Ahuja et al., 2008).

Selective crossbreeding can combine desired characteristics of indigenous and commercial chicken breeds. The Kuroiler chicken was developed in India in 1993 as a high-yielding, fast-growing dual-purpose bird that retains its indigenous feather colours, ability to evade predators, disease resistance, and suitability to rural environments (Ahuja et al., 2008; Sharma et al., 2015). Kuroiler chickens are produced at a parent farm, with hatchery units then supplying day-old chicks to “Mother Units” to rear until two to three weeks of age. A network of mobile vendors then sell these chicks door-to-door in villages, where households rear the Kuroiler chickens mostly for sale in village markets, but also for home utilisation (Ahuja et al., 2008). Kuroiler households could earn more than 5 times the income from poultry production than non-Kuroiler househlds, although net profit margin ratios were lower due to higher production costs (Ahuja et al., 2008).

In Thailand, the Kai Baan Thai (Thai Village chicken) has been developed as a fast-growing broiler that retains the meat texture and flavour characteristics of indigenous chickens (Choprakarn and Wongipechet, 2008). This is an example of the commercial adoption of indigenous poultry genetics to supply a high-end, niche market.

8.2. Small-scale poultry for sustainable development

When considering the increasing demand for food by a growing global population and the challenges facing agriculture in the near future, including the impact of climate change, and decreasing land and water availability, the outlook may seem bleak. However, the UN's SDGs have been developed as a set of globally applicable guidelines and targets aimed at improving human life, eradicating poverty, promoting peace and prosperity, and protecting the planet (UNDP, 2015). Although SSP production will not be the only solution to increasing global food production, they can have a strong impact on the most vulnerable sectors of society and play a role in the sustainable development of communities. Table 1 summarises the potential contribution of SSP production systems to eight of the 17 SDGs. By tackling the constraints to SSP production efficiently, their potential contribu-

Table 1
Contributions of small-scale poultry to the UN Sustainable Development Goals (Alders and Pym, 2009; de Bruyn et al., 2015; UN, 2015).

Contribution pathway of small-scale poultry	Sustainable Development Goal
Increasing the availability, accessibility, utilisation and stability of supply of food and nutrients.	2: Zero hunger 3: Good health and well-being
Small-scale poultry are able to be kept by vulnerable groups, giving them access to a source of income. Community-supported models for Newcastle disease prevention can provide employment, including for women, and increased production can promote rural economic growth.	1: No poverty 8: Decent work and economic growth
By targeting a livestock species and production system that is largely under the control of women, improvements to the SSP production systems can preferentially benefit women, promoting their empowerment. Income under the control of women is also more likely to be used to support the education of their children.	5: Gender equality 4: Quality education
Efficient and sustainable use of natural resources while achieving adequate nutrition globally requires high-income countries to decrease food wastage and consumption of calorie-dense, nutrient-poor foods, while low-and-middle-income countries need to increase their consumption of nutrient-rich foods. Small-scale poultry are nutritious and locally-available, typically with a short supply chain, and measures to improve health and welfare will improve production efficiency and ensure sustainability.	12: Responsible consumption and production
Production of SSP does not require land clearing, contributes positively to ecosystem health, and can reduce loss of biodiversity by being a rich pool of genetic diversity and by being an alternate protein source to bushmeat.	15: Life on land

tion to sustainable development can be enhanced.

9. Conclusion

The roles of SSP in LMICs are many, and this review highlights the multitude of avenues through which they can contribute to improved household food and nutrition security. As a highly available and accessible form of livestock in rural, resource-poor areas that often experience food insecurity, SSP are a significant source of income, nutrition and security for the poorest of households. In particular, the importance of these systems to the livelihoods of women, children, the elderly, and the chronically ill should not be overlooked. Barriers to maximising the potential impact of SSP production systems are significant, with high burdens of disease and predation limiting production and utilisation of poultry products, but many of these constraints can be addressed with local adaptations of management strategies, including the development of gender-sensitive training and extension materials (Bagnol et al., 2013). Finally, SSP production systems have persisted for thousands of years, and the local chickens within these systems are well-adapted to harsh environments. Recognition of their ability to survive and reproduce in these conditions, their value as a rich source of genetic biodiversity, and their potential to contribute to sustainable development should promote interest in investing in the protection and conservation of local breeds kept in SSP systems.

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