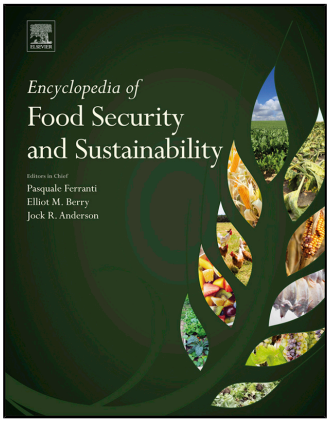

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Smallholder Poultry: Leveraging for Sustainable Food and Nutrition Security

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Abstract

Achieving sustainable food and nutrition security in the face of climate change is a complex global endeavour that requires feasible strategies that are appropriate to local cultural, economic and geographical circumstances. This complexity is also reflected in (i) the diversity of strategies required to enable smallholder poultry production to realise its potential in an environmentally and financially sustainable manner; and (ii) the number of the United Nation's Sustainable Development Goals (SDGs) linked to smallholder poultry production.

For the greater majority of smallholder poultry producers, poultry are raised as part of their household livelihood strategy. Income derived from smallholder poultry production is usually used to meet household needs. To facilitate increased home consumption or the purchase of foods with higher nutrition value with the proceeds of poultry production, a complex mix of factors must be addressed: basic household needs such as sufficient income (SDG1), access to education (SDG4) and health care (SDG3) achieved including access to information concerning the specific nutritional requirements of children and women of reproductive age; efficient, economically- and environmentally-sustainable poultry production and marketing (SDGs 2, 8, 9, 10, 12, 15) to ensure optimal return on investments such as the purchase of quality feed (approximately 70% of the cost of poultry production), infrastructure, household labour and poultry health inputs; gender equity (SDG5) in relation to the control of poultry assets, distribution of food within households and access to education and training.

Introduction

The presence of smallholder poultry worldwide and the increasing popularity of 'backyard' poultry in high-income countries reflects their multiple and crucial roles in human societies (Alders et al., 2018). However, the potential of smallholder poultry is yet to be fully and efficiently attained in terms of their contribution to sustainable national and household food and nutrition security.

The current intensive commercial poultry production systems rely on grain-based diets to achieve optimal growth of relatively homogenous genetic lines of meat-type chickens and egg production in laying hens. With increasing water scarcity, rising temperatures and changes to crop nutrient composition due to rising atmospheric levels of CO_2 levels, global crop production is predicted to decrease. Each degree-Celsius increase in global mean temperature would, on average, reduce global yields of maize by 7.4%, and soybean by 3.1% (Zhao et al., 2017). These two grains are core components of commercial poultry rations in most countries in addition to contributing significantly to human caloric intake.

Food pricing globally is based on price per unit weight or volume and this has influenced poultry breeders to focus on food conversion efficiency in relation to body weight gain and high egg production generally without adequate attention to nutrient composition of the final product. The selection of fast-growing broilers has been accompanied by a range of non-communicable

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diseases (NCDs), such as ascites syndrome (i.e. heart failure) and lameness, which have also led to health problems in intensively raised broilers at the smallholder level (Gupta, 2011). Concurrently, the composition of the broiler carcasses has changed with changing ration formulation. Together with other drivers of poor nutrition in society, this impacts on the quality of food entering the human food system at a time when obesity, micronutrient deficiencies and other NCDs have become major public health issues in low-, middle- and high-income countries (WHO, 2017). Wang et al. (2009) report a substantial increase in the amount of non-essential fats and a loss of essential fats derived from contemporary animal husbandry, including poultry meat, with modern organic and broiler chickens sold for human consumption providing more energy from fat than protein.

With an increasing human population and the impact of climate change on food production, there has never been a more important time to align sustainable agricultural and poultry production with human nutritional requirements. This paper presents opportunities to leverage family poultry production for sustainable food and nutrition security using the United Nations Sustainable Development Goals (SDGs; UN, 2015) as a framework and Planetary Health (i.e. the recognition that human health is totally dependent on the health of ecosystems that underpin it; Horton and Lo, 2015) as a unifying paradigm.

Increasing the Contributions of Smallholder Poultry to Food and Nutrition Security

Achieving sustainable food and nutrition security in the face of climate change is a complex global endeavour that requires feasible strategies that are appropriate to local cultural, economic and geographical circumstances. This complexity is also reflected in (i) the diversity of strategies required to enable smallholder poultry production to realise its potential in an environmentally and financially sustainable manner; and (ii) the number of the United Nation's Sustainable Development Goals linked to smallholder poultry production (Table 1).

Table 1 Activities that will leverage smallholder poultry production in support of sustainable food and nutrition security within the framework of the United Nations Sustainable Development Goals which are to be met by 2030

Sustainable development goal[a]	*Goal-associated activities in smallholder poultry production that will promote food and nutrition security*	*References*
GOAL 1: No Poverty - end poverty in all its forms everywhere	Smallholder poultry production (SPP) can contribute to strategic income generation, which can strengthen indirect food security pathways and disaster risk mitigation.	Alders and Pym (2009); Wong et al. (2017)
GOAL 2: Zero Hunger - end hunger, achieve food security and improved nutrition and promote sustainable agriculture	Improved SPP can contribute directly and indirectly to ending malnutrition in all its forms: undernutrition, overweight and 'hidden' hunger resulting from micronutrient deficiencies. Appropriate SPP can also contribute to sustainable food production systems and resilient agricultural practices including maintaining the genetic diversity of poultry, which is crucial for resilient food production.	de Bruyn et al. (2015); Pym and Alders (2016); Wong et al. (2017)
GOAL 3: Good Health and Well-being - ensure healthy lives and promote well-being for all at all ages	Good health and well-being is underpinned by access to and utilization of safe, nutritious food especially for children and women of reproductive age. Reduce the risk of zoonotic diseases of poultry-origin by using appropriate and adequately-resourced poultry production systems.	de Bruyn et al. (2015); Derksen et al. (2018); Wong et al. (2017)
GOAL 4: Quality Education - ensure inclusive and quality education for all and promote lifelong learning	SPP can contribute to quality education by: • Generating income to pay school fees • Improving diets to enhance cognition • Providing opportunities for students to learn about biology, poultry production and nutrition by incorporating elements of SPP into curricula	Alders and Pym (2009)
GOAL 5: Gender Equality - achieve gender equality and empower all women and girls	By ensuring that the SPP systems more likely to be under the control of women (i.e. extensive and semi-intensive systems) receive adequate support, women's knowledge, positions and decision-making within households and communities will be enhanced.	Alders and Pym (2009); Bagnol (2012)
GOAL 6: Clean Water and Sanitation – Ensure access to water and sanitation for all	Improved and appropriate SPP with reduced poultry-associated food-, water- and fomite-borne disease will improve food utilisation and nutrition.	Wong et al. (2017)
GOAL 8: Decent Work and Economic Growth – Promote inclusive and sustainable economic growth, employment and decent work for all	Appropriate and stable pricing of high quality, safe poultry products will enable SPP by families to continue with farming being seen as a viable profession by the next generation of men and women in farming households.	

(Continued)

Table 1 Activities that will leverage smallholder poultry production in support of sustainable food and nutrition security within the framework of the United Nations Sustainable Development Goals which are to be met by 2030—cont'd

Sustainable development goal[a]	*Goal-associated activities in smallholder poultry production that will promote food and nutrition security*	*References*
GOAL 9: Industry, Innovation and Infrastructure – Build resilient infrastructure, promote sustainable industrialization and foster innovation	Develop quality, reliable, sustainable and resilient SPP production and marketing infrastructure to support economic development and human well-being, with a focus on affordable and equitable access for all. Increase the access of small-scale industrial and other enterprises, in particular in low- and middle-income countries, to financial services, including affordable credit, and their integration into value chains and markets. Significantly increase access to information and communications technology to enable poultry producers to be more informed of market prices, disease risks, changing feed prices, etc.	FAO (2010)
GOAL 10: Reduced Inequality – Reduce inequality within and among countries	Reduce inequity in current global trade in poultry products by promoting the importance of family farmers and locally-produced poultry products. Work to reduce the dumping of poorer quality poultry products in low- and middle-income countries.	
GOAL 11: Sustainable Cities and Communities – Make cities inclusive, safe, resilient and sustainable	Backyard poultry local regulations to be updated to allow production to be conducted in areas were both bird welfare and appropriate public health requirements can be achieved.	Whitehead and Roberts (2014)
GOAL 12: Responsible Consumption and Production - ensure sustainable consumption and production patterns	SPP to be achieved without negative environmental impacts by matching production systems with local agro-ecological systems, using local and innovative feed formulations and ensuring that human quality foodstuffs fed to poultry are used to produce safe poultry products of high nutritional value. Ensure efficient use of all poultry products (meat, offal and eggs) fit for human consumption by monitoring use along human and animal (companion and livestock) value chains.	FAO (2010); Wang et al. (2009)
GOAL 15: Life on Land - Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss	SPP production to employ sustainably produced crops and poultry waste products (including manure) to be used to maintain soil health through composting.	Alders and Pym (2009)

[a]Full descriptions of the Sustainable Development Goals available at UN (2015).

For the greater majority of smallholder poultry producers, poultry are raised as part of their household livelihood strategy. Income derived from smallholder poultry production is usually used to meet household needs, which includes the purchase of or bartering for other food usually of lower nutritional value than the original poultry product. In general, the more vulnerable the household, the less likely poultry products are to be used for home consumption.

Recommendations

To facilitate increased home consumption or the purchase of foods with higher nutrition value with the proceeds of poultry production, a complex mix of factors must be addressed:

- Basic household needs such as sufficient income (SDG1), access to education (SDG4) and health care (SDG3) achieved including access to information concerning the specific nutritional requirements of children and women of reproductive age;
- Efficient, economically- and environmentally-sustainable poultry production and marketing (SDGs 2, 8, 9, 10, 12, 15) to ensure optimal return on investments such as the purchase of quality feed (approximately 70% of the cost of poultry production), infrastructure, household labour and poultry health inputs;
- Gender equity (SDG5) in relation to the control of poultry assets, distribution of food within households and access to education and training.

Sustainable Production and Marketing Systems

Moving forward, smallholder poultry production and marketing systems must be closely assessed to ensure that new initiatives are aligned with local agroecological zones (i.e. land resource units that share defined climate, landform and soils, and/or land cover), input supply options and opportunities to support nutrient recycling.

Recommendations

Specific recommendations across the production and marketing systems include:

(i) Poultry feed - Increasing research and development activities focusing on using poultry feed that yields both acceptable levels of feed conversion efficiency (i.e. the efficiency with which the bodies of livestock convert animal feed into the desired output) and poultry products with a nutritional profile that this optimal for human health and nutrition are required. As fish meal and other feed inputs have increased in price globally in line with declining fish stocks, alternative high-quality, lower-cost feed such as insects (e.g. crickets, black fly larvae) must be explored (Allegretti et al., 2018).

(ii) Biosecurity and poultry health - To ensure that the benefits of poultry production in terms human nutrition outweigh the risks of zoonotic disease (i.e. disease that can be transmitted between animals and people) and antimicrobial resistance, the smallholder production and marketing systems employed must match local socio-economic and agro-ecological conditions. Appropriate, feasible biosecurity practices and preventative veterinary medicine, with a "flock" and not individual approach, combined with responsible use of veterinary pharmaceutical products (i.e. safe and effective vaccination regimes and responsible antimicrobial use; **Table 2**) will be essential. Where government compensation of poultry infected by a notifiable disease (e.g. highly pathogenic avian influenza and/or Newcastle disease) is not feasible, it is essential that cost-efficient poultry flock health preventative programs be implemented to reduce the likelihood of disease outbreaks. Poultry product marketing systems and value chains require infrastructure and regulations that facilitate compliance with practices that promote the sale and consumption of poultry products of high nutritional value free of microbial and toxin contamination with due attention to animal welfare.

(iii) Genetics and genomics - In addition to proper management, vaccination and biosecurity, selection of birds with appropriate genetic composition is essential to achieving economically and ecologically sustainable smallholder poultry production. Different poultry breeds match different production systems with indigenous and dual-purpose breeds being more suitable for extensive and semi-intensive systems and single purpose breeds for intensive systems. The selection and breeding of poultry breeds that are better adapted to high temperatures and with robust immune systems are key research and development objectives. For example, with the decreasing efficacy of Marek's disease (i.e. an infectious disease of poultry caused by a herpesvirus) vaccine, attention will likely return to the selection and production of birds resistant to the disease. Indigenous and dual-purpose poultry breeds could potentially represent an opportunity to identify disease resistance alleles 'missing' from current commercial pure line stocks (Muir et al., 2008). This interest in the genetic heterogeneity of indigenous chickens now also includes programmes to enhance genetic resistance through genomic selective breeding for disease control in low-input poultry production systems (GIP, 2018).

(iv) Marketing - The marketing systems of the future must increasingly match local conditions, comply with regulations (including public health, food safety, poultry welfare and biosecurity), promote fair trade and facilitate efficient and nutrition-sensitive value chains through the use of appropriate infrastructure and communication technologies. Given the exceptionally high nutritional quality of eggs and the relative ease of storing and transporting eggs in areas without robust cold storage facilities, focussing on efficient, ethical centralised egg production and distribution is attractive. In many Asian societies, there is a preference for consuming the meat of layer birds when they cease laying eggs. In most low- and middle-income countries poultry offal is regularly consumed. Offal such as liver is very high in essential nutrients such as iron, zinc and vitamin A and therefore can be an excellent source of these micronutrients for children and women of reproductive age (de Bruyn et al., 2015). It will be important to extend food safety testing procedures to include mycotoxin levels, especially in areas where grains are reported to have high levels of contamination.

Enhancing Contributions to Nutrition- and Gender-Sensitive Agriculture and Value Chains

Sustainable food and nutrition security will involve feed conversion efficiencies that not only result in optimal weigh gains or egg production but also nutrient profiles in the final product that efficiently contribute to optimal human nutrition.

Recommendations

The efficiencies that the poultry industry has achieved in relation to the preparation of least-cost rations should be adapted to monitor a broader range of nutrients (e.g. omega 3 fatty acids) that are essential to good human nutrition. The care that the poultry industry has taken with the regular testing of feed composition sets a good example for human nutrition. The nutrient composition of poultry products for human consumption should be regularly updated at the national level to enable consumers to more accurately choose food that best meets their nutritional requirements (de Bruyn et al., 2016).

Integrated Educational and Training Activities

Education and training activities of the future will take a holistic approach that promotes poultry welfare, the production of high quality poultry products in terms of food safety and nutrient profiles, nutrient recycling and the contributions of poultry products to human nutrition and culture across different life stages.

Table 2 Overview of options to address major smallholder poultry health and production constraints

Constraint	*Backyard*	*Extensive rural poultry*	*Semi-intensive rural poultry*	*Intensive peri-urban poultry*	*References*
Zoonotic infectious disease	• Early identification and control of zoonotic disease promoted through general improvement of poultry health (so that disease outbreaks become a rarer and more noteworthy event). • Strengthened relations between poultry owners and disease control agencies via face-to-face meetings, tailored and effective awareness raising activities and increased options for actual or virtual dialogue. • Appropriate smallholder poultry production systems that minimise the risk of infectious disease emergence and/or occurrence				Alders and Pym (2009); FAO (2010)
Other infectious disease	• Employ a combination of participatory and conventional epidemiological and diagnostic techniques to efficiently identify key diseases • Conduct a risk assessment and benefit-cost analysis to identify key diseases requiring prevention and control measures • Employ participatory methodologies to identify and implement economically and environmentally sustainable prevention and control programs • Introduce birds that are certified free of notifiable and economically important diseases • Ensure biological products such as vaccines and antibiotics are stored correctly and used responsibly				Ahlers et al. (2009); Catley et al. (2012)
Biosecurity	• Conduct participatory biosecurity audits and risk assessments to identify risk and preventive factors representative locations • Employ participatory training and monitoring program to improve comprehension and implementation of appropriate and feasible biosecurity measures				Alders et al. (2003); Catley et al. (2012); Derksen et al. (2018)
Predation	• Employ participatory methodologies to identify types of predators, timing and impact of predation and options for control in relation to housing design and other security measures				FAO (2010)
Scavenging feed resource base	• Employ participatory and observational studies to categorise available scavengable feed across the seasons • Work with poultry carers to calculate sustainable carrying capacity by season			• N/A	Ahlers et al. (2009); FAO (2014)
Supplementary feed	• Match supplementary feed to quality and quantity of scavengable feed • Minimise risk of contamination by pathogens and contaminants • Place in locations inaccessible to wild birds			• Ensure access to balanced, contaminant-free feed • Ensure feed is stored in pest-free location	Ahlers et al. (2009); FAO (2014)
Food safety	• Employ a combination of participatory and conventional epidemiological and diagnostic techniques to efficiently identify key food safety risks • Conduct a risk assessment and benefit-cost analysis to identify key food safety risks requiring prevention and control measures • Employ participatory methodologies to identify and implement economically and environmentally sustainable prevention and control programs				FAO (2010); Wong et al. (2017)
Marketing	• Include information on appropriate biosecurity and animal health and food regulations in messaging associated with sale and movement of poultry	• Employ participatory methodologies to identify and match where possible periods of high demand with high production • Investigate options for strengthening 'local brand' • Support feasible options for sharing market prices of different categories of birds • Work with poultry traders to decrease losses along the value chain		• Where possible link producers with private sector operators involved with marketing and input supply to increase quality of both activities	FAO (2010)
Input supply	• Encourage carers to purchase quality inputs from reliable local sources • Ensure poultry carers are aware of regulations relating to responsible antibiotic usage			• Where possible link producers with private sector operators involved with marketing and input supply to increase quality of both activities	FAO (2014)
Loss of genetic heterogeneity	• Characterize and identify breeds found in local area including phenotypes, production and survivability traits and reasons for farmers' preferences • Develop a strategy to ensure that genetic diversity can be maintained and avoid dilution of local gene pool				Ebegbulem and Ita (2016)
Owner formal education levels	• Assess formal and informal knowledge of poultry men and women carers and owners • Develop and implement training programs tailored to match interests, knowledge and aspirations of carers and owners as well as local conditions				FAO (2010)

Education Recommendations

In areas where poultry raising is common, elements of poultry health and production, associated public health issues (e.g. food safety and zoonotic disease) and the contributions of poultry to human health, nutrition, wellbeing and culture will be incorporated into school curricula (both theoretical and practical).

Multi-sectoral Training and Extension Recommendations

Gender-, nutrition- and climate-sensitive integrated training and extension involving aspects of poultry health, production and marketing, biosecurity, human and poultry nutrition, gender and sanitation needs to be tailored to appropriate socio-cultural and production systems.

In relation to nutrition-security, where food prohibitions exist in relation to poultry products, for example the custom that pregnant women not consume eggs, harmonised nutrition messaging should be agreed between health workers and poultry extension agents. In a number of locations where access to obstetrical care during childbirth is limited, some pregnant women practice 'eating down' (i.e. not consuming highly nutritious food; Alders et al., 2003) to reduce the likelihood of a large birthweight child leading to obstructed labour Arzoaquoi et al., 2015. Therefore, in addition to adequate nutritional knowledge, pregnant women also require ready access to appropriate health services.

In smallholder production system where the consumption of hatching eggs is practiced, this can be further complicated by the risk that, by the end of the 21st day of incubation, an infertile chicken egg or one with very limited embryonic growth and which could have been consumed at an earlier stage, has become contaminated with spoilage or food poisoning bacteria. Simple egg candling technology (Ahlers et al., 2009) that allows eggs to be checked after four days of incubation enables infertile and similar eggs (~30% in one study) to be removed and eaten (Conroy et al., 2005). Candling is a method that employs a bright light source behind the egg to outline detail of embryo development through the shell. It is so called because the original sources of light used were candles.

The appropriate marketing, transport and conservation of poultry products requires broad training in relation to poultry welfare (especially when trading live birds), food safety and maintenance of product quality. In the case of egg marketing, where refrigeration is not available, the quality of albumen declines very rapidly when eggs are stored at room temperature, especially in hot climates. Refrigeration is effective in maintaining quality for several months. Oiling eggs on the day of lay will preserve their quality for several weeks and the oil film also prevents germs from entering (Ahlers et al., 2009). Fresh eggs can be distinguished from old ones by the size of the air space (intact shell) or the height of the albumen (the white or clear part of the egg) once an unboiled egg is opened and put on a dish (Ahlers et al., 2009). Hard-boiled eggs can be stored for several weeks. These eggs might also be oiled to preserve their quality for even longer periods. Another possibility is to store raw eggs in water glass (sodium silicate) solution. Eggs will keep for several months in water glass (sodium silicate) if covered and stored in a cool place (Ahlers et al., 2009).

Conclusions

The Planetary Health paradigm and the United Nation's Sustainable Development Goals (SDGs) are a response by the global community to unprecedented existential threats to humanity and the ecosystems that sustain life on earth. Increasing the efficiency of agricultural and animal-source food production is vital to reversing practices that are impacting negatively on the environment. Poultry production has been a feature of human society for thousands of years. To ensure that it continues to make positive contributions to stable human society, it is essential that production and marketing are tailored to local systems and associated value chains, maximise nutrient cycling and efficient utilisation of all products and maintain genetic diversity. These approaches to smallholder poultry production should be accompanied by improvements to local health services (especially for children and women of reproductive age) and holistic education and training that highlights the links between poultry production, human health and nutrition and sustainable ecosystem services.

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References

Ahlers, C., Alders, R.G., Bagnol, B., Cambaza, A.B., Harun, M., Mgomezulu, R., Msami, H., Pym, R., Wegener, P., Wethli, E., Young, M., 2009. Improving village chicken production: a manual for field workers and trainers. ACIAR Monogr. No. 139, 194 pp.

Alders, R.G., Pym, R.A.E., 2009. Village poultry: still important to millions, eight thousand years after domestication. World's Poult. Sci. J. 65 (02), 181–190.
Alders, R., dos Anjos, F., Bagnol, B., Fumo, A., Mata, B., Young, M., 2003. Controlling Newcastle Disease in Village Chickens: A Training Manual, second ed. ACIAR Monograph No 86.
Alders, R., Costa, R., Gallardo, R.A., Sparks, N., Zhou, H., 2018. Smallholder poultry: contributions to food and nutrition security. In: Elsevier Encyclopedia of Food Security and Sustainability (this edition).
Allegretti, G., Talamini, E., Schmidt, V., Borgorni, C.P., Ortega, E., 2018. Insect as feed: an emergy assessment of insect meal as a sustainable protein source for the Brazilian poultry industry. J. Clean. Prod. 71, 403–412.
Arzoaquoi, S.K., Essuman, E.E., Gbagbo, F.Y., Tenkorang, E.Y., Soyiri, I., Laar, A.K., 2015. Motivations for food prohibitions during pregnancy and their enforcement mechanisms in a rural Ghanaian district. Journal of Ethnobiology and Ethnomedicine 11, 59.
Bagnol, B., 2012. Advocate gender issues: a sustainable way to control Newcastle Disease in village chickens. In: International Network for Family Poultry Development. Good Practices of Family Poultry Production Note (3).
Catley, A., Alders, R.G., Woods, J., 2012. Participatory epidemiology: approaches, methods, experiences. The Veterinary Journal 191, 151–160.
Conroy, C., Sparks, N., Chandrasekaran, D., Sharma, A., Shindey, D., Singh, L.R., Natarajan, A., Anitha, K., 2005. Improving backyard poultry keeping: a case study from India. In: AgREN Network Paper No. 146.
de Bruyn, J., Wong, J., Bagnol, B., Pengelly, B., Alders, R., 2015. Family poultry and food and nutrition security. CAB Rev. 10 (13), 1–9.
de Bruyn, J., Ferguson, E., Allmann-Farinelli, M., Darnton-Hill, I., Maulaga, W., Msuya, J., Alders, R., 2016. Food Composition Tables in resource-poor settings: exploring current limitations and opportunities, with a focus on animal-source foods in sub-Saharan Africa. Br. J. Nutr. 116 (10), 1709–1719.
Derksen, T., Lampron, R., Hauck, R., Pitesky, M., Gallardo, R.A., 2018. Biosecurity Assessment and Seroprevalence of Respiratory Diseases in Backyard Poultry Flocks Located Close to and Far from Commercial Premises. Avian Diseases 62 (1), 1–5.
Ebegbulem, V.N., Ita, U.R., 2016. Conservation of genetic diversity: it's relevance in poultry production. Anim. Mol. Breed. 6 (3), 1–5. https://doi.org/10.5376/amb.2016.06.0003.
FAO, 2010. Smallholder poultry production – livelihoods, food security and sociocultural significance. In: FAO Smallholder Poultry Production Paper No. 4, Rome.
FAO, 2014. Decision tools for family poultry development. FAO Animal Production and Health Guidelines No. 16. Rome, Italy.
GIP, 2018. Feed the Future Innovation Lab for Genomics to Improve Poultry. University of California, Davis. Available: http://gip.ucdavis.edu/.
Gupta, A.R., 2011. Ascites syndrome in poultry: a review. World's Poult. Sci. J. 67 (03), 457–468.
Horton, R., Lo, S., 2015. Planetary health: a new science for exceptional action. Lancet 386 (14), 1921–1922.
Muir, W.M., Wong, G.K., Zhang, Y., Wang, J., Groenend, M.A.M., Crooijmans, R.P.M.A., Megensd, H.-K., Zhang, H., Okimoto, R., Vereijkeng, A., Jungerius, A., Albers, G.A.A., Taylor Lawley, C., Delanyi, M.E., MacEachern, E., Cheng, H.H., 2008. Genome-wide assessment of worldwide chicken SNP genetic diversity indicates significant absence of rare alleles in commercial breeds. PNAS 105 (45), 17312–17317.
Pym, R., Alders, R., 2016. Helping smallholders to improve poultry production. In: Achieving Sustainable Production of Poultry Meat. Burleigh Dodds Science Publishing, Cambridge, UK, pp. 441–471 (Chapter 22).
UN, 2015. Transforming Our World: The 2030 Agenda for Sustainable Development. United Nations – Sustainable Development knowledge platform. Available: https://sustainabledevelopment.un.org/post2015/transformingourworld.
Wang, Y., Lehane, C., Ghebremeskel, K., Crawford, M.A., 2009. Modern organic and broiler chickens sold for human consumption provide more energy from fat than protein. Public Health Nutr. 13 (3), 400–408.
Whitehead, M.L., Roberts, V., 2014. Backyard poultry: legislation, zoonoses and disease prevention. J. Small Animal Pract. 55, 487–496. https://doi.org/10.1111/jsap.12254.
WHO, 2017. Malnutrition Fact Sheet. World Health Organization of the United Nations, Geneva. Available: http://www.who.int/mediacentre/factsheets/malnutrition/en/.
Wong, J.T., de Bruyn, J., Bagnol, B., Grieve, H., Li, M., Pym, R., Alders, R.G., 2017. Small-scale poultry in resource-poor settings: a review. Glob. Food Secur. 15, 43–52. https://doi.org/10.1016/j.gfs.2017.04.003.
Zhao, C., Liub, B., Piaoa, s, Wanga, X., et al., 2017. Temperature increase reduces global yields of major crops in four independent estimates. PNAS 114 (35), 9326–9331.