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**Title:** Sustainable and ethical animal-source food systems: are they possible?

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**Abstract**

Supplying sustainable, optimal, ethical and safe nutrition for more than 8 billion people and 27 billion dependent livestock predicted by 2050 is among the most important and complex of human responsibilities. During the past 10,000 years, the growing human population has been sustained through the domestication of plant and animal species for use as food sources and the industrialization of agricultural systems, without taking natural capital into account. A review of this strategy suggests that our modern food systems are not necessarily optimal and, in some instances, are undermining long-term food and nutrition security and the health of people and the planet.

Intensification of livestock production systems has steadily increased since the mid-1880s and capital-intensive integrated industrial production systems now dominate global livestock food systems. Intensification has contributed to the emergence, spread and maintenance of new disease agents, changed the nutritional profiles of animal-source foods, and increased the interaction and movement of people and their livestock. Simultaneously, changing diets have led to the triple burden of malnutrition: undernutrition; overweight; and obesity and micronutrient deficiencies.

**Introduction**

Supplying sustainable, optimal, ethical and safe nutrition for a global population forecast to be more than 8 billion people and 27 billion dependent livestock 2050 is among the most important and complex of human responsibilities (Alders et al. 2017a). Yet, even under current conditions, more than 10 per cent of people globally are undernourished and about 30 per cent are deficient in key micronutrients (Glopan 2014). These burdens tend to be higher in resource-poor households, and especially amongst the more vulnerable members of households. This is reflected in the fact that households in low- to middle-income countries (LMICs) account for almost all undernourished children. Anemia is prevalent in approximately 50 per cent of pregnant women in LMICs, with the highest prevalence in Africa (57.1%) and in South-East Asia (48.2%)(WHO 2017). In Australia, women of reproductive age and the elderly are disproportionally affected by micronutrient deficiencies (ABS 2014).

Use of wild animal-source foods through hunting and gathering was the main evolutionary driver of an upright posture and gait and was critical to nutritional health, development and early expansion of the human species (Kock et al. 2011). Efficient and appropriate consumption of animal-source food (ASF) can provide protein with an optimal mix of amino acids and bioavailable micronutrients such as heme iron that can significantly enrich cereal-based diets (de Bruyn et al. 2015). In particular, meat is high in bioavailable heme iron and is known to enhance the uptake of less-readily absorbed non-heme iron found in cereals and green leafy vegetables (de Bruyn et al. 2015; Hallberg et al. 2000; Neumann et al. 2012). It is notable that heme iron content varies between meat types, with offal and red meat highest and fish lowest (Rangar et al. 1997). Using a biophysical simulation model Peters et al. (2016) calculated human carrying capacity in the United States under ten diet scenarios and found that the carrying capacity of the vegan diet was lower than that of two of the healthy omnivore diets.

**Global food systems**

Globally, food systems have contributed to decreasing undernutrition. However, many food systems adversely affect the ecosystem by driving declines in biodiversity (including soil microorganisms, animals and plants) and enhancing the risk of zoonotic disease and antimicrobial resistance. Poor community health and nutrition further compound low agricultural productivity and poverty at local, regional and national levels. The growing global population and associated environmental pressures necessitate a realignment of agriculture towards providing sufficient safe and nutritious food without excessive or poorly targeted production.

**Food and nutrition security**

Food security exists when populations have access on an ongoing basis to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 2009). Despite increases in agricultural production during the past two decades, malnutrition rates in have not diminished significantly and undernutrition remains a significant problem in many LMICs and overnutrition becoming a major issue globally (Glopan 2014). Changing diets have led to the triple burden of malnutrition (Pinstrup-Andersen 2007): undernutrition (insufficient calories), overweight and obesity (excess calories) and micronutrient deficiencies (insufficient vitamins and minerals). These trends are reflected statistically with 200 million children under the age of five classified as having stunted growth due to chronic undernutrition, or wasting due to acute undernutrition; two billion people suffering physical and cognitive effects resulting from a lack of essential vitamins and minerals in their diets; and 1.4 billion people who are overweight or obese. Levels of stunting in children under five remain unacceptably high in the Asia-Pacific region, ranging from over 30% in Indonesia, more than 40% in Papua New Guinea and more than 50% in Timor-Leste (DFAT 2015). High levels of undernutrition, lack of education among adult women (who frequently play a key role in agricultural production, feeding of the household, care of children, and care of sick people) and gender inequality have also shown a strong positive association with the prevalence of child undernutrition. Two of the 17 United Nations Sustainable Development Goals (SDGs) outline targets to end hunger and achieve gender equality and empower all women and girls. SDG2 aims to, to ‘end hunger, achieve food security and improved nutrition, and promote sustainable agriculture’ with a particular focus given to young children, adolescent girls, pregnant and breastfeeding women. SDG5 aims to ‘achieve gender equality and empower all women and girls’ and further specifies the need to address gender disparities to improve female nutrition.

**Linkages between food and disease**

Throughout history infectious diseases have tended to emerge and maintain themselves in centers where human and animal density is high or where human activities encroach on naive environments. Emerging infectious diseases (EIDs) are increasing, causing losses in human and animal lives, decreasing food security, and resulting in large costs to society. Many of the factors contributing to disease emergence, including climate change, globalization and urbanization, may to some extent be attributed to human activity (Lindahl and Grace 2012). Intensification of livestock production systems has steadily increased since the mid-1880s and capital-intensive integrated industrial production systems now dominate global livestock food systems. Intensification has contributed to the emergence, spread and maintenance of new disease agents through shifting ecological immunology, the immunity produced as a result of interactions between the host, the environment and with the active involvement of parasites (Sadd and Schmid-Hempel 2009). Intensification has also changed the nutritional profiles of animal-source foods and increased the interaction and movement of people and their livestock.

For example, during the past two decades the commercial chicken industry has emphasized the selection of production traits over disease resistance. A 2008 study reported that commercial pure lines of chicken, both broiler (meat) and layer (egg), are missing significant genetic diversity found in noncommercial chickens (Muir et al. 2008). The evolution of new avian viruses and variants of existing virulent viruses has been facilitated due to the following characteristics of current poultry production systems including: (i) host genetic homogeneity (with few host adaptive bottlenecks); (ii) high density rearing (allowing close animal-to-animal contact and favoring transmission of virulent over low pathogenic strains); and (iii) intensive vaccination programs that provide selective immune pressures and may be executed improperly in resource-poor settings (Alders et al. 2013).

As a result of the HPAI H5N1 pandemic, millions of poultry were killed or slaughtered to control the spread of the disease. More than 50 million domestic birds were slaughtered and destroyed in Vietnam alone due to HPAI H5N1 infection. Widespread culling of family poultry has negatively affected vulnerable households, including those headed by women, contributing to increased stunting in children under five in Egypt and decreased enrolment of girls in school in Turkey after HPAI H5N1 control activities. Economic losses in the South East Asia region have totaled about US$10 billion and have had direct and indirect negative effects on food security (Alders et al. 2013).

The link between our food systems and EIDs is also demonstrated by other recent outbreaks of Ebola, SARS and antimicrobial resistant bacteria (Lindahl and Grace 2012). It is estimated that by 2050, the global consequences of antimicrobial resistance (AMR) will result in up to 10 million human deaths annually (O’Neil 2014). Antimicrobial use within agriculture is now established as one of the key drivers of antimicrobial resistance in humans. There are insufficient data of the amount of antimicrobial consumption in food-producing animals. However, Van Boeckel et al. (2015), estimated antimicrobial consumption in livestock to account for about 63,151 tons in 2010 with a 67% growth estimated by 2030. The global increase is largely attributed to the growing number of animals being produced for food and the adoption of intensive animal farming (Van Boeckel et al. 2015). Evidence of the transmission of antimicrobial-resistant microbes from animals to humans is particularly well established for common foodborne pathogens such as *Salmonella* serovars and *Campylobacter spp.* (Holmes et al. 2016). For example, in north-eastern Thailand Sinwat et al. (2015) found all the tested Salmonella isolates from raw pork, raw chicken meat and humans suffering diarrhea were resistant to at least one antibiotic, with most exhibiting multi-drug resistance (Sinwat et al 2015).

The selection of fast-growing broilers has been accompanied by a range of non-communicable diseases (NCDs), such as ascites syndrome and lameness, which have also led to health problems in intensively raised broilers at the smallholder level (Gupta 2011). Concurrently, the composition of broiler carcasses has changed with changing ration formulation. This affects the quality of food entering the human food system at a time when obesity and other NCDs have become major public health issues in both developing and developed countries (Doku and Neupane 2015). Wang et al. (2009) reported 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.

**Planetary Health**

A Planetary Health approach, recognizing that the health of human civilization depends on the health of natural systems (Whitmee et al. 2015) was used in the framing of this discussion paper. The production of sustainable, nutritious and safe ASF delivered with minimal waste has the potential to promote human, animal and environmental health. As governments worldwide grapple with unsustainable health budgets, nutrition-sensitive ASF value chains, bolstered by more effective policy frameworks, can help to prevent malnutrition and ensure that the ASF produced delivers maximum benefits. Resourceful and strategic production and utilization of ASF has a crucial role to play in SDG2.

**Conclusions and the way forward**

As we move forward, it is essential that the agriculture, health, education and infrastructure sectors work together closely to ensure that food is produced and used efficiently, effectively and safely. A heightened awareness of the importance of the ecological systems that underpin food and nutrition security is vital. A planetary health approach to the production of sustainable, nutritious and safe food delivered with minimal waste will promote improvements to human, animal and environmental health (Alders et al. 2016).

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