Animal source foods: contributions to food and nutrition security

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Issues

According to the UN (United Nations World Food Program, WFP), food security is defined as "The condition in which all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life." Given the current debate around the impact of livestock on human health and the environment, it is of interest to consider how livestock fit into this broad definition at present and if they will continue to be a relevant contributor to food security in the future. Within the foregoing definition, there are multiple dimensions of food security that require attention, including food availability, food access, food safety and food utilization. These elements form the pillars of food security, but also begin to detail the nuances involved to achieve true *nutritional security* within the broader idea of food security. The FAO defines nutritional security as "… exists when all people at all times consume food of sufficient quantity and quality in terms of variety, diversity, nutrient content and safety to meet their dietary needs and food preferences for an active and healthy life, coupled with a sanitary environment, adequate health, education and care" (UN HTLF, 2012). Using the UNICEF framework as a general model to frame malnutrition, it is clear that limited access to food and specifically nutrient-dense foods will contribute to food and nutritional insecurity (Figure 1). Another element of nutritional security is related to food safety, which may impact not only nutrient content and wholesomeness but the capacity to utilize nutrients as well (and that is considered later in this review). This is particularly important at the household level, where nutritional security can be challenged even in a food secure environment. This is due to hidden hunger, which affects 2 billion people and occurs when the quality of food eaten does not meet nutrient requirements due to critical deficiencies in micronutrients needed for growth and development (WHO, 2014). Thus, the goal of this paper is to consider the impact of animal source foods in achieving food and nutrition security rather than just food security.

Animal source of foods and nutrient security

The primary targets of improvements to food and nutritional security are pregnant and lactating women (PLW) and infants and young children (IYC) during the first thousand days of life (Ianotti, 2018). These groups have greater requirements for certain nutrients relative to the broader population, and deficiencies during this stage can be life altering and persistently reduce the potential for an "… active and healthy life". Scarcity and limited intake of animal source foods for PLW and IYC, even when caloric requirements are being met, can lead to physical, emotional, and cognitive stunting with lifelong impacts. Relative to children with a normal growth curve, stunted children are 4 times as likely to die before 2 years of age, experience an average 11-point reduction in I.Q. score, and as adults earn 22% less income (Black et al., 2013, de Onis and Branca, 2016). Indeed, stunting is one of the best measures of chronic undernutrition, affecting over 151 million children under 5 years of age across the globe. Considering a total world population of 650 million children under 5-years old, almost **22%** of the total population of children is stunted and thus suffers the negative effects. Malnutrition, an underlying cause of stunting, is associated with several nutritional deficiencies that suggest a link to lack of consumption of animal source foods (ASF; WHO Stunting Policy Brief).

In addition to providing of a balance of appropriate amino acids, and hence, high quality protein, ASF are also the sole source of specific nutrients, including vitamin B12 and essential fatty acids integral to brain development. Of interest, a decreasing trend in the proportion of stunted children in various countries globally is observed with increasing per capita consumption of meat or projected milk consumption (Figure 2; Adesogan et al., 2019), whereas no similar trend is found when considering only total caloric intake and the proportion of stunting (Figure 3). Although these associations at the country level cannot be interpreted as providing evidence for a causal relationship, they do support the hypothesis of beneficial effects of ASF on child growth, which requires further evaluation. Thus, interventions that reduce food and nutritional insecurity via improved access to ASF may lead to reductions in stunting. A recent meta-analysis did not find a consistent relationship between ASF consumption and stunting or other indicators of growth and development (Shapiro et al., 2019), which may have been a function of inconsistencies in study designs. Rigorous studies of the impact of ASF on malnutrition are therefore a key research priority. Such studies should consider malnutrition as a multifactorial problem, in line with the UNICEF framework.

But deficits In nutrient access are not the only potential issue associated with ASF. Indeed, there are many examples, especially in the developed world, of excess consumption of ASF in the context of nutrient requirements. For example, adherence to a Paleolithic or Mediteranian diets, both of which include reduced levels of ASF relative to typical western diets, are associated with lower mortality (Whalen et al., 2017). In a Canadian study cohort, increased obesity and BMI measures were linked to self-reported adherence to dietary guidelines for meat and alternatives, but for vegatables and fruits as well (So et al., 2017). A meta analysis of meat consumption pattern studies and obesity identified a relationship at high consumption levels, but significant variation among study responses were observed (Rouhani et al., 2014). Thus, it appears that excess intake of some ASF may affect obesity incidence, seperating those effects from overall caloric intake is difficult.

Food security and animal source of foods

Threats to food security are varied and include climate change, population growth, food production capacity, food prices, conflict, loss of crop varieties, and land and water scarcity. Many of these threats are not new, but reflect the ongoing need for improved crop and livestock productivity, particularly in some regions. Considering the global food security index, it is clear that Africa and parts of Asia are least resilient to shocks to food security, and thus nutrition of women, infants and children is most compromised in these regions (The Economist, 2018). The impact of climate change on food security is multifaceted and includes effects on food availability, food access, food safety, and food utilization. Variation in rainfall and temperature increases will alter growing seasons and production capacity. Ultimately, food quality will diminish as drier, hotter climates reduce yields and some aspects of food safety, because hotter climates increase contaminants such as aflatoxins and bacterial pathogens (US Global Change Program, 2016; ECDC, 2012). With regard to access, with drought and other negative climactic events on the rise, it is reasonable to expect that feed resources for animals will suffer and result in periods of increased market pressure as herds are depopulated. In the absence of solid, functional trade relationships, access to these products will be constrained. Similarly, as production pressures increase demand on women's time, less time will be available for child feeding activities, and food utilization may be compromised.

Food security and societal norms

Vulnerability to food insecurity at the household level depends on a number of factors, which individually may not pose a threat, but in combination can be significant. Societal norms related to gender roles can affect the quantity and quality of food choices, and even decisions around the fate of nutrient-dense foods such as ASF and whether family consumption or external sale of those commodities is prioritized. In addition to gender, other social stratifications, such as class, caste, ethnicity, or even geography may interact to further adversely affect women's ability to trade or otherwise improve their economic status through livestock production. Household nutritional security, however, is likely to improve with increased animal production compared to households without livestock holdings. Livestock producers have higher levels of ASF consumption relative to others, and livestock production leads to higher incomes and greater capacity for improved nutrition (Flores-Martinez, 2016; Jin and Iannotti, 2014; Rawlins et al., 2013) . In addition, ownership or co-ownership of livestock by women has been associated with improved nutritional outcomes of children within the household (Jin and Ionnatti, 2014). The economic status of women is improved by livestock production when compared to women with no livestock, and thus resilience to economic shock is greater in the presence of livestock versus without (Ashley et al., 2018; Dumas et al., 2018; Njuki and Sanginga, 2013), though this may not reflect the situation with some pastoralist communities. But the evidence, mainly, supports a role for livestock production as a method to improve food and nutritional security (FAO, 2009).

Challenges to livestock for food and nutrition security

So what are the challenges to livestock production that may limit it as a solution to greater food and nutritional security? Animal source foods presently account for 25% of the protein and 18% of the calories consumed globally, and demand will continue to grow (Henchion et al., 2017). Capacity to support demand, especially in developing and emerging countries, appears to be one such challenge. World population growth projections of another 3 billion people by 2050 are a concern, and most of that population increase will occur in emerging and developing countries. As incomes rise, demand for animal source foods increase. This is exacerbated by the fact that households not reliant on agriculture for their livelihood have faster income growth and thus purchasing power for ASF relative to those that rely on agriculture only for their income. But the demand represents a potential for higher returns to livestock holders and an opportunity for economic advancement, which in general improves the nutritional outcomes of the poor (Webb and Block, 2012).

Humans versus animal competition for crop use

Competition among humans and animals for crop outputs is often cited as a hurdle to greater food security. Indeed, the conversion ratio of grain to animal product ranges from 1.5:1 to 8:1 for poultry to beef cattle (FAOSTAT 2016) respectively, suggesting that a move away from ASF, especially ruminant derived ASF, would improve food security by limiting competition for grain crops primarily. That notion, however, is flawed when one considers that grain comprises only 15% of a typical cattle diet, with the remainder coming from forage and byproducts of grain and food processing; components unsuitable for human consumption (Mottet et al., 2017). In addition, approximately 60% of the world's land is completely unsuitable for crop production, but those areas of grassland provide forage for a significant number of grazing livestock. Therefore, the conversion of crop materials by ruminants is actually much more efficient when calculated on the basis of output of human consumable ASF per unit of human consumable plant material input. Further, as mentioned throughout this manuscript, the specific nutrient profile supplied from animal source foods and the contribution to nutritional security relative to plant based sources leans heavily in favor of ASF being a component of all diets of PLW and IYC to avoid stunting and its negative short and long-term sequelae. In fact, the World Bank notes that animal source foods are the best nutrient-rich foods for children aged 6 to 23 months (World Bank, 2017). So the "feed for animals versus food for humans" debate must be carefully addressed to make meaningful comparisons, and is much more complex than simple calculations of efficiency would indicate.

Animal source food and the environment

The impact of animal production on the environment is another factor commonly mentioned as a constraint and potential threat to sustainability. With regard to water utilization, it is clear the animal production depends on significant quantities of water, and inappropriate manure management can damage water resources. However, manure also serves as a significant source of fuel and building material for homes in many developing and emerging countries. Further, manure serves as a critical fertilizer for more than half of the crops and pasture grown around the world (FAO, 2018). So the view that animal waste only has a negative effect on food and nutritional security via water system contamination is not consistent with the broader utility of manure in many developing and emerging economies. Additional benefits to water systems are found in the recharge capacity of crop and pasture land as well as their potential for net carbon sequestration, when certain well managed options like silvopasture systems are used. For instance, a recent meta-analysis of 86 studies on "which agroforestry system stores the most carbon?" concluded that the net accumulation of soil carbon or net sink of greenhouse gases is greatest when grassland is converted to silvopastures i.e. forest combined with livestock (Figure 4; Feliciano et al., 2018). Such ecosystem services are difficult to quantify but should be considered in the global environmental impact of livestock production.

Greenhouse gas output from livestock is a concern, as the output of CO_2 and methane, especially from ruminants, has been identified by some as the single largest contributor to GHG emissions worldwide. However, as with the debate over "feed vs. food", a more complex picture emerges when all aspects of the production cycle are considered. Technology to improve efficiency of ASF production has the greatest potential to reduce GHG output per unit of ASF production (Mitloehner, white paper). In this regard, genetic selection is important but requires more general improvements in feeding, management and animal health to sustain those increases in yield. As the efficiency of production increases, an inverse relationship with GHG output is realized when assessed on a unit of ASF product basis. In highly efficient livestock systems such as those present in developed and developing countries, contributions to total GHG output from agriculture in general are 3-4 %, and from livestock are 2%; compared with transportation that contributes 15%. Improvements of productivity on a per animal basis is one of the highest potential targets for reducing GHG per unit of animal product from livestock (Mitloehner, white paper). For example, a doubling of milk yield from the current Ethiopian herd could be associated with a reduction of cattle numbers by 50% without a drop in milk supply. Yet that same reduction in herd size would halve total CO_2 and methane for that same amount of ASF output. Indeed, annual milk yields in the US have increased from 2074 kg/cow in 1944 to 9,193kg/cow, whereas the national herd of dairy cows has declined from 25.6 million to 9.1 million cows over that same period (Capper et al., 2009). Therefore, gains in production efficiency can produce reductions in overall output of GHG per unit of ASF realized.

An emerging area of potential negative outcomes for nutrition related to animal production is the relationship of animal exposure and enteric disease that reduces nutrient uptake. For example, the emphasis on small holder poultry production to improve child nutrition is valid, but not in cases where chicken housing, or lack thereof, exposes those same children to increased potential for asymptomatic infections by enteric pathogens, specifically *Campylobacter* spp., which lead to reduced intestinal integrity and ultimately poor nutrient absorption. Interventions that increase the supply of ASF without consideration of local impacts on gut health are likely to have limited sustainability. Recent evidence has suggested that whereas diarrhea did not have a significant effect on child growth, asymptomatic gut infections by enteropahtogens including *Campylobacter* spp. and enteroaggregative Escherichia coli did signicantly reduce length and weight attainment in children under 2 years of age. These authors suggested "modifying the longstanding Unicef framework of malnutrition by adding enteropathogen infection in the absence of diarrhea". (MAL-ED Network, 2018). Transmission pathways of these pathogens are complex and may include direct exposure to animal or human excreta, unsafe foods, contaminated drinking water and lack of personal hygiene. Studies to unravel the se complex pathways in order to develop effective intervention strategies to complement ASF interventions are a critical need.

Economic impacts of animal source food

Economic impacts of ASF production must be considered across the value chain from the household level to local and regional markets. At the household level, market access, capital availability and capacity for withholding some product for home consumption are basic considerations for decision support on new enterprises. It is also clear that nutrition training for smallholders is key to create an understanding of the importance of ASF consumption, even at the "expense" of less external income, is essential to improve nutritional outcomes at the household level. But these will be influenced by structural hurdles related to demand variability, regulatory constraints and trade policies at the state, national and international levels, that may restrict movement of animals or their products and stymie trade. Capacity building in the area of market access is likely to be critical to support sustainable economic opportunities for small holders. An additional consideration to explore is the cost of diets with and without ASF, which may pose a burden at the household level. Specifically, recent analysis of the cost of the EAT-Lancet diet reveals a significant disconnect between diet affordability and income (Hirvonen et al., 2019). Indeed, the cost of the diet exceeded the daily income for at least 1.56 billion people globally.

Summary and policy implications

It appears that a disconnect is present in the current debate around animal source food consumption and production as they relate to nutritional security. On the one hand, it is clear that deficiencies in ASF consumption and availability in many emerging and developing economies have dramatic negative outcomes for the nutritional security, health and well-being of PW and IYC, with implications for development of those economies. Livestock production in those same countries, however, generally suffers from low productivity with negative implications for environmental and resource degradation. In contrast, consumption patterns of ASF in developed economies often exceed requirements and may be associated with certain negative health outcomes, although direct cause:effect realtionships are not available cross the broad population. But unlike developing countries, the production of ASF in developed countries is highly efficient and the burden on environmental and resource use is much lower than other sectors (e.g. transportation) and thus of limited potential for significant mitigation impacts.

With regard to policy development, messaging is critical to reflect the foregoing nuanced arguments. The first point is that animal source foods do provide significant nutritional security across the globe and elimination of ASF in human diets would result in significant health and economic burdens. Recognizing that certain ASF production approaches increase environmental degradation and human health, policies that encourage full consideration of the impacts of ASF production systems on all aspects of sustainability should be implemented. But given the initial point on the importance of ASF, overall demand for ASF is likely to increase, so sustainably intensifying that production is key. In addition, messaging to livestock producers must include a focus on overall demand versus individual consumption in order to reduce anxiety over threats to their livliehood.

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Figure 1 UNICEF framework for malnutrition.

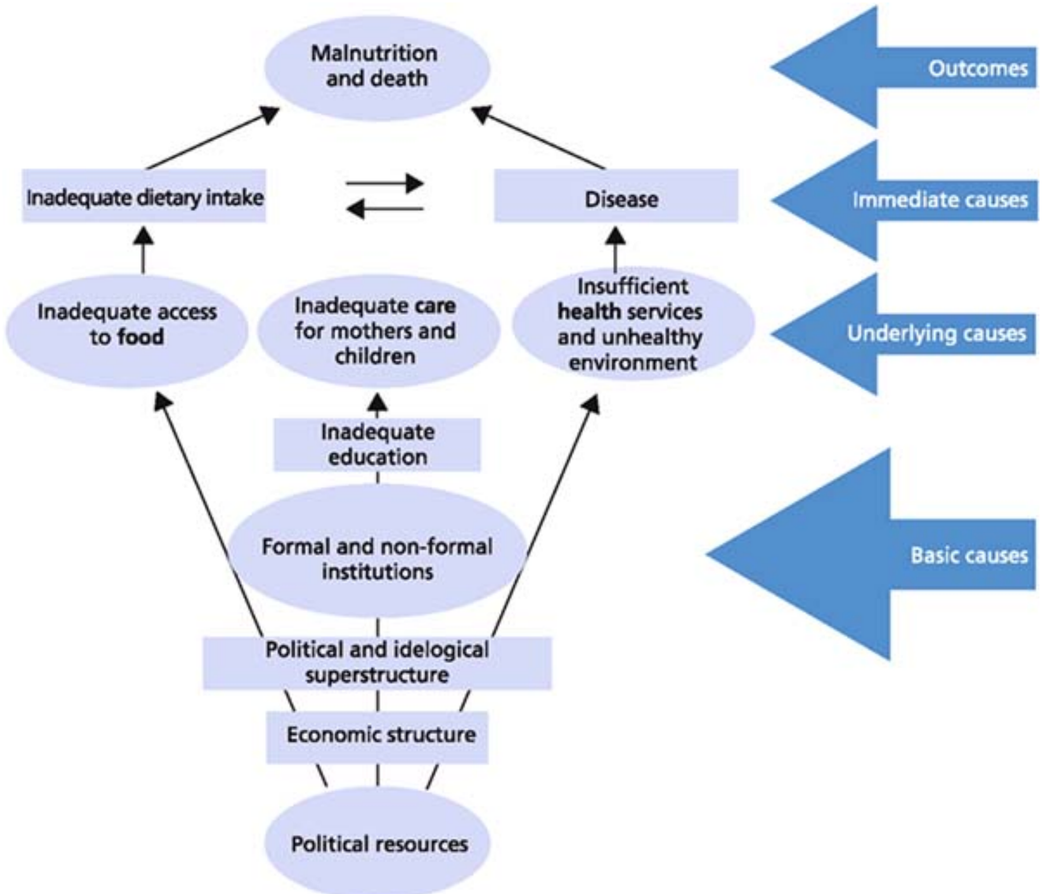

Figure 2. Form and amount of ASF consumption against stunting rates in 37 countries.

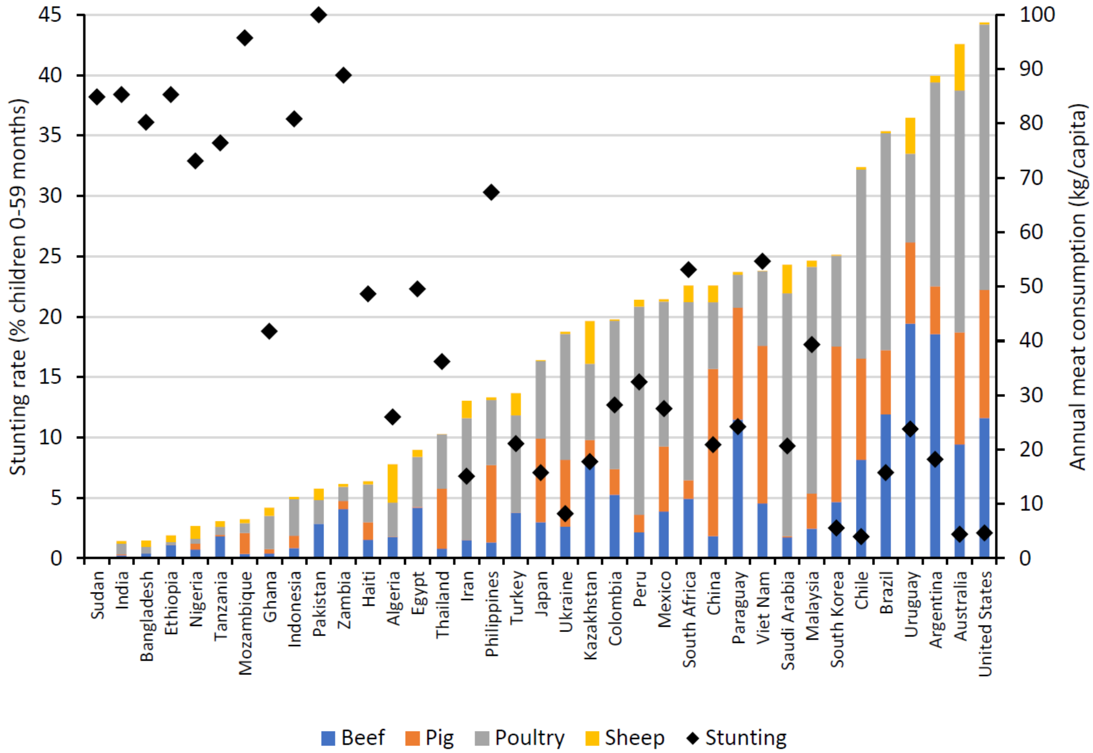

Figure 3 Total food calorie consumption against stunting rates in 37 countries.

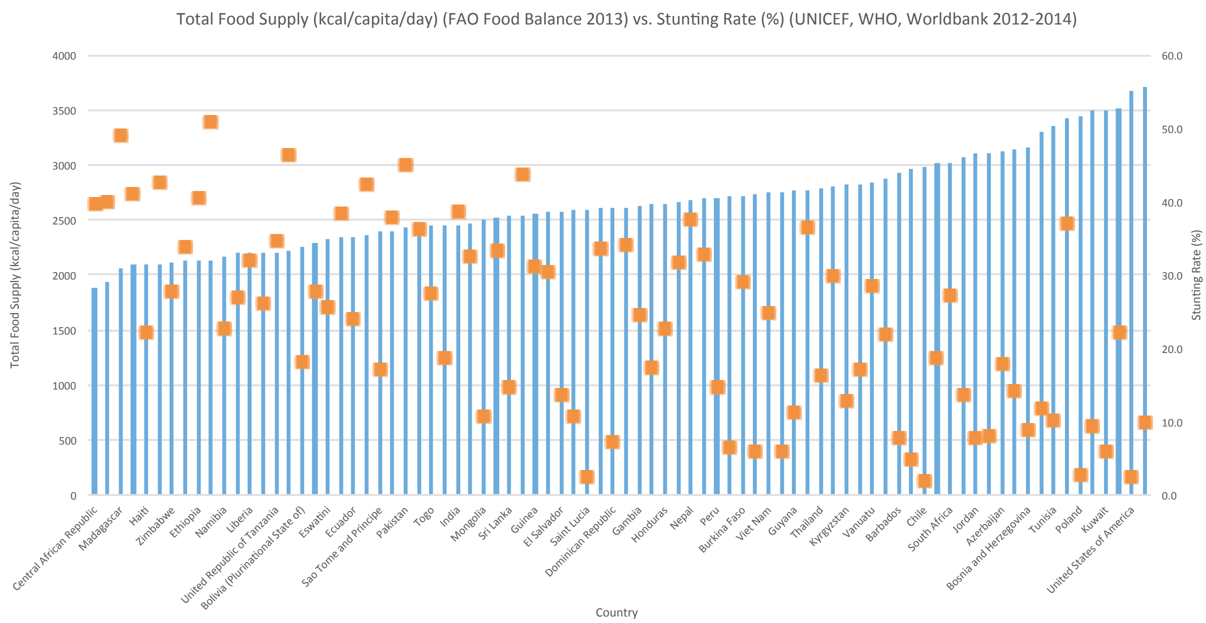

Figure 4. Mean, maximum and minimum above ground (A) and soil (B) carbon sequestration in agroforestry systems implemented in Tropical climates. Number of observations (n) is presented in brackets. (Feliciano et al., 2018).